THE NEW CROP INDUSTRIES HANDBOOK

Edited for the Rural Industries R&D Corporation
by Sue Salvin, Max Bourke, AM and Tony Byrne

Asian vegetables

Fruits and berries

Wildflowers

Native foods

Grains and legumes

Herbs and spices

Essential oils

Nuts

Miscellaneous crops
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Foreword

Farmers today, both those in existing businesses and new entrants, live in an environment where they by necessity have to keep an eye on new opportunities.

Changes in commodity prices, or new value chain opportunities let alone changes in types of food or new products demand a flexible approach to farming. Many crops themselves have a “fashion” element where a new variety or cultivar of fruit or vegetable can be “in” for a period then “out” with the market. Consumers expect farmers to be able to continue to provide their needs in both food and fibre when they follow these new trends.

As well diversification of cropping opportunities, within the limits of good business sense, provides an essential part of the risk management in modern farming.

The Rural Industries Research and Development Corporation is tasked, within a number of its programs, with assisting agribusiness and the food industries to stay ahead of changes by looking at new potential crops, their management and potential in the food and fibre industries. Some of these crops are aimed at Australian markets others are aimed at a mix of domestic and export.

Undertaking the research and supporting industries searching for new products is only the first stage of their work. Unless that work is communicated to the widest possible audience the potential of these new crops will never be fully realised.

This book is aimed at consolidating much of the recent research information into a handy format for those searching for the latest information on new crops. I am sure it will prove to be as valuable to both potential and existing farmers as the first edition was.

Senator the Hon Judith Troeth
Parliamentary Secretary to the Minister for Agriculture, Fisheries and Forestry

September 2004
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Preface

Each month almost a million visitors go to the RIRDC web site. There they surf through or research over 1,000 reports. One of the most visited areas and consistently so over many years, has been *The New Rural Industries* and the popularity of this site is confirmed by the continuous demand for, and sales of, the hard copy of this book.

Two of my predecessors Mr Keith Hyde and Mr Peter Core were responsible for the production of *The New Rural Industries* the “first edition” of this publication and it proved to be an excellent initiative. Each week our research managers get numerous enquiries which often follow from people looking at this publication either in hard copy or on-line so the editors believed it was essential to bring out a new and fully revised edition.

Now we are updating the contents but because it has grown we are splitting it into a “new crops” and a “new animals” format. We have also included updated financial indicators for some crops, using the same models as those used in the previous two volumes of *The New Rural Industries Financial Indicators*.

This Handbook will also differ from the first by being released as a CD as well as hard copy, which will provide substantial cost savings for those purchasing that format, but also provide users with easy searchability.

Each chapter in the book aims to provide a comprehensive introduction to a particular crop, but it is important to repeat the caveats in the previous edition of *The New Rural Industries*. Potential investors and industry advisors should make their own more detailed enquiries about a crop or industry before making decisions or providing advice about them. While every effort has been made to ensure the accuracy of information in each chapter, the markets are changing and new information is becoming available regularly.

Also the fact that a crop has been included in this book should not be regarded as an automatic endorsement of its prospects. A decision to invest in a new crop industry depends very much on an individual’s circumstances and, while success is not guaranteed, there are some important factors that must be taken into account if there is to be any chance of success. The first two chapters in this publication are essential reading for a better understanding of what is involved in considering a new crop investment.

The authors of the individual chapters have been chosen from amongst research or industry agribusiness experts with an intimate knowledge of the crop they are writing about. The chapters have also been reviewed by others with close knowledge of the industry or crop.

The main editorial work for the publication was done by Sue Salvin of Hassall and Associates. She was assisted by Max Bourke and Tony Byrne, the two RIRDC Research Managers responsible for new crop programs. The design and layout of the book was undertaken by RIRDC’s communications team, Cecile Ferguson and Martin Field. I would also like to thank the many authors who contributed their time and expertise to this publication.

This book is further evidence of RIRDC’s commitment to communication and accessibility of information. It is meant to inform both future economic activity and further research. We hope it is also an interesting read.

Simon Hearn
Managing Director
Rural Industries Research and Development Corporation

September 2004
New crops

Rob Fletcher and Ray Collins

Introduction

This chapter discusses the nature of new crops and some of the key factors involved in making decisions about them. The next chapter illustrates the new crop development process by describing a set of courses that help new entrants work through these decisions.

New crops defined

New crop industries usually involve new species or varieties, new locations or technologies for producing a product, new markets or some combination of these factors. For example, the seedless melon industry is based on new varieties and much of its production is in new locations; freekah wheat involves a new adaptation of ancient technology; and the Asian vegetable industry in Australia is based on new markets for existing products.

Several of Australia’s current major industries have been developed from new crops since 1950. They include cotton, mushroom, lupin, sunflower, broccoli, soybean, melon, canola, triticale, avocado, macadamia, chickpea, mango, kiwifruit and almond. Most of these were previously grown successfully overseas or perhaps on a small scale somewhere else within Australia. To be successful in their current areas, they needed breeding, new or modified production systems and/or exposure to markets.

New crops, supply chains and consumers

Successful new industries need satisfied consumers. Consumers will be satisfied when the products they purchase meet their needs at a price that represents, to them, value for money. This price must cover the growing, harvesting, processing and marketing costs of the product, as well as the profit margins for each business in the chain between the producer and the consumer.

The chain of firms that produces the raw material, converts it into a saleable product and makes it available to the consumer is called a supply chain. Each business in a supply chain does something for the final product and is paid accordingly. So supply chains have to exist, if only to ensure that the product gets from the producer to the consumer.

If firms in a supply chain consciously manage their interacting activities for the benefit of the consumer, greater consumer satisfaction can be achieved along with greater benefits for the members of the supply chain. This is a business strategy called supply chain management and it has been shown to be a highly effective way for firms in new crop industries to organise themselves.

For example, the Australian non-astringent persimmon industry has a core group, the Australian Persimmon Export Company, which has built its own supply chain based on the involvement of

The Australian Persimmon Export Company is owned and managed by the growers and a marketer. (Source: Options for Change—New ideas for Australian farmers RIRDC Pub. No. 03/030)
chain partners such as exporters and importers, and a clear focus on what the consumer wants. It began by twelve growers getting together to discuss how they could work together instead of competing against each other in the marketplace. In many new industries it is common for growers to meet to discuss issues of mutual interest. These meetings can become the stimulus for the first stage of supply chain building, simply by shifting the focus to questions about which firms, technologies and systems the new industry will have to deal with so that its product can reach and satisfy consumers. Working co-operatively with the right firms downstream of the producer is essential in creating and sharing the benefits from adopting a supply chain management strategy.

At this level, successful new crop development is about people and how they can improve their individual results by working together.

Learning to work together pays dividends because it leads to stronger relationships at all levels of the supply chain. Stronger relationships allow problems to be solved more easily, initiatives to be taken between chain partners and joint strategies to be developed to counter competition. In a new crop industry, these activities are especially important because they have the potential to flow through to increase consumer satisfaction and sustain the new crop’s advantages for everyone in the supply chain.

Thus, by building stronger relationships and ensuring satisfied consumers, effective supply chain management can contribute to the success of a new crop venture. Developing a successful business around a new crop is as much about the effectiveness of people working together as it is about the effectiveness of the product itself.

In the following sections we explore what attracts people to new crops, some of the challenges involved with developing a new crop or a new product, what risk is and how it is managed and the benefits of collaboration.

Throughout these sections, the focus is maintained on the central role of people and their decision-making processes. In the next chapter, we provide details of some of the resources available to assist with the new crop development process.

A supply chain is the chain of firms that produces the raw material, converts it into a saleable product and makes it available to the consumer. By building stronger relationships and ensuring satisfied consumers, effective supply chain management can contribute to the success of a new crop venture.

Facing up to the new crop decision

Why the interest in new crops?

The reasons that people are attracted to new crops vary widely. The issues discussed below have become evident from the responses given by hundreds of participants in Do Our Own Research (DOOR) Marketing short courses conducted throughout Australasia over the past six years and more than one hundred conferences and workshops addressed by the authors over that period.

I want a change

The most frequently declared purpose amongst Australian new crop developers has been their desire to introduce changes to the way they manage their farms, the supply chains in which they operate, or their lifestyles, before change is forced upon them. Increasing numbers of people are also coming from the cities, seeking a “sea change” or “change of life”.

While curiosity drives much new crop activity, the pursuit of a new crop as a hobby may provide a change from everyday activity but it does not have the same profit motive as a commercial business.
Hobbies are for pleasure, and the pursuit of pleasure usually costs money.

**I want to improve**

When Australian new crop developers have been asked why they want to make a change (that is, when asked the “purpose of their purpose”), they have usually indicated that they want to make money.

There have been some new crop schemes in the past that have provided significant returns for promoters. Such entrepreneurs have attracted attention because their idea is unusual, but their products have often not satisfied the consumer for very long. These products are unable to sustain a presence in the market because they are not attractive enough to consumers or cannot be marketed at a value-for-money price.

In a similar way, new crops have also often featured in tax-driven schemes. Such schemes have sometimes failed to produce a viable product in the market, perhaps because the promoters and/or the managers responsible did not have the skills, motivation or desire to properly nurture the development of the product’s supply chain.

While they may provide short term benefits to a small number of people, neither of these two approaches to new crop development amount to improvement in any long term sense.

New crop developers have often indicated that their businesses should be performing better than they are; new crops are therefore sought to stabilise or improve rural incomes.

New crops have also been targeted as possible solutions during reorganisation in a primary industry sector, for example, as alternative enterprises to the dairy, tobacco or sugar industries in some areas.

**I want to create some benefit**

When Australian new crop developers have been asked why they want to make money, they have frequently indicated that they wish to provide some sustainable long term benefit, which is not necessarily just for themselves.

Such purposes have included the establishment of a new sustainable rural industry for a region or the improvement of the value of their business assets before they are eventually transferred to the next generation.

**I expect it will be worthwhile**

It is possible to examine whether an interest in new crops is worthwhile by testing its future purpose. This assumes that the current, realistic new crop aims will be achieved in the time frame allowed. Looking back from the future, once achieved, was it worth the effort?

For example, assume the purpose amongst the members of a horticultural supply chain is to build up to a $1 million turnover over fifteen years. If achieved, it is possible to examine whether an interest in new crops is worthwhile by testing its future purpose.

| Table 1. Challenges of new crops and new products compared with existing crops |

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<th>Existing Crop - Product Already Traded</th>
<th>Existing Crop - New Product</th>
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<td>Improving the way the crop is grown and harvested</td>
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<td>Making the product available to more consumers who are likely to want it</td>
<td>Finding out from potential consumers what they want in the new product</td>
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<td>Making the new product fit the consumer’s needs as closely as possible</td>
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<td>Organising the supply chain for the new product to get it to market</td>
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<th>New Crop - Product Already Traded</th>
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<td>Establishing an efficient way to grow and harvest the crop</td>
<td>Making sensible alternative crop choices available to farmers so they can diversify their farming systems</td>
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<tr>
<td>Finding out from current consumers what they like about the product and finding ways that the new crop can offer them more benefits</td>
<td>Establishing an efficient way to grow and harvest the crop</td>
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<td>Organising the supply chain for the new product to get it to market</td>
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would it seem worthwhile after this time, given the initial investment required, the effort expended over fifteen years and the risks taken?

To have any hope of hitting a target, we must aim at it. The aim of new crop development is to be profitable. This needs to be realistically stated and it should become the focus of planning. If we eventually hit the target, was it worth the trouble?

**New crops and new products: know the challenges**

Amongst the Australian new crops mentioned in the introduction, all but lupin and macadamia had previously been grown and traded in a market somewhere. Such experience was helpful in making them commercial here. In each case, although there was still a major marketing challenge to be resolved, there was at least existing knowledge about the crop’s production requirements.

Developers of new crops which do not have a previous growing and trading history face the greatest challenges of all, as outlined in Table 1. However, if successful, they also have significant profit potential.

**Better information leads to better decisions**

“Information” can be envisaged as one point in a continuous range from media reports to wisdom (Figure 1).

Each point in the range varies in availability (vertical axis) and usefulness (horizontal axis). Media reports are plentiful and of little relevance to specific new crop businesses. Wisdom is very useful but much harder to find.

In the field of new crop development there is no shortage of media reports and hunches, but there is a distinct lack of reliable data, information and knowledge. This is partially because of the nature of the problems being addressed and partially because some people believe that if they keep data, information and knowledge to themselves and do not share it, they have an advantage over others. The advantages of becoming more competitive through co-operation are addressed below.

New crops are often promoted using the news media as a form of publicity. It may be the first time that many people have heard of a particular crop and they may find the new crop interesting. However, the factual content or relevance of such media reports will vary. The circumstances of most media reports mean that the information is only relevant to those featured in the report. Interesting new crop ideas are extremely plentiful and by themselves add little commercial value to an enterprise.

So, in such an uncertain environment, while it is clear that decisions need to be based on the best possible information, problems can only be solved by testing possible solutions through trial and error.

The difficulty with this approach is that the successful commercialisation of a new crop does not depend on a single factor with a single solution. It consists of a great many factors operating together across the entire supply chain from producer to consumer. The need to deal with such complexity, even on a trial and error basis, brings the solution once again back to starting with the best possible information and the best possible people and accepting the additional challenge of managing a higher than usual level of risk.

![Figure 1. The continuum from media reports to wisdom in relation to availability and usefulness](image-url)
New crop information is of no value unless it can apply to our specific new crop supply chain. We need to be our own experts since we know our own part of the chain and we must be conscious of the risks involved for all chain participants.

Acknowledging and managing risk

Risk is the chance of injury or loss. The level of risk depends on the chance of the injury or loss actually occurring and its impact when it does.

Injury or loss can be internal or external to the new crop business. If internal, it arises from production problems or difficulties with the planning for the business or the economic and political environment in which the business operates.

If it is external, it results from problems with the market in which the product is traded, the supply chain to which the business belongs or the economic and political environment in which the business operates.

External risk factors usually have the greater influence on the ultimate commercial success of the new crop product.

Attempts to estimate external risk by imagining the future can provide some benefit in preparing for future management action but have less validity if the product is new.

External risk factors are best investigated through having a product in the market.

By following the 13 step commercialisation process outlined below, new crop supply chain members can enter a market with a product under a strict set of benchmark and monitoring conditions and test its appeal to the consumer directly. The steps are as follows:

1. the proposal of the new crop by those willing to commit financial resources to such development.
2. the acknowledgment that new crop development is a high risk adventure.
3. the recognition of the need to protect intellectual property rights.
4. the assessment of the appeal of the new crop product to the potential purchaser, using all relevant available criteria with an indication of those criteria for which no information is available.
5. a theoretical assessment of the production potential of the new crop using all relevant criteria with an indication of how this information is obtained.
6. the establishment of an integrated development group comprising producers, processors, distribution and marketing partners with research providers in a facilitation role.
7. agreement within the group on resource requirements, expected outcomes, action plans to achieve them and proposed distribution of any profits.
8. the establishment of a process of project monitoring to identify and resolve problems quickly and efficiently.
9. the establishment of economic benchmarks and an agreement to abandon the proposed development if these have not been met.
10. the establishment of a system of review to determine whether the development is worthwhile and to analyse the critical contributions for success or failure.
11. trial production for trial marketing.
12. trial production for trial processing and packaging.
13. experimental production, using properly designed scientific trials.

A range of Australian Desert Limes products at a farmers' market in Brisbane (Photo: Australian Desert Limes, 2003)
What are the “best bets”?

Attempting to predict which new crops are likely to be commercially successful in a general sense is probably a waste of resources. New crop options that may become ‘best bets’ for one person may be rejected by another.

There are no generic ‘best bets’ because new crop commercialisation systems behave chaotically, just like weather systems and market systems. Such chaotic systems:

- are in a state of continuous change
- are influenced by a large number of factors, each of which is changing as well
- are strongly influenced by interactions among these factors
- have feedback and regulatory mechanisms so that past behaviour can influence future behaviour.

One of the main reasons that the future behaviour of a chaotic system, such as a new crop supply chain, is very difficult to predict is because very small changes can influence outcomes in a major way. However, it is a mistake to conclude that because a system is chaotic there is no point in trying to manage it. On the contrary, managers who are better at making ‘best bet’ decisions can prosper in such environments.

One way to improve the chances of making ‘best bet’ decisions in new crop development is to base such decisions on the best possible information, evaluated in a non-emotional way and to make these decisions in collaboration with other members of the supply chain.

Such an approach reflects the findings of Collins (2003) who showed that the three major impediments to success in new crop industries are lack of reliable information, lack of an orientation to the market, and lack of collective behaviour.

The courses described in the following chapter help participants build a personal ‘best bet’ list of new crops.

Then, having made the decision about which crop to become involved with they help managers to learn what is required to ‘hand craft’ their own supply chain as a way of improving their new crop enterprise’s chances of success.

Co-operating to compete

Some new crop developers work alone, others choose to work in groups. Those who work alone are often successful by keeping information to themselves and in the short term at least, profit from their way of growing and marketing the new crop.

However, because no business can operate independently of the supply chain for its product, sooner or later the success of the individual attracts competitors whose objective is to copy successful systems.

Frequently, once the ‘secrets’ of the individual have been learned, the system is easy to copy and intense competition between individual firms is the result.

Such competition usually reduces the returns to all competing firms, and if one partner competes to gain an advantage over the other, future hopes of co-operation are severely diminished.

On the other hand, new crop developers can choose to work collaboratively and they can choose to consider the whole supply chain as the ‘field’ for their work.
Then it becomes possible to generate and share a far greater range of data, information and knowledge and ultimately to improve the chances of success for everyone by making better decisions.

As shown earlier in the case of the Australian Persimmon Export Company, over the longer term, co-operation produces the most beneficial outcomes.

There are presently a number of other new crop groups in industries such as bamboo, native flowers, tropical fruits and vegetables who are exploring ways of becoming more competitive through co-operation and adopting a whole of supply chain strategy.

The downside of collaboration is the need to manage interpersonal relationships and the dynamics of a group of people trying to jointly solve a common problem.

However, these are exactly the same skills that will be required in the on-going management of the supply chain for the new crop product.

So collaboration can also provide a learning opportunity that will continue to pay off commercially.

Learning how to co-operate to become more competitive is the aim of the “Forming and Managing Supply Chains in Agribusiness” short course described in the next chapter.

Key references (see page 13)

About the authors

Dr Rob Fletcher teaches biology and plant breeding at the University of Queensland Gatton. His research interests for the past fourteen years have focused upon commercial innovation in the establishment of new rural industries. He manages the Australian New Crops Web Site (www.newcrops.uq.edu.au) and has facilitated short courses and spoken at conferences and workshops on new rural industries throughout Australia and overseas.

Dr Ray Collins is Associate Professor in Agribusiness in the School of Natural and Rural Systems Management, at the University of Queensland. His teaching and research focus on new agribusiness enterprises, supply chain management and export development strategies. Over the last 15 years Ray has worked with new rural industries as both researcher and consultant. His contribution to the Australian persimmon industry is sometimes quoted as a model of how a new export oriented horticultural industry can guide its own future. Ray is a recipient of the University of Queensland Excellence in Teaching Award, and two International Collaborative Research Awards.

Disclaimer

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Introduction

The previous chapter described some of the main factors involved in decisions about investing in new crops, focusing particularly on the importance of understanding markets and building a supply chain. This chapter provides more detail about new crop development by outlining the content of three courses available to assist and encourage commercialisation of new crop products.

The DOOR (Do Our Own Research) Marketing short course

The DOOR Marketing short course comprises a two day workshop for groups of up to thirty motivated new rural industry participants (producers to consumers) at a time.

The principles behind the DOOR Marketing course can be summarised as follows:

- new crop participants cast themselves as experts in their own farming systems or supply chain components and cooperate with others to find solutions
- participants need to focus on their principal motivation;
- there is no pre-determined outcome
- participants own the outcomes themselves.

The course assists new crop participants in determining whether their selected new crop product warrants investment in the types of strategic plan prepared in the Fresh Fields short course, described below.

The DOOR Marketing program consists of the following:

1. **Introduction of participants to each other**

Psychological research has indicated that primary producers tend to be “loners”. Production dominates their minds. It may therefore be difficult for them at first to think laterally, that is, “past the farm gate” and to collaborate in new crops planning along the supply chain. Experience with DOOR Marketing and similar short courses throughout Australia has indicated that once participants understand who else is involved in a course, they have no trouble collaborating or planning together.

At the commencement of the course, participants provide their names, affiliations, reasons for attending and expectations for the course. Each person also nominates a new crop/rural industry upon which to focus her/his attention.

The facilitator vigorously interacts with all participants during these introductions and subtly encourages the participants to interact with one another as well.

As a result, each participant knows something about every other participant since they have all been able to speak about themselves. Each participant also experiences the difficulties of publicly committing to a single new crop for the course.

Participants in DOOR Marketing realise they all share the same problem; namely, they want to do better through designing their own future.
2. **The 10 steps for planning**

The 10 steps for planning were originally developed in response to enquiries from individuals wanting to know about ‘best bets’ amongst new crops but they have also come to be useful in the DOOR Marketing short course.

The exercise provides an introduction to the issues relevant to new crop development and demonstrates for participants the usefulness of sharing problem solving with others.

The questions relating to each of the planning steps are shown in Table 1.

3. **Systems exercise**

To encourage systems thinking, a series of generic questions has been designed to target each participant’s future scenario, enquiring about:

- likely information sources
- the participants’ principal motivations
- the physical and economic environment
- the availability of colleagues and partners;
- the types of inputs required, including equipment and technology;
- the outcomes sought.

Four scenarios have been used:

- wishful thinking
- reality
- the local modifications needed
- the likely action plans.

This exercise encourages lateral thinking and encourages each participant to consider likely relevant sources of information for the modification of her/his farming and supply chain system.

4. **A brainstorming session on the types of information required**

Participants cooperate in a brainstorming exercise to identify the types of information required to bring their new crop developments to reality. After the session, each type of information is classified as a marketing, economic, research and/or production issue and the marketing issues are ranked for perceived importance amongst the participants.

Brainstorming is also a useful tactic to encourage new crop developers to think laterally, since no criticism or discussion is permitted following any contributions.

Often, possible solutions to problems which appear to be difficult to surmount can be discarded before the implications are properly analysed; brainstorming amongst motivated individuals extends the range of possibilities in problem solving/solution finding.

5. **Strategic marketing management**

Strategic marketing management asks the question: “what market conditions are necessary to stimulate the commercialisation of new crop products?”

The questions in Table 2 comprise the outline of the “homework” for participants and once attempted, permit the completion of the SWOT analysis during the second day of the DOOR Marketing short course.

During the brainstorming session, it is invariably external issues which predominate, with market research perceived as more important than consumers, competition or the business environment (Table 2).

---

**Table 1. The 10 steps for planning**

<table>
<thead>
<tr>
<th>Step</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The participant’s current situation</td>
<td>Are you a contented person?</td>
</tr>
<tr>
<td>2. The participant’s principal motivation for change</td>
<td>What is your interest in new crops?</td>
</tr>
<tr>
<td>3. Personal skills</td>
<td>What do you enjoy doing?</td>
</tr>
<tr>
<td>4. Commitment</td>
<td>Have you chosen a new crop to which you are willing to commit money and time?</td>
</tr>
<tr>
<td>5. Information available</td>
<td>Do you have easy access to germplasm and useful information?</td>
</tr>
<tr>
<td>6. New crop supply chain</td>
<td>How do you describe the new crop product to be sold?</td>
</tr>
<tr>
<td>7. Market research</td>
<td>What is the marketability of the new crop product?</td>
</tr>
<tr>
<td>8. Production</td>
<td>Will the new crop grow in your area?</td>
</tr>
<tr>
<td>9. Personal factors</td>
<td>Are you contemplating forming a group to grow and market the new crop product?</td>
</tr>
<tr>
<td>10. Economics</td>
<td>Have you formed a group already and if so, what is its structure and how will it function?</td>
</tr>
</tbody>
</table>
Table 2. The outline for a strategic marketing management investigation for a new crop participant (adapted from Aaker 1995).

<table>
<thead>
<tr>
<th>External factors</th>
<th></th>
</tr>
</thead>
</table>
| Customers | Who are our customers?  
Are the customers a uniform group?  
Will the product satisfy our customers' needs?  
What is our customers' motivation in buying the product?  
What are our customers' unmet needs?  |
| Competitors | Who are our current and potential competitors?  
Is our product likely to encourage fierce competition in the market?  
Are our competitors a uniform group?  
What are the characteristics of our competitors?  |
| Market analysis | What is the size of the market?  
How long is the product life-cycle expected to be?  
What will the profitability of the market be?  
What are the cost structures along the supply chain?  
What distribution channels will be used for our product?  
What are the overall market trends?  
Are there any key success factors within the industry requiring attention?  |
| Environment | What important forces outside our company and the immediate market that may have an effect on success of the new crop product?  
Is it possible to develop optimistic, realistic or pessimistic scenarios?  
What areas of information are currently limited, requiring attention?  |

<table>
<thead>
<tr>
<th>Internal factors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance</td>
<td>What measures for profitability and performance should we use?</td>
</tr>
</tbody>
</table>
| Strategic options | What kinds of strategies have we used in the past?  
Do the strategies need to change in the future?  
What is our company's sustainable competitive advantage?  
What are our problems?  
How will these problems be overcome?  
What are the financial resources available?  
What business are we in?  
What type of enterprise are we?  
What is our strategic vision?  |

6. **SWOT analysis**

The core activity of the DOOR Marketing course is preparing for the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of new crop products, the products having been chosen by the participants themselves.

There has usually been a break of two days to seven weeks between the first and second days of the course so participants can complete their “homework” in preparation for the SWOT.

The second meeting of the DOOR Marketing short course commences with another introduction session with similar questions to those asked on the first day, focusing on this occasion on new crop products and the outcomes of the homework.

The SWOT analysis is then completed (Table 3).

The focus in the SWOT analysis is not on picking winners, but on a qualitative identification of any fatal flaws in a proposal.

The intention is to find a reason to throw every proposal away; those that are not thrown away can be considered for potential commercialisation.

In Table 3, only the clear boxes need to be considered (the others are not relevant) and fatal flaws are marked with a hash sign.

If participants identify any threats in terms of customer demand, current market price, industry trends or production factors or any weaknesses in terms of expected returns, then their proposals cannot be considered viable.
<table>
<thead>
<tr>
<th>Internal factors</th>
<th>External factors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Factors</strong></td>
<td><strong>STRENGTH</strong></td>
</tr>
<tr>
<td>Customer demand</td>
<td></td>
</tr>
<tr>
<td>Competition</td>
<td></td>
</tr>
<tr>
<td>Start-up costs</td>
<td></td>
</tr>
<tr>
<td>Current market price</td>
<td></td>
</tr>
<tr>
<td>Expected returns</td>
<td></td>
</tr>
<tr>
<td>Industry trends</td>
<td></td>
</tr>
<tr>
<td>Promotional strategies</td>
<td></td>
</tr>
<tr>
<td>Distribution strategies</td>
<td></td>
</tr>
<tr>
<td>Experience</td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td></td>
</tr>
<tr>
<td>Commercialisation</td>
<td></td>
</tr>
<tr>
<td>Production factors</td>
<td></td>
</tr>
</tbody>
</table>

Fletcher et al. 1997

Approximately 90% of the initial proposals from participants in DOOR Marketing short courses so far conducted throughout Australasia have been abandoned by them as a result of such findings.

Most participants have then repeated the process, focusing on other products from the same new crop and/or other new crop species.

**Fresh Fields short course**

The Fresh Fields short course uses the same principles as the DOOR Marketing short course. New crop developers plan strategies for their businesses, leading to the creation of business and marketing plans. The course was designed to assist those participants whose new crop product ideas survived the DOOR Marketing SWOT analysis described above. In a sense, it helps participants to build a personal ‘best bet’ list of new crops.

The Fresh Fields program focuses on the business satisfying its customers’ needs profitably and consists of the following:

- identifying the needs of each member of the supply chain
- understanding the way that these needs will be met
- setting realistic targets
- identifying a process to follow
- analysing the businesses with which to deal
- establishing priorities;
- selecting future actions to take
- creating a plan to follow.

**Forming and Managing Supply Chains in Agribusiness learning package**

The Forming and Managing Supply Chains in Agribusiness short course will help managers to learn what is required to ‘hand craft’ their own supply chain as a way of improving their new crop enterprise’s chances of success. This learning package would be of interest to anyone in the new crop development process, but is specially targeted at those who are close to the full commercialisation stage.

The learning package (comprising a workshop, CD and workbook) was developed out of a need expressed by large numbers of applicants for funding under the federal government’s New Industries Development Program (NIDP) run by the Australian Government Department of Agriculture, Fisheries and Forestry. These applicants often had a clear idea of the product or service they were developing, but very poorly thought out strategies to ensure that the supply chain that would deliver their product to consumers would do so competitively and at a profit.

The learning package is a joint venture between NIDP and the University of Queensland. Its aims are:

- to demonstrate the need for a whole-of-supply-chain perspective on new enterprise development
- to show how a supply chain can be ‘hand crafted’
- to ensure that new enterprise
developers know what must be managed, and how, in making their supply chains as competitive as possible.

The CD contains formal instructional material that is heavily supported by recorded interviews where practising managers recount their own experiences and strategies in respect of each supply chain learning principle. Thus the CD is oriented towards learning from the experiences of others. It also contains the downloadable workbook, two complete case studies of supply chain management in action in new enterprise development, a library of additional reading resources and a list of contacts for further information.

Participants usually begin by attending a one day workshop where they are introduced to the CD and workbook, and begin working on their own new enterprise's supply chain.

Having their own copy of the CD and being familiar with how to use it as a learning tool means that they can then work towards developing supply chain strategies in their own time and with prospective chain partners. Using the workbook to record what they are thinking and doing brings a level of discipline and structure to the process, and creates a record for future evaluation of progress.

These workshops are organised through NIDP or the University of Queensland.

Conclusions

The future viability of new crop options cannot be predicted accurately because biophysical, marketing, economic and human systems often behave chaotically.

Rather than trying to predict winners, members of new crop industries can use the resources outlined above to collectively focus their goals and pursue them in ways that improve their chances of making ‘best bet’ decisions. This will involve identifying consumer needs, clearly defining the new crop product, establishing the human and technical components of the supply chain and entering a commercial market, once appropriate benchmarks for investment, growth and returns have been set.

Such an approach can be applied to firms in any new crop industry. At a collective level this can also provide a framework for the industry to determine its needs in terms of future research and development.

Some new crop industries will eventually prove to be commercially significant over large areas, but trying to predict in advance which ones will achieve this level of success has proven to be a waste of resources.

A new crop industry’s most valuable resource is its people.
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Many thanks to Professor Gary Jolliff, Dr Colin Birch, Greg Ferguson, Nick Walker, Brett Reisenleiter, David Milstein, Sibylla Hess-Buschmann and many others for helpful comments on earlier drafts of these chapters.

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Key references


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Japanese taro 66
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Asian brassicas
(Chinese broccoli, Chinese cabbage, bok choy and choy sum)

Michael Clark

Acknowledgement is given to Stephen Moore, Wendy Morgan, Bruce Tomkins, Paul Daly and Mandy Chew, the authors of the chapters on Asian brassicas in the first edition of this publication.

Introduction

Asian brassicas belong to the Brassica family – the Brassicaceae, which includes vegetables such as cabbage, broccoli, cauliflower, radish and turnips.

Asian brassicas include Chinese broccoli (Brassica oleracea L. var. alboglabra Bailey), Chinese cabbage (Brassica pekinensis), bok choy (Brassica rapa L. var. chinensis) and choy sum (Brassica rapa L.var. parachinensis).

Chinese broccoli is also known as kai lan and gai lum. The whole plant can be eaten, but the older leaves and stems are generally stringy and discarded. Young leaves and stalks (15–20 cm high) with compact florets are selected. These parts of the plant are sweet and tender.

Depending on cultivar Chinese cabbage can vary substantially in appearance, from the short squat wong bok types to the long, slender rocket or michihili types. Chinese cabbage is the most frequently eaten vegetable in Asia. It is commonly eaten as a freshly cooked vegetable in stir fries and is often further processed as brined product or used in pickles such as kim-chi.

Bok choy or pak choi does not form a true head. The whole plant (minus the roots) is eaten with only the older leaves being discarded. Bok choi is eaten in both mature and ‘baby’ forms. After Chinese cabbage, bok choy is the most commonly consumed Asian vegetable in Australia.

Choy sum is also known as Chinese flowering cabbage and tsoi sum. The whole plant can be eaten including the normally yellow flowers.

The height of the plant varies from 20 to 30 cm. The pleasant taste and cooking qualities of choy sum have made it the most common leafy
vegetable in Hong Kong.

Asian brassicas are annual or biennial plants that are normally grown commercially as an annual. Asian brassicas have been grown successfully and are available in all Australian states. Farms vary from smaller urban market gardens, plots of around 1 to 2 ha, to larger and more remote holdings, say 5 to 15 ha.

**Markets and marketing issues**

Asian brassicas are available nationally throughout the year in wholesale markets, Asian grocery stores and supermarkets. All Asian brassicas are sold fresh or fresh-processed as a constituent of a salad-mix. The marketing chain is relatively simple. Growers pick, wash and pack or bunch product and deliver it to market on the same day as harvest. Chinese cabbage is packed into cartons, other species are sold in bunches. The fresh-cut salad market is more sophisticated – only leaves are harvested, washed, spun, refrigerated, either packaged for food-service, or sent to a secondary processor for inclusion in a salad mix, followed by packaging again and retail. Asian brassicas (usually in a baby-leaf form) that may be included in a salad-mix include mizuna (*B. rapa var. nipposinica*), tatsuoi (*B. rapa var. rosularis*), Chinese mustard (*B. juncea*). Recent price and volume data for Chinese cabbages and bunching lines at major wholesale markets are shown in Table 1. It is estimated that around 80% of New South Wales and Victorian production passes through the central markets while in other states the proportion is closer to one half.

**Table 1. Asian brassica sales by volume and value at wholesale markets (2001)**

<table>
<thead>
<tr>
<th></th>
<th>Volume (tonnes)</th>
<th>Value of sales ($/t)</th>
<th>Gross value of total sales ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW – Flemington</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>3,112</td>
<td>645</td>
<td>2,008,073</td>
</tr>
<tr>
<td>Chinese Vegetables#</td>
<td>2,316</td>
<td>1,853</td>
<td>4,291,030</td>
</tr>
<tr>
<td>Victoria – Melbourne</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>3,795</td>
<td>683</td>
<td>3,653,475</td>
</tr>
<tr>
<td>Chinese Vegetables#</td>
<td>1,653</td>
<td>2,211</td>
<td>4,415,417</td>
</tr>
<tr>
<td>Queensland – Brisbane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>1,418</td>
<td>506</td>
<td>718,454</td>
</tr>
<tr>
<td>Chinese Vegetables#</td>
<td>788</td>
<td>1,948</td>
<td>1,535,254</td>
</tr>
<tr>
<td>South Australia–</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adelaide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>369</td>
<td>914</td>
<td>336,954</td>
</tr>
<tr>
<td>Chinese Vegetables#</td>
<td>262</td>
<td>2,750</td>
<td>720,033</td>
</tr>
<tr>
<td>Western Australia–</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>840</td>
<td>535</td>
<td>449,034</td>
</tr>
<tr>
<td>Chinese Vegetables#</td>
<td>572</td>
<td>1,679</td>
<td>959,534</td>
</tr>
</tbody>
</table>

Source: AusMarket Consultants, *no disaggregated data available believed to include Chinese broccoli, bok choi, Chinese flowering cabbage,* *only Year 2000 data available. Small amounts also grown in Tasmania, Northern Territory and Australian Capital Territory

While export growth has stalled in recent years, Singapore, Hong Kong and Taiwan remain important outlets for Australian product. Australian exports face strong competition in these markets from an increasingly well-organised and low cost production base in China. Chinese competition based on low cost labour also limits the potential of highly processed product such as pickles in both export and domestic markets. Fresh-processed salads containing Asian brassicas do not compete with product imported into Australia which is restricted on phytosanitary grounds.

**Production requirements**

Asian brassicas are cool season crops that prefer uniform moist conditions and full sunlight. The ideal temperature for growing is between 15 and 20°C. High temperatures and long days tend to induce bolting. Tropical cultivars of Chinese cabbage should be sought out for production in hotter climates. Most varieties tolerate light frosts.

Preferred soils are fertile, high in organic matter and moisture-retentive. Ideal pH is around 6.5 to 7.0 for bok choi, 5.5 to 7.0 for Chinese cabbage and 6.0 to 7.0 for Chinese flowering cabbage and Chinese broccoli. The addition of lime will help control club root and planting into raised beds can prevent soft rots.

Asian brassicas are shallow rooted and require frequent light watering. This will also prevent the leaching of nutrients from the soil. Lack of moisture at any stage can promote bolting and poor quality plants. Young plants are fragile and should be protected from the wind.
Asian vegetables

Varieties/cultivars

Australian growers of Asian brassicas use hybrid seed in preference to open-pollinated seed or retaining seed from their own crops. Seed for most Asian brassica varieties is sourced from China and multiplied under contract in Australia. Popular and emerging varieties are shown in Table 2.

Agronomy

Asian brassicas can be either sown directly from seed or transplanted into a fine well-prepared seedbed. Seed sowing is typically at a rate of two to three seeds per station 12-15 mm deep. Seedlings are hand thinned after germination. Chinese cabbage seeds are sown at a rate of 500-750 g/ha, with plant spacing of approximately 35 cm. A similar distance is required between rows.

Chinese broccoli and choy sum are sown at about 0.6 cm in depth in rows about 30 cm apart and thinned to about 10 cm. Closer spacing will produce less fibrous plants with better eating quality. Bok choy is normally grown in rows spaced around 20 cm apart, large types like ‘Chinese White’ require more space and baby bok choi less.

Table 2. Asian brassica varieties

<table>
<thead>
<tr>
<th>Asian Brassica</th>
<th>Varieties</th>
<th>Strengths/features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese broccoli</td>
<td>F2 Green Lance</td>
<td>A more vigorous hybrid than the common white-flowered varieties</td>
</tr>
<tr>
<td></td>
<td>Chinese Yellow Broccoli</td>
<td>A smaller yellow flowering variety recommended for summer production</td>
</tr>
<tr>
<td></td>
<td>WR Green 60, RS1446 and China Pride wong bok types</td>
<td>Most tolerant to gomasho, bolting and internal rots and provided high marketable yields in WA, Tas and SA</td>
</tr>
<tr>
<td></td>
<td>Cream and Manoka</td>
<td>Good late planting varieties with high marketable yield, Victoria.</td>
</tr>
<tr>
<td></td>
<td>Yuki, Treasure Island and WR Green 60</td>
<td>Best performing early varieties, WR Green 60 also showed least evidence of chilling injury</td>
</tr>
<tr>
<td>Bok choy</td>
<td>Chinese White Bok Choy (eg Joi Choi)</td>
<td>Sturdy variety with thick green leaves that curl outwards and bright white stems, 30 cm at harvest. Cold tolerant but with a tendency to bolt</td>
</tr>
<tr>
<td></td>
<td>Shanghai Bok Choy (eg Mei Qing)</td>
<td>Leaf stalks are light green, broad flat and widen at the base, 15 cm at harvest. Hardy and will grow all year round</td>
</tr>
<tr>
<td></td>
<td>“Soup Spoon” type (eg Japanese white celery mustard, Tai Sai Nikanme, Seppaku)</td>
<td>Thin leaves and stalks, leaves lightly cupped, stalks are semi-circular, 45 cm at harvest. Vigorous and versatile. Tolerate both heat and cold</td>
</tr>
<tr>
<td></td>
<td>Canton or squat</td>
<td>Compact with dark green leaves. Stalks are white, short and thick. Can be harvested as baby bok choy or left to maturity. Best in warmer areas and bolt in the cold</td>
</tr>
<tr>
<td>Choy sum</td>
<td>sze sap yat (40 days)</td>
<td>Varieties are classified by the number of days from sowing to harvest and their susceptibility to bolting</td>
</tr>
<tr>
<td></td>
<td>ng sap yat (50 days)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>luk sap yat (60 days)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bat sap yat (80 days)</td>
<td></td>
</tr>
</tbody>
</table>

Chinese cabbage cultivar trials, East Gippsland
Transplants are generally raised in a greenhouse or polyhouse for three to four weeks before planting in the field. Transplanting is more expensive than direct seeding but assists with environmental control during the early phases of the plant’s life.

Fertiliser requirements differ markedly between soil types and soil testing is the best way to determine the elements needed for crop production. In general terms Asian brassicas require large amounts of fertiliser, particularly nitrogen, potassium and phosphorus. Fertilisation often starts with an application of animal manure two weeks before planting followed by regular applications of nitrogen and potassium. Application of fertiliser through the watering system is effective. Over-fertilisation can result in soft rot and plant tip damage.

Maturation takes anywhere from 30 days for bok choy to 100 days for Chinese cabbage.

Pest and disease control

The availability of registered agricultural chemicals for pest and disease control in Asian brassicas is problematic.

Asian brassicas compete poorly with weeds in their first few weeks of life. Hand weeding or Dutch hoeing is commonly used to control weeds. A pre and post transplant herbicide application may also be necessary.

Major diseases of Asian brassicas include:

- **clubroot** – a soil born fungus that results in malformation of the roots and plant wilting during warm weather. Control is via crop rotation, fumigation, sanitation, maintenance of high soil organic matter and a pH above 7.3

- **downy mildew** – infected leaves develop purple, yellow or brown patches on the upper surface and white or grey downy fungal growth underneath. Older leaves develop dead spots. Control through improved ventilation to decrease humidity and avoid overhead irrigation

- **white rust or white blister** – small circular spots raised on both sides of the leaves, underside a mass of white powdery spores. Control through the removal of cruciferous weeds, crop rotations and ensuring that all plant residuals are removed or composted before the next crop is sown

- **edema** – wart like structures on the underside of leaves. Control of the disorder can be achieved by not allowing the soil to become too wet and improving the ventilation of polyhouses.

Major pests of Asian brassicas include:

- **aphids** – live on the underside of leaves. Affected plants will wilt, look distorted and curled. Aphids are also vectors for viruses. Control cruciferous weeds in the vicinity of Asian brassicas

- **caterpillars** – will attack and severely damage brassica crops. Many species, especially diamondback moth, have developed resistance to common control chemicals and Integrated Pest Management is recommended

- **snails and slugs** – eat whole young plants and are especially active during mild damp weather. Control with pellets.

**Harvest, handling, storage, post harvest treatments and processing**

Harvest should occur in the cool early morning. Asian brassicas are hand-harvested at the base with a knife. Old or damaged outer leaves are trimmed off and the butt trimmed flush at the base. All blemishes and defects should be removed.

Harvest should occur before the outer leaves become yellow and the plant becomes fibrous.
Key Messages

- Asian Brassicas are cool season crops that prefer moist conditions and full sunlight.
- Seed from most Asian Brassica varieties is sourced from China and multiplied under contract in Australia.
- The industry is experiencing price pressure as supply continues to grow and domestic and export markets mature.

Key statistics

- Australia produced over 15,125 t of Asian Brassicas in 2001.
- The gross value of Asian Brassicas sales produced in Australia for 2001 was over $19 million.
- After Chinese cabbage, bok choy is the most commonly consumed Asian vegetable.

Financial information

Asian brassicas, especially bunching types, are often grown on rented land in the urban fringe of capital cities with few establishment costs. They offer a low entry cost enterprise for newly arrived migrants. Chinese cabbage tends to be grown on larger more remote farms and requires greater mechanisation.

Establishing a cost of production and generating crop gross margins is limited by the availability of data and the cultural expectations of growers. For example, growers in New South Wales of Vietnamese origin do not consider labour to be a cost of production. Profit is based on the gross return of the crop minus the cost of materials (seed fertiliser, chemicals, rent, etc.). This perception of production returns is exacerbated by difficulties in obtaining labour costs and yield data from growers wary of revealing financial information.

Typically the extended family provides the farm labour and appropriately priced external labour is difficult to secure.

The industry is experiencing price pressure as supply continues to grow and domestic and export markets mature. Strong price competition has placed downward pressure on product quality. The general perception is that an acceptable profit margin is still available on most crops, but that it is insufficient to retain the second generation of growers.

Representative yield, unit prices and gross returns are shown in Table 3 below.

Table 3. Yield and gross income estimates

<table>
<thead>
<tr>
<th>Asian Brassica</th>
<th>Yield range (t/ha)</th>
<th>Av yield (t/ha)</th>
<th>Sale price ($/t)</th>
<th>Gross sales ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese broccoli</td>
<td>6 to 10</td>
<td>9</td>
<td>2,000</td>
<td>18,000</td>
</tr>
<tr>
<td>Chinese cabbage</td>
<td>35 to 80</td>
<td>60</td>
<td>600</td>
<td>36,000</td>
</tr>
<tr>
<td>Chinese chard</td>
<td>8 to 17</td>
<td>15</td>
<td>2,000</td>
<td>30,000</td>
</tr>
<tr>
<td>Chinese flowering cabbage</td>
<td>6 to 18</td>
<td>12</td>
<td>2,000</td>
<td>24,000</td>
</tr>
</tbody>
</table>

Source: Asian Vegetable Industry Situation Assessment, RIRDC 2003

For the fresh-cut salad industry, leaves can be either mechanically or hand-harvested. Leaves are cut at the petiole. Leaves are often washed in sanitised water, spun-dried, packaged and cooled.

Brassicas should be stored at 2–5°C. Product should be covered with plastic sheet to maintain high humidity and keep out air-currents from the refrigeration system. Bunching lines can be stored for up to a week. Chinese cabbage will store for longer periods. Brassicas should be handled carefully as they are easily damaged.

Chinese cabbage cvs. ‘Yuki’ and ‘WR Green’ 60, East Gippsland
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About the author

Michael Clarke is an experienced agricultural economist, researcher, policy analyst and business planner. His work for RIRDC includes An Asian Vegetable Industry Situation Assessment, a review of Hydroponics as an Agricultural Production System, Financial Analysis of New and Emerging Rural Industries, Market Opportunities for Australian Grown Jojoba and an Audit of the Australian Organics Industry. In 2004 Michael prepared a business development strategy for a Cambodian Vegetable Growers Cooperative and was part of a team that reviewed the efficiency and effectiveness of Horticulture Australia Limited. Michael is principle consultant, AgEconPlus Pty Ltd.
Bitter melon

Melinda Gosbee

Introduction

Bitter melon (*Momordica charantia* L.) is a cucurbit vegetable consumed as an immature fruit in many Asian and Indian cuisines. It is considered by Asian cultures to confer a wide range of health benefits. The fruit is cut open, the seeds and membranes discarded and the remaining flesh used in soups and stir fry, or stuffed. Young shoots, leaves and flowers are also consumed, but this article is concerned with production the fruit.

Bitter melon is a sub tropical or tropical crop, and recent trial data shows that it can be grown in most Australian states in the correct season (Morgan and Midmore 2002). Growers with experience in vegetable production should find the production of bitter melon similar in many ways to that of other cucurbit crops such as zucchini and cucumber. However, the most difficult task is determining harvest maturity which has a major impact on the crop quality and price.

Current supply of bitter melon is to the Australian domestic market, particularly Australians of Asian descent. Unlike other Asian type vegetables, bitter melon may not be readily adopted by Australians from other backgrounds due to its strongly bitter flavour.

Alternative names for bitter melon include Alligator pear, balsam pear, bitter gourd, and foo gwa (Chinese).

Markets and marketing issues

Farm areas of production are usually small, commonly only 0.5 ha on 5 or 20 ha properties, which
Bitter melon may be producing several other crops concurrently. Bitter melon is harvested, cooled, packed and refrigerated transport is used to take it to market.

Within Australia, most bitter melon is sold in Sydney and Melbourne. This is largely due to the greater population of Australians from Asian descent in these cities. Distribution is both within and outside the major produce markets. They are commonly sold in a 10 kg box. Wholesale prices range between $1.00 and $3.50/kg depending on supply, the average price is between $2.00 and $2.50.

The main producers of bitter melon are in the Northern Territory, where production has been steadily increasing since 1996 (Table 1). Data is not available for national production.

Table 1. Northern Territory production of bitter melon

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tonnes</td>
<td>337</td>
<td>514</td>
<td>611</td>
<td>864</td>
</tr>
<tr>
<td>Value ($’000)</td>
<td>981</td>
<td>1028</td>
<td>1370</td>
<td>2159</td>
</tr>
</tbody>
</table>

Source: PrimeStats; Horticulture Industry, Department of Business, Industry and Resource Development, NT.

Bitter melon is grown and consumed in most Asian countries, however bitter melon is not currently exported from Australia.

The main constraint to developing export markets is the cost of transport of bitter melon relative to its low value, and its highly perishable nature. Competition from low priced local product in importing countries would limit the price.

Fresh bitter melon is not imported into Australia.

Production requirements

Bitter melon is a tropical or sub tropical crop, it can be grown around Australia at different times of the year. It is currently harvested around Darwin and northern Western Australia during May to October, in the Northern Rivers district of New South Wales from January to May and around Sydney and Melbourne from December to February. These production areas are based on either the location of market garden type enterprises or proximity to the markets of Sydney and Melbourne. Considerable areas of the East and West Coasts with a sub tropical or tropical climate and available water would be suitable for bitter melon production. It can also be grown in hot houses, however this is generally uneconomical.

Minimum temperatures of 18°C are preferred for growth; a reduction in growth occurs with temperature lower than 16°C. Areas prone to frosts are not suitable for this tropical vegetable; 24 to 27°C is optimum temperature range, although it copes reasonably well with higher temperatures. Irrigation is required where rainfall is inadequate.

Varieties/cultivars

The current preferred type of bitter melon in the market is medium green, 18 to 22 cm long and 5 to 7 cm diameter. It has many small but prominent bumps over the surface, and few ridges. A wide range of shape and size can be seen in seed catalogues from overseas companies. It is important to establish the local market requirements before ordering seed. A Quality Descriptor Manual for bitter melon (Vujovic et al., 2000) is a useful tool for describing some of these characteristics.

Most of the bitter melon produced in Australia is from open pollinated seed. Seed is selected by the farmer and stored for the next crop. Several hybrid varieties are available from seed companies within Australia and overseas. These have the advantages in consistency and yield over some open pollinated varieties, however open pollinated types selected for their performance in specific environments can yield as well as the hybrids. Preferred
commercially available varieties include Baizin (available from Fairbank's Selected Seed Co.) and Moonlight (Known You Seed Co., Taiwan).

White flesh bitter melon are also available, however there is currently no known domestic market for the white type.

Cultural practices/ agronomy

Bitter melon is grown on trellises, which are in turn placed on raised beds or ridges. These can be covered in mulch to improve growth where necessary. Trellises are usually steel posts 2 m high, with wires at 50 cm from the ground and then 20 cm intervals, and 100 mm nylon netting. Overhead trellises are also used, these are similar in construction but have additional horizontal spans. Lateral branches below the first production wire are removed, as is the tip of the main runner when it reaches the top of a vertical trellis.

Bitter melon grows best in well-drained soils rich in organic matter, but will tolerate many soil types with adequate fertiliser application. Optimum soil pH is 6.0 to 6.5. Plant spacing varies from 2 to 3 m between rows and 0.5 to 1 m between plants. Seeds are generally established in trays and transplanted into prepared beds.

Fertiliser application should be determined depending on the soil type and history. Adequate basal fertiliser is essential to establish vigorous vine growth prior to flowering, as the largest production peak is due to the first flowering. Nitrogen application is reduced during fruit set to promote flowering and fruit development. Plants should be irrigated to maintain 10 to 20 centibar tension in the root zone, this can be measured with tensiometers. Irrigation with drip tape, microsprinklers or drippers to the root zone is preferable to overhead watering, which can increase disease in the crop.

Bitter melon will produce its first flowers 45 to 55 days from sowing. Pollination is by insects, and poor pollination can be improved by importing beehives. Fruit are harvested approximately 15 to 20 days from fruit set. As the fruit need to be picked every 2 to 3 days, there is a high labour requirement.

 Marketable yields of 20 to 30 t/ha are commonly reported, however total yields over 50 t/ha are also possible. Non-marketable fruit can be from 10 to 20% of the total crop, this is usually due to misshapen fruit, insect damage and ripening.

Pest and disease control

Thrips, cucumber moth, heliothis, whitefly and root knot nematodes all affect bitter melon. No pesticides are specifically registered for bitter melon in Australia, however off-label use permits are available. It is necessary to check with the relevant state department for current permits. Biological insecticides and 'soft' chemicals such as potassium soaps are also available to control some pests. Nematodes can be controlled by growing an off-season cover crop, such as sorghum.

Powdery mildew has been reported affecting bitter melon in the Northern Territory, Queensland and NSW. It can be difficult to distinguish from downy mildew, and diagnosis should be confirmed.
before implementing a spray program.

Bitter melon are also susceptible to cucumber mosaic viruses and aphids, which transmit the virus and should be carefully controlled.

**Harvest and postharvest**

One of the most difficult tasks in producing bitter melon is determining the stage of harvest. Bitter melon is picked and consumed immature. However, if allowed to mature on the vine or after harvest they rapidly change colour to bright yellow flesh with red seeds, then split, rendering them inedible and unsaleable. Bitter melon are also sensitive to ethylene, so one ripening melon will cause adjacent melons to ripen.

Harvest indices are difficult to detect, but include the fullness of the ridges and bumps and a slight change in colour. The seed coats change colour from a creamy white through pink to red – any tinge of pink is over-mature. However this cannot be detected without opening the fruit.

After harvest it is important to cool the fruit to between 7 to 10°C. Above this temperature the fruit may continue to ripen, below this chilling injury, observed as pitting of the fruit surface, may develop. Fruit are commonly transported at low temperatures of 4°C, however prolonged exposure to these temperatures will result in chilling injury. Storage at high humidity maintains turgidity. Plastic packaging is not recommended due to the potential for ethylene to build up in non-vented bags. Bitter melon are packed into 10 kg boxes. Interstate quarantine requirements should be investigated prior to marketing interstate.

**Financial information**

Establishment costs for bitter melon include firstly the land, then a tractor and some type of bed former, trellis materials, irrigation and spray equipment, and a cooling and cool storage facility after harvest. Production costs include fertiliser and irrigation costs, and pest and disease control plus the labour required to carry out these activities.

The greatest costs in bitter melon production are labour for the repeated harvests and packing, packaging, and transport. Packaging includes cartons and liners, and transport costs vary depending on the distance between the farm and market. Successful marketing also requires time to follow up the quality of the product and, of course, payments.

The main potential risks for successful production of bitter melon are selection of planting material, correct harvest maturity, establishing a market for the product and within and between season price fluctuations. The latter are caused primarily by fluctuations in supply. While some of these issues are common for many vegetable crops, they can be traps for new growers. Careful planning before planting will increase the success of bitter melon production.

**Key references**


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Key messages

- Trellises are essential for quality
- Harvest maturity is critical
- Harvest every second day
- Cool fruit after harvest
- Establish a market before planting

Key statistics

- Production volume from the NT is steadily increasing
- Main supply is during winter months
- Prices average from $2.00 to $2.50/kg

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Introduction

Burdock (*Arctium lappa* L.) which belongs to the chrysanthemum family (Compositae), is a native of Asia. It has become naturalised in many parts of the world, growing wild throughout Europe and North America where it is used as folk medicine. The Japanese developed it as an edible vegetable when it was introduced into Japan probably a thousand years ago. Today, large areas of burdock are grown only in Japan. China, Taiwan and other South East Asian countries produce some burdock mainly for export to Japan which became significant from 1999.

Burdock is a biennial plant that is grown and harvested as an annual. Seeds are not produced until the second year. The plant carries its leaves on long stems of about 60cm, originating from the crown. Leaves are large, almost heart-shaped, have a rough texture and are covered with short white hairs, dark green on the top and a paler green underneath with pinkish veins.

The long, tapering tap-root can reach lengths of up to 120cm. However, roots grown for fresh markets need to be 60-90cm long and less than 3.5cm in diameter at the crown. Roots usually have a brown skin with white flesh that oxidises (discolours) quickly when exposed to the air.

The roots of burdock are the most commonly eaten part of the plant. Burdock is tasty and high in fibre, potassium, calcium, iron, silicon, sulphur, volatile oil and resin as well as containing several antibiotics and it has recognised medicinal properties.

While the consumption of burdock in Japan is stable, the production is falling (Table 1). This offers an opportunity for Australia to supply the market, particularly during the period of Japan’s off-season.
Markets and marketing issues

Burdock is a new crop to Australia and is grown year-round on the coastal areas of New South Wales and Queensland. In WA burdock has potential to be grown during late spring and early autumn in the sandy loam soils of the Swan Coast Plain from Medina to Guilderton. Most burdock including fresh and frozen forms are sold through niche markets and Japanese supermarkets. Dried burdock which is used as a tonic is sold in the Chinese medicinal stores or Asian groceries. Estimates for the domestic market are not reliable and quality data has not been collected. However, statistics from Japan’s Ministry of Agriculture, Forestry and Fisheries have shown that Australia has exported some burdock to Japan, around 100-200 t per annum (Table 2).

International trade in burdock focuses on Japan where burdock production was approximately 200,000 t in the 1990’s. In the early 2000’s Japan produced only 130-150,000 t per annum. Table 1 shows that the size of the Japanese market is still stable at approximately 210,000-230,000 t per annum, valued at ¥53 billion, equivalent to A$534 million (Table 1).

China has supplied the greatest amount of burdock to Japan since 1999, representing about 90% of the importation and occupying 34% of Japanese market. This is probably due to cheap CIF imported prices from China (Table 2). Burdock has also been imported into Japan from Taiwan, South Korea, Australia, France and Indonesia. Exports from these countries are, however, very small.

### Table 1. Production and importation of burdock in Japan, 1989-2002

<table>
<thead>
<tr>
<th>Year</th>
<th>Area, ha</th>
<th>Volume, ton</th>
<th>Fresh, ton</th>
<th>Processed, ton</th>
<th>CIF Prices (Fresh) ¥/kg</th>
<th>Imported</th>
<th>Wholesale</th>
<th>Retail</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>15,200</td>
<td>219,000</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>291</td>
<td>687</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>13,400</td>
<td>190,000</td>
<td>Nil</td>
<td>Nil</td>
<td>Nil</td>
<td>263</td>
<td>702</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>11,400</td>
<td>164,900</td>
<td>71,715</td>
<td>5,914</td>
<td>72 (105)</td>
<td>248</td>
<td>793</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>10,700</td>
<td>153,900</td>
<td>81,676</td>
<td>6,768</td>
<td>60 (82)</td>
<td>214</td>
<td>683</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>10,100</td>
<td>143,600</td>
<td>80,683</td>
<td>7,600</td>
<td>64 (92)</td>
<td>215</td>
<td>667</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>9,670</td>
<td>134,600</td>
<td>74,665</td>
<td>7,607</td>
<td>44 (90)</td>
<td>246</td>
<td>689</td>
<td></td>
</tr>
</tbody>
</table>

Source: 1) Poketto Norinsuisan Toke 2003. Published by Norinsuisan Sho Toke Ba, Tokyo Japan.  
2) Yasai Yunyu no Doko, 2002.  
4) Processed including frozen and salted burdock.  
5) Prices (CIF) of processed burdock.

### Table 2. Prices of imported burdock into Japanese market, 1999-2002

<table>
<thead>
<tr>
<th>Year</th>
<th>Prices, CIF- ¥/kg</th>
<th>China (Fresh) ¥/kg</th>
<th>Taiwan (Fresh) ¥/kg</th>
<th>Australia (Fresh) ¥/kg</th>
<th>French (Frozen) ¥/kg</th>
<th>Indonesia (Salted) ¥/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fresh</td>
<td>Frozen</td>
<td>Salted</td>
<td>Fresh</td>
<td>Frozen</td>
<td>Salted</td>
</tr>
<tr>
<td>1999</td>
<td>49</td>
<td>115</td>
<td>93</td>
<td>4</td>
<td>143</td>
<td>Nil</td>
</tr>
<tr>
<td>2000</td>
<td>60</td>
<td>93</td>
<td>71</td>
<td>55</td>
<td>82</td>
<td>111</td>
</tr>
<tr>
<td>2001</td>
<td>64</td>
<td>103</td>
<td>81</td>
<td>59</td>
<td>87</td>
<td>(154t)</td>
</tr>
<tr>
<td>2002</td>
<td>44</td>
<td>102</td>
<td>78</td>
<td>41</td>
<td>69</td>
<td>120 (185t)</td>
</tr>
</tbody>
</table>

Source: Vinas Booklet 25: Yasai Yunyu no Doko, 2002. Published by Norin Toke Kyokai, Tokyo Japan
to the full depth of the final root size to prevent forking. Burdock does not like acid soils, and the optimum pH range should be between 6.0 to 7.5.

Burdock for sale as a vegetable is harvested from first-year plants, normally at four or five months’ growth if planted in spring, or six or seven months’ growth if planted in autumn.

**Varieties/cultivars**

In Japan, burdock is classified into several groups such as Takinogawa, Oura, Hagi and Echizen Shiroguki.

*Takinogawa*, which is the most common group, has slender, long roots and red petioles. Popular cultivars for this group are Takinogawa, Watanabe wase, Yamade wase, Tohoku riso, Shinden, Nakanomiya, Kunpu, Takimasari and Tokiwa.

*Oura, Hagi and Echizen shiroguki* have thicker and shorter roots. Cultivars of the Oura group include Oura and Horikawa; the Hagi group include Hagi and Hyakunichishaku and the Echizen shiroguki group including Shiroguki wase.

There is a very small demand for the burdock leaf. The leaves are taken from small plants two to three months old and grown in shade at a very high density planting.

**Cultural practices/agronomy**

Burdock can be sown year round but best in spring and autumn. Spring burdock can be sown as soon as soil temperatures are above 10°C. A better establishment will be achieved if planting is delayed until the soil has reached 15°C. Seed germination is very slow, taking 10-14 days for emergence, and can be uneven. In fact, some seeds may lie dormant in the soil and germinate the following autumn. Using primed seed breaks this dormancy and increases both the rate of germination and overall percentage of germinated seed (Figure 1). Autumn burdock must be sown late so that plants are still very small when the first frost occurs. Leaves will die back and the plant stops growing until temperatures become warmer in

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**Figure 1.** Priming burdock seed increased both the rate of germination and the final percentage of germinated seed at both 15°C and 20°C.

Growing burdock in New South Wales for Australian fresh markets and export to Japan
spring. There is a risk of plants bolting (going to seed) in spring if roots are larger than 5 mm diameter before winter. Autumn sowing produces an earlier crop during the following spring/summer.

Before sowing, the soil must be cultivated very deeply – up to 90 cm if possible. Soil must be left in a loose, friable state for roots to penetrate otherwise they will fork and the yield of “A” grade roots will drop dramatically. Up to 80% of roots that fork do so in the top 15 cm due to either a change in soil structure where soil has been shallow cultivated, or if fertiliser with a high N content is banded below the seed line (Figure 2).

A fertiliser with low nitrogen and high phosphate to encourage root growth can be worked into the soil before sowing during deep cultivation. Apply approximately 120 kg/ha P in sandy soils. This rate can be reduced in more fertile, sandy loam or alluvial soils.

Two side dressings of nitrogen and potassium fertiliser should be applied, the first at the two-three leaf stage (approximately 60 kg/ha of elemental N and K) and the second approximately three months after sowing (100 kg/ha of elemental N and K).

Burdock is direct-seeded with 10 cm between plants and approximately 50 cm between rows. Seeds should be sown at about 1-2 cm deep and kept wet until after seedlings become established. Once plants are established, water can be cut back to force roots to seek moisture deeper in the soil profile. It is important not to over-irrigate and saturate the soil profile as excessive moisture can lead to root rot diseases.

### Pest and diseases control

As burdock is a new crop to Australia, there are no registered chemicals available for weed, pest and disease control. However, burdock is a hardy plant and has few pests or diseases and weeds can be controlled with cultivation and hand chipping.

The slow establishment rate of burdock gives weeds a head start on the crop so it is important to ensure that the site is prepared well in advance of the sowing date. The site should be pre-irrigated and any emerging weeds sprayed off with a knockdown herbicide just before or immediately after sowing. Weeds that establish after the crop has emerged have to be cultivated out or hand chipped.

![Figure 2. Preparation for burdock sowing: deep ripping (80-100cm) to encourage roots to grow straight and longer.](image)

Burdock in the Ota wholesale market, Tokyo, Japan
The crop will form a complete canopy approximately eight weeks after germination, which restricts further weed establishment.

A burdock crop grown chemical-free may attract a premium price in Japan and even in Australia where consumers are very health conscious and have shown a willingness to pay extra for “organically clean”, healthy, quality foods.

Nematodes (burrowing nematode; *Radopholus similis*) is a major pest and soils should be assessed for nematode population before sowing. A nematode-repelling crop, such as oats or canola, may be sown as a cover crop during winter and incorporated into the soil before sowing burdock.

In some years, red-legged earth mite can cause damage to young seedlings early in the season. If earth mite are likely to be a problem, planting should be delayed until their activity diminishes.

Powdery mildew may become a problem in mid- to late summer if wet, humid conditions prevail. Symptoms are similar to powdery mildew on cucurbits though the causal agent is different. In most cases the crop will tolerate a mildew infection and it is only in extreme circumstances that crop losses will occur. Wettable sulphur (a natural compound) can be used to control powdery mildew if it is deemed necessary.

Black root is a fungal disease caused by *Aphanomyces raphani*, which may also cause crop losses. Warm, hot weather and waterlogged soil favour its development. The disease is controlled by correct irrigation scheduling, good drainage and crop rotation.

### Harvesting and packaging

Spring-sown burdock will be ready for harvesting about 4-4.5 months after sowing. To obtain the best commercial return, the crop should be harvested when most of the roots are 20-35 mm diameter and at least 70 cm long. If harvest is delayed to increase tonnage, quality will decline. Roots will be over-mature and become woody and pithy and the market will not accept them.

To harvest burdock, shoots are first removed by slashing or mulching the tops, leaving approximately 10 cm of stalk. Roots are then loosened with a vibrating ripper then pulled out by hand. It may be possible to pick up the roots with a modified carrot harvester once they have been loosened. After the roots are lifted from the soil, they must not be left exposed to the hot sun as this causes them to wilt and the flesh quickly oxidises and becomes discoloured.

Harvesting should be carried out early in the morning and the burdock taken to a shady area or packing shed as quick as possible.

The fresh market in Australia and Japan demands long, straight roots without any forks or side shoots. Roots need to be at least 60 cm long (preferably 70 cm) and between 16-35 mm diameter (Table 3). The market in Japan has recently accepted the Oura type for salads. Oura burdock needs to be 40 cm long and 30-40 mm diameter. Shorter or forked roots may be sent for processing at reduced price.

Roots are then washed and side shoots and root hairs are removed. After washing and trimming, roots

### Table 3. Burdock size grading for Japanese markets

<table>
<thead>
<tr>
<th>Grade</th>
<th>Size</th>
<th>Root diameter, mm</th>
<th>Root length, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3L</td>
<td>≥36</td>
<td>≥60</td>
</tr>
<tr>
<td></td>
<td>2L</td>
<td>31-35</td>
<td>≥60</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>26-30</td>
<td>≥60</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>21-25</td>
<td>≥60</td>
</tr>
<tr>
<td></td>
<td>2M</td>
<td>16-20</td>
<td>≥60</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>11-15</td>
<td>≥55</td>
</tr>
<tr>
<td></td>
<td>2S</td>
<td>≤10</td>
<td>≥35</td>
</tr>
<tr>
<td>B</td>
<td>BL</td>
<td>≥35</td>
<td>45-60</td>
</tr>
<tr>
<td></td>
<td>BM</td>
<td>25-35</td>
<td>45-60</td>
</tr>
<tr>
<td></td>
<td>BS</td>
<td>≥15</td>
<td>45-60</td>
</tr>
<tr>
<td></td>
<td>Process</td>
<td>≥20</td>
<td>≥40</td>
</tr>
</tbody>
</table>

Burdock sold in Tokyo supermarket, Japan.
are graded and packed into plastic-lined 10kg cartons. Table 3 also lists the fresh market grades that are used in Japan.

**Quarantine requirements**

A declaration must be provided to the Australian Quarantine and Inspection Service (AQIS) that the burdock crop has been inspected by an authorised person and is free of burrowing nematode (*Radopholus similis*). The crop must have been grown on a farm that has been inspected by soil sampling during the growing season and found to be free from *Radopholus similis*. *Radopholus similis* does not occur in the Riverina of New South Wales, but is present along the north-east coast of Australia, especially in banana-producing areas. A further requirement is that all soil must be removed from the roots.

**Financial information**

The production costs vary between seasons, growing locations, time of consignment and the business resources. Field trials on the Central Coast of New South Wales have shown that high gross margins for Australian burdock, estimated at A$2.51/kg (Table 4), would never be competitive with China in the Japanese market, where China’s CIF prices have achieved only in the range of ¥41-59/kg (A$=¥75) (Table 2). However, exporting of Australian burdock remains potentially high if the Australian burdock industry can reduce its production cost by mechanising the weeding and harvesting operations, translating its “Clean & Green” vegetable into sale with acceptable margins.

Table 4 shows an enterprise budget for 1.0ha for Burdock *Tōhoku Riso* located in Somersby, NSW, for a period of 4-5 months.

---

**Table 4. Gross margin for Burdock growing on the Central Coast of New South Wales, 2004**

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost (A$)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>800 cartons</td>
<td>10kg</td>
<td>4.00</td>
<td>32,000</td>
</tr>
<tr>
<td><strong>A. TOTAL INCOME</strong></td>
<td></td>
<td></td>
<td></td>
<td>32,000</td>
</tr>
<tr>
<td><strong>Variable costs</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cash</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>8hrs</td>
<td></td>
<td>18.48/hr</td>
<td>147.84</td>
</tr>
<tr>
<td>Burdock seed</td>
<td>2.5kg</td>
<td></td>
<td>366.00/kg</td>
<td>915.00</td>
</tr>
<tr>
<td>Planting labour</td>
<td>4hrs</td>
<td></td>
<td>18.48/hr</td>
<td>73.92</td>
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<tr>
<td><strong>Fertilisers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural lime</td>
<td>4.0t/ha</td>
<td></td>
<td>130/t</td>
<td>520.00</td>
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<tr>
<td>Fertilisers Multigro</td>
<td>1.5t/ha</td>
<td></td>
<td>495/t</td>
<td>742.50</td>
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<tr>
<td>Spreader machinery cost</td>
<td></td>
<td></td>
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<td>3.88</td>
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<tr>
<td>Labour</td>
<td>2hrs</td>
<td></td>
<td>18.48/hr</td>
<td>36.96</td>
</tr>
<tr>
<td><strong>Nematode control</strong></td>
<td></td>
<td></td>
<td></td>
<td>85.00</td>
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<tr>
<td><strong>Weed control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand weed labour (3-4 times)</td>
<td>20days</td>
<td>8hrs/day</td>
<td>18.48/hr</td>
<td>2,956.80</td>
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<tr>
<td>Pesticides, machinery, labour</td>
<td></td>
<td></td>
<td></td>
<td>48.14</td>
</tr>
<tr>
<td>Irrigation (water pump &amp; maintence)</td>
<td></td>
<td></td>
<td></td>
<td>219.50</td>
</tr>
<tr>
<td><strong>Harvesting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carton 10kg</td>
<td>800</td>
<td></td>
<td>2.00/carton</td>
<td>1,600.00</td>
</tr>
<tr>
<td>Slashing tops machine cost</td>
<td>2hrs</td>
<td></td>
<td>10/hr</td>
<td>20.00</td>
</tr>
<tr>
<td>Slashing labour cost</td>
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<td></td>
<td>18.48/hr</td>
<td>36.96</td>
</tr>
<tr>
<td>Per carton cost for all harvesting</td>
<td>800</td>
<td></td>
<td>15.00/ctn</td>
<td>12,000.00</td>
</tr>
<tr>
<td><strong>Transportation &amp; fees</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freight to Sydney</td>
<td>800</td>
<td></td>
<td>0.50/ctn</td>
<td>400.00</td>
</tr>
<tr>
<td>Levies</td>
<td>800</td>
<td></td>
<td>0.25/ctn</td>
<td>200.00</td>
</tr>
<tr>
<td>Agent commission 10%</td>
<td>800</td>
<td></td>
<td>0.10/ctn</td>
<td>80.00</td>
</tr>
<tr>
<td><strong>B. TOTAL VARIATION COSTS</strong></td>
<td></td>
<td></td>
<td></td>
<td>20,086.50</td>
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<tr>
<td><strong>GROSS MARGIN (A-B)</strong></td>
<td></td>
<td></td>
<td>$/ha</td>
<td>11,914.50</td>
</tr>
<tr>
<td><strong>Break even</strong></td>
<td></td>
<td></td>
<td>$/kg</td>
<td>2.51</td>
</tr>
</tbody>
</table>
Key references


Honda, F. (1987) “Gobo” (Burdock) in Mame, Konsai no Jojuna tsukurikata (Hi-tech to produce bean and root vegetables). Inohikari, Tokyo, Japan (In Japanese).


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Key Messages

- High capital investment and long term commitment required
- Labour intensive
- High returns are possible

Key statistics

- A potential market in Japan where demand is 210,000 t/year - Japan produces only 130,000 t and imports about 80,000 t/year
Introduction

Chinese waterchestnut (Eleocharis dulcis (Burm. f.) Trin. ex Henschel) is a tropical member of the sedge family and as its name implies, it is an aquatic species. Plants consist of four to six upright tubular stems approximately 1.5 m tall. Vegetatively propagated, the corms (or tubers), the edible portion, are produced at the end of underground stems (or rhizomes).

A botanical novelty twenty years ago, although in its wild form it was reputedly harvested by Aboriginals, it is now produced and marketed commercially in Australia, substituting for the importation of canned produce but offering the Australian consumer the opportunity to savour the fresh product. However, it is only available over the period June to October, thereby limiting the effectiveness of import substitution.

Premium Australian waterchestnuts are >38 mm in diameter with no visible or internal injuries (bruising), have a crisp coconut-like texture and a detectable sweetness, which adds to their unique flavour. Their taste is best enjoyed by firstly peeling the thin skin which sometimes harbours muddy flavours. Fresh diced or sliced pieces are a useful salad ingredient. Light steaming releases an appetising aroma of corn with a hint of macadamia. As such, they are better than those from traditional production zones in Thailand (Suphanburi), China (Guai Lin) and Taiwan (Tainan County) but, according to connoisseurs, Australian produce at times lacks sweetness and tastes starchy.

The crispy texture, which is retained after processing or cooking, is due to the presence of the ferulic acid-containing hemicelluloses in cell walls of the waterchestnuts. The product is...
favoured for fresh stir-fry mixes and apart from the domestic kitchen market, is particularly sought after by Asian restaurants, which predominantly buy the large size corms (≥38 mm) due to ease of peeling. It also forms the basis for heavily sweetened drinks in Asia, appearing in cans and “popper” drinks as well as dry granule sachets, which can all be found as imported products in most Asian style supermarkets and stores within Australia.

A tradition of production in Taiwan and China, and the recent introduction of a canning industry in Thailand - underpin the world trade in waterchestnut, and the US is the major importer of the canned form, marketing approximately 40 million cans.

Markets and marketing issues

Waterchestnuts are marketed in Australia in the fresh, frozen and canned forms. Frozen and canned forms are peeled and predominantly originate from China and Thailand; fresh waterchestnuts are sold with their skins (the lignified 0.75 mm thick peel) intact. In Asian wet markets fresh waterchestnuts are peeled by hand in quantities to satisfy demand. The fresh nature of waterchestnuts (i.e., with approximately 86% moisture) necessitates their storage, transport and display under cool (<10º C) and humid conditions. The importance of this to retail markets cannot be over-emphasised.

Currently levels of canned imports into Australia are unknown because ABS data are pooled with those of true chestnuts and retailers prefer not to divulge such information.

Retail prices for canned waterchestnuts (approx. 90 cents/227 g [gross]) are similar to, or less than those in Asian countries (Singapore A$1.20/340 g [gross]; Thailand A$1.25/227 g [gross], and wholesale prices of canned waterchestnut in Australia (48 cents to 79 cents/230 g [gross]) convert to $3.7 to $6.0/kg of net waterchestnut. Current illustrative farm gate prices for fresh Australian waterchestnuts range from $4.00 for small (i.e., 25-32 mm) to $12.00 for large corms, which is highly competitive with the net retail cost of canned produce, although 10 to 20 % of fresh product will be lost through peeling, the larger figure for smaller corms.

A recent survey indicated that consumers, although preferring large fresh corms, are discouraged by high retail prices – up to $20/kg. Non-Asian consumers are largely ignorant of the uses, availability and taste of fresh waterchestnut.

The current production in Australia has apparently declined from around 20 t/year in 1997 to less than 8 t/year in 2003. The bulk of this production has come from three growers; two in New South Wales and another from Central Queensland, with a number of small-scale producers located not only in these states but Victoria and WA as well. The recent survey disclosed product sourced from Darwin. Product is predominantly offloaded at the Sydney and Melbourne Wholesale Markets in bagged and boxed form where demand can fluctuate wildly depending on the vagaries of the weather and concurrent eating habits.

Consumers tend to be of Asian extraction because of their familiarity with the product and the fact that agents get the highest response from Asian shop-owners aware of the existing demand. A ready market has been identified for a fresh peeled product. Just one of at least ten food processors is known to currently import over 7 t of peeled product annually to incorporate in their dim sim and fish ball line of products. That same processor indicated that they could envisage a demand for over 100 t of peeled product if it could be sourced from Australia for their product line. A number
of producers still believe that an economically viable method of producing a peeled product will greatly magnify both the existing and potential markets. This will go hand in hand with an improvement in commercial harvesting equipment. An added benefit would be the greater utilisation of smaller corms, perhaps down to 15 or even 10 mm depending on the efficiency of the technology employed.

Overseas markets are of interest; production in Japan is on the decline (1600 t in 1984 to 1200 t in 1992) as it is in Taiwan (1200 t in 1991 to 860 in 1995). The best retail prices are gained in Japan from September to December, ranging from A$9.0 to A$30.0/kg while in Taiwan retail price is quite stable at A$6.0/kg, double that of the farm-gate price. Australian production currently pales into insignificance compared with that of Japan and Taiwan, and with that of China which dominates the supply of canned and semi-preserved waterchestnuts to the USA. Approximately US $35 million as canned and US $8 million as semi-preserved product was imported to the USA in 1996. With an established and potentially larger national market, it is opportune to embark upon export ventures, especially now that the Australian industry draws upon four mechanised harvesting systems which considerably reduces the labour requirement for the crop.

**Production requirements**

A puddled or clay-base soil, along the same lines as for paddy rice, is ideal for waterchestnut cultivation. Highly porous and sandy soils are not suitable because ponds drain rapidly, unless lined with industrial quality (200 – 500 micron) polyethylene sheets. Although clay soils favour water retention and puddling, they present serious drawbacks for some harvest systems, particularly since they need more labour for hand-harvesting. In such instances, producers may add sand or composted filter press mud, from sugar mills, to clay soils to ease the harvest burden.

Since the crop is grown in an almost entirely flooded condition, flat or terraced land is necessary. Access to irrigation that will replenish at least the evaporative demand (measured as pan evaporation at standard weather stations) is essential if rainfall during the cultivation season does not exceed evaporation. Although an inland species in the wild, cultivated waterchestnut does not tolerate irrigation water salinity values of greater than 3.3 dS m⁻¹ without loss of germination and corm yield.

The crop is customarily grown in a sub-tropical to temperate climate, planted in the spring where the growing temperatures are 15°C - 25°C. Immature corms, with white undeveloped skins, may appear throughout the growing season forming at nodes along the root stem where new culms arise as daughter plants. Mature corms seem to appear in response to stress such as a drying soil (drought), overcrowding (lack of space and nutrients) and/or shortening daylight hours (autumn).

Corms form as the day length becomes less than 12.5 hours and stems senesce in autumn in response to plant maturity rather than as a response to low temperature.
Chinese waterchestnuts

Generally a 220 day frost-free period is necessary for natural completion of the crop cycle. High daytime air temperature (~30ºC) favours growth of the crop. Current and potential production areas in Australia are indicated on the accompanying map.

**Varieties**

The wild form of waterchestnuts, with small hard corms (approx 10-20 mm diameter), grows extensively in South Asia and much of Oceania. The cultivated form has larger corms, selected in China for their sweetness and juiciness. On various occasions superior cultivated lines (≈ varieties) have been imported to Australia. A summary of the officially reported importations and acquisitions is presented in Table 1. The distinction between varieties currently cultivated was all but lost, but using the technique of DNA-based genetic finger-printing, the identity and origins of various lines in Australia is now known. This is of primary importance for maintenance of quality standards for local and export markets. Prospective growers should be aware of the genetic identity of the material to be planted. It is possible that some lines are more suited to the climatic conditions of Victoria as opposed to those of Queensland, but without clear identification of lines such information is impossible to confirm.

Quite recently, the variety named “Shu-Lin” was imported for trials in Australia, and is now referred to as “Taiwan”. In 2003 it was sold for the first time through Sydney Markets – about 350 kg. Chosen for its superior texture and flavour it will comprise a significant part of the 2004 harvest.

**Agronomy**

Land preparation comprises construction of ponds, or paddies, the dimensions of which should relate to the proposed form of harvesting. Fertiliser application depends upon soil type and expected corm yield. For a 30 t/ha crop, nutrient demand would be: 160 kg N/ha; 80 kg P/ha and 280 kg K/ha. One half N and all P and K should be applied and incorporated in the dry soil before planting, and may be substituted by an earlier application of organic manure at rates of ≈ 12 t/ha. The soil is then well watered but not flooded. Sound corms, preferably sweet (for evidence suggests that planting sweeter corms leads to better harvest) and with a viable terminal bud, are used as planting material. The terminal bud is face-up at planting. Corms may be directly planted to the field, or planted at high density (corms almost touching each other) in a nursery for production of transplants. Corms sprout as ground and water temperature rise above 13ºC, and this may be hastened under nursery conditions in cooler climates by the judicious use of clear polyethylene sheet covers. Following direct planting to the wet field, at a depth not exceeding 4 cm, the field is flooded and allowed to drain naturally. Further flooding may be undertaken within three weeks, or when stems are 20 to 30 cm tall. Deeper flooding will usually cool the environment around the corm and slow germination, hence shallow flooding is to be favoured in southern climates, both for plant establishment and during the growth period of growth.

Corms in nurseries are treated similarly to those in the field, and germinate approximately 10 days after planting. They are transplanted into moist or flooded ponds when they reach 20 to 30 cm height, and in the warm tropics the tops may be trimmed before transplanting if too tall. Crops from transplants in temperate climates will usually mature 5/6 weeks earlier than crops directly planted to the field on the same date as transplanting. This difference diminishes where temperature, especially at night, is more equable year-round. Plant spacing in the field depends largely upon climate and planting date (more southerly climates and/or later planting reduces opportunity for rhizome and daughter plant production and filling-in by the canopy to capture

<table>
<thead>
<tr>
<th>Year</th>
<th>Importer</th>
<th>Local name</th>
<th>Origin/source</th>
</tr>
</thead>
<tbody>
<tr>
<td>?</td>
<td>Allan Hibberd</td>
<td>Botanical garden at Mt Coot</td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>Allan Hibberd</td>
<td>Black skin</td>
<td>Taiwan to Qld</td>
</tr>
<tr>
<td>1988</td>
<td>Allan Hibberd</td>
<td>Red skin</td>
<td>Taiwan to Qld</td>
</tr>
<tr>
<td>1989</td>
<td>Dalis Raynor</td>
<td>Dalis</td>
<td>Taiwan to Qld</td>
</tr>
<tr>
<td>1989</td>
<td>Hans Erkin</td>
<td>Matai supreme’</td>
<td>Chinese farmer in Qld</td>
</tr>
<tr>
<td>1988</td>
<td>Werner Leutert</td>
<td>Hon Matai</td>
<td>China to USA (PI 106274) to WA</td>
</tr>
<tr>
<td>1995</td>
<td>Greg Gunning</td>
<td>Shu-Lin</td>
<td>Taiwan to Qld</td>
</tr>
<tr>
<td>1994, 1996</td>
<td>Greg Gunning</td>
<td>China to Qld</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Greg Gunning</td>
<td>Shu-Lin</td>
<td>Taiwan to Qld</td>
</tr>
</tbody>
</table>
all light energy, therefore closer spacing should be used), but soil fertility and level of fertiliser input will govern plant vigour, and plant spacing should be adjusted accordingly. On average between two to five transplants (or corms) are planted per one square metre, with a triangular positioning often preferred.

Once established, the crop is continually maintained in a flooded condition, even during the application of the remainder of the inorganic fertiliser, which should conveniently be split and applied incrementally at monthly intervals. Eight to ten weeks after planting the secondary (daughter) plants appear and just prior to the autumn equinox notable development of corms is evident. Seeding the pond with the water fern \textit{Azolla} can reduce the overall need for N fertiliser in the subsequent crop. The nitrogen-fixing fern can fix about 50 kg N ha/yr. Besides NPK, calcium and magnesium should also be added (at 6 and 25 kg/ha respectively) and micro-nutrients if the soil substrate is known to be deficient. Removed nutrients must be replenished to minimise ‘mining’ of soil nutrients. Nitrogen fertiliser is best applied in the NH$_4^+$ (ammonium) form, for this is the favoured form for uptake by waterchestnut, and is less easily leached than the NO$_3^-$ (nitrate) form.

After planting, crop attention centres around prophylactic pest control, fertiliser application, water-level monitoring/adjustment and weed minimisation both within and around the ponds. Once corms have formed they are susceptible to physical damage as a result of trampling in the field. The canopy of the crop, in reality the stems for the plants have no true leaves, is so dense that it is best to prevent physical entry to the field for fear of lodging and loss of photosynthetic activity. Stems should as far as possible be kept free from damage by wind, herbivores, and pests and diseases.

Experimentally, artificial shortening of daylight using blackout plastic sheets from early January in Victoria can hasten formation of corms and provide a longer duration corm growth before frosts kill the stems in winter. Conversely, extending the natural day length with suspended lamps in the tropics from March onwards can delay corm formation and lead to later harvest, thereby extending the duration of fresh product availability.

The incidence of both larger corms and high yield appears to be linked to a lengthy (>5 months) hot growing season combined with optimum plant spacing and adequate nutrition which culminates in medium-high density culm formation just prior to the onset of senescence. Farm-level yields in Australia reach >20 t/ha but maximum marketable yields (i.e. > 25 mm corm diameter) are less than 20 t/ha. These values are similar to those reported for China, although small plot yields of up to 40 t/ha have been reported in Australia.

\section*{Pests, weeds and disease control}

Regular slashing and brush cutting of pond margins and perimeters helps reduce habitat for rodents and pests. Ponds should be effectively fenced from herbivores such as cattle and horses. Well-tilled land treated with general purpose herbicides (e.g. Roundup) reduces the incidence of most weeds, as does the use of compact and composted mulches (e.g., filter press mud) during the fallow season. If soil type dictates that ponds and bunds are lined with polyethylene sheets, then the incidence of weeds is much reduced. Aquatic species such as the giant sedge (\textit{Cyperus exaltatus}) are well adapted to compete with waterchestnut and seed sources should be eliminated wherever possible.

Insect pests of waterchestnut are known, but with few exceptions are not devastating. Green and long-horned grasshopper and snout moth larvae bite the bases of stems and the rice water weevil (\textit{Lissorhoptrus oryzophilus}) damages corms, as do mole crickets (\textit{Gryllotalpa} sp.). Stem damage has reportedly been prevented by use of Lorsban 500EC although this chemical is not registered for use in Chinese waterchestnuts in Australia. There is no easy remedy for corm damage in the field.

In 1997 outbreaks of \textit{Nisia grandiceps} (a sucking insect) and \textit{Scirpophaga} (a moth species) were reported in Queensland and also...
Field storage can extend the harvest depths ranging from 7-20 cm. In severe, for the corms are found at well underground if frosts are not in a drained pond. Corms store either physically or burned to ashes browned off and been removed can take place once the stems have during or after rainfall. Harvest flexibility of use; they can operate other three harvesters is in their advantage of the mechanical harvesters developed in Australia. The advantage of the other three harvesters is in their flexibility of use; they can operate during or after rainfall. Harvest can take place once the stems have browned off and been removed either physically or burned to ashes in a drained pond. Corms store well underground if frosts are not severe, for the corms are found at depths ranging from 7-20 cm. In-field storage can extend the harvest period, and raises the sweetness of corms, but once temperatures around the corms rise to 13°C shoot formation occurs and the retail attractiveness of the corms is lessened.

Waterchestnuts are readily bruised during harvest – drop tests from as little as 5 cm show damage – leading to saprophytic fungal and bacterial activity and at times fermentation; therefore they must be handled with care. Following harvest, corms are washed, cleaned, and graded for discards and by size according to market outlet. Likewise, packaging form and size also depends on market outlet, with types ranging from 200 g plastic bags to 5 kg cartons. Currently corms are not graded for sweetness. Non-invasive near infra-red apparatus are available to quantify sweetness, but the market is not of a sufficient size to warrant commercialisation.

Cool storage is essential for the holding of produce in Queensland, while ambient winter temperature storage suffices in Victoria and most of New South Wales for short periods. Sound, dry corms may be stored for up to six months at c. 4°C in low density polyethylene bags, and surface sterilising with sodium hypochlorite reputedly extends that period. A small proportion of the harvest is saved for next year’s crop, and is usually stored in this manner. To gain chain store markets for fresh produce in Australia, it is important to have fresh produce available throughout the whole year, hence the interest in extending storage life of fresh waterchestnut.

Currently no large-scale peeling of Australian produce is undertaken, although core punching of small waterchestnuts is used as a means of value-adding for the low priced small-size category. A range of bottled produce, at the cottage industry level, is niche-marketed.

### Financial information

Costs of production were variously estimated at from $2.00/kg to $5.75/kg as a response to a 1997 survey amongst waterchestnut growers, and a study in 2000 calculated breakeven farm gate prices to range between $2.80 and $12.42/kg, but precise data are not available. Table 2 outlines the most probable general costs involved, expressed as that required for setting up 0.1 ha of commercial production. Economies of scale are evident particularly in the fixed costs, and hiring of facilities, especially the harvester and cold storage and will prove more attractive to the smaller-scale grower.

### Table 2. Set-up and ongoing costs of production for 0.1 ha

<table>
<thead>
<tr>
<th>Fixed costs</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond construction</td>
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</tr>
<tr>
<td>Harvester (range)</td>
<td>10,000-200,000</td>
</tr>
<tr>
<td>Sorting &amp; grading equipment</td>
<td>Up to 10,000</td>
</tr>
<tr>
<td>Pump &amp; irrigation</td>
<td>1,000 +</td>
</tr>
<tr>
<td>Cold storage</td>
<td>Market price acc. to volume</td>
</tr>
<tr>
<td>Netting</td>
<td>500-800</td>
</tr>
<tr>
<td>Variable costs</td>
<td></td>
</tr>
<tr>
<td>Planting material (annual)</td>
<td>200-500¹</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>400-600</td>
</tr>
<tr>
<td>Labour costs production</td>
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<tr>
<td>Labour costs harvest (mechanical)</td>
<td>1,500-3,000</td>
</tr>
<tr>
<td>Packaging and transport</td>
<td>1,500</td>
</tr>
<tr>
<td>Sundries</td>
<td>1,500</td>
</tr>
</tbody>
</table>

¹Owner produced after first year, representing opportunity cost.

Chinese waterchestnuts
Key statistics

- USA imports c. US$40 million per year
- Australian production (c. 10-20 t/yr) insignificant compared to Japan and Taiwan (c 800-1200 t/yr)
- Costs of production ($2.00-5.75/kg) can be less than farm-gate prices ($4.00-12.00/kg)
- Four mechanised harvesting systems have been developed, facilitating expansion of production

Key messages

- Purchase planting material of a known named variety from a reliable source
- Ensure access to mechanical harvesting and to markets have been established before embarking on large-scale production
- Monitor growth of plants on regular basis (x 3 times weekly) to ensure appropriate water level and freedom from pest/diseases (including wild fowl and herbivores)

Key references


Lodge, G. and Midmore, D.J. (1997) Development of a collaborative grower to processor water chestnut system. Final Report to RIRDC for project LOD-1A.


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Culinary bamboo shoots

Steven Keilar and Ray Collins

Acknowledgement is given to David Midmore, the author of this chapter in the first edition of this publication.

Introduction

Bamboo shoots are the actively growing immature culms emanating from buds on the underground rhizome section of the plant. Shoot characteristics vary widely depending on the species. Of the more than 1,500 recognized species less than 100 are commonly grown specifically for their shoots.

Bamboo species are commonly divided into two groups. Sympodial species (clumping bamboos) produce compact clumps, with tightly packed culms or poles (Figure 1). Monopodial species (running bamboos) spread over much larger areas (Figure 2). Clumping species tend to be found in tropical and subtropical areas, while running species are more cold tolerant. The limiting factor in the distribution of most bamboos is the availability of water.

Clumping species mature more quickly, with the first harvest of shoots usually between 3 and 5 years after planting. Shoots appear from late spring to early autumn.

Running species take longer to establish with the first harvest up to 8 years after planting. They have an earlier and shorter shoot season in early spring.

Australian bamboo shoot growers presently supply the fresh domestic market, but potential export markets include Japan, Singapore, Hong Kong, Taiwan and Korea. Asian markets, in which fresh bamboo shoots are a widely consumed traditional
food, represent an opportunity for counter-seasonal supply by Australian producers. Worldwide, most of the trade is in canned bamboo shoots, with China and Thailand the major suppliers.

**Markets and marketing issues**

Bamboo shoots are considered a healthy, low energy, non-fattening food source. They are used for their crisp texture, their delicate flavours and their ability to take on the flavour of the dish with which they are cooked. As bamboo shoots contain cyanogens, it is important that they be properly prepared (usually by boiling) before consumption.

The worldwide consumption of bamboo shoots is estimated to exceed two million t/yr. China, Japan, Thailand and Taiwan dominate both production and consumption. Most bamboo shoots are processed (canned, dried, pickled) but every country has a market for fresh shoots as well. Consumption of bamboo shoots outside of Asia is minor but the market is thought to be increasing in countries such as Australia, the United States and Canada.

The relatively small Australian domestic market is dominated by imports of 4,000 to 10,000 t annually of canned bamboo shoots (Cusack, 1999; Midmore et al., 1998). However, there is an increasing demand for fresh shoots. Asian markets for fresh Australian bamboo shoots are yet to be developed, but preliminary indications are that counter-seasonal opportunities do exist. Australia’s proximity to these markets is also an advantage.

In 2003 fresh shoots returned between $2.75 and $10.00/kg wholesale on the Australian domestic market while canned shoots sold for $2.00 to $6.00/kg. Consumers of Asian backgrounds were the major purchasers of bamboo shoot products in Australia.

**Production requirements**

The large range of species means that bamboo can be cultivated in most Australian climates. Temperature and precipitation are the most important climatic factors when selecting the best bamboo species for a particular site.

In general, sympodial (clumping) species grow best in warmer tropical climates where the minimum summer temperature does not fall below 15° C, and with rainfall in excess of 1,400 mm annually. In areas where there is not enough rainfall, irrigation is needed.

The high water demand for commercial, high quality bamboo shoot production means that a reliable supply of water such as from a river or bore is usually required.

Monopodial (running) bamboos are considered harder. They tolerate subtropical and temperate areas and can thrive with less water. Both types require most of...
<table>
<thead>
<tr>
<th>Species</th>
<th>Origin</th>
<th>Min Temp (°C)</th>
<th>Shoot Size (kg)</th>
<th>Average (t/ha)</th>
<th>Max (t/ha)</th>
<th>Range (Plants/ha)</th>
<th>Shoot Season</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Dendrocalamus asper</em></td>
<td>Thailand</td>
<td>-3</td>
<td>0.5-4</td>
<td>8-10</td>
<td>15</td>
<td>100-400</td>
<td>Nov-May</td>
</tr>
<tr>
<td><em>Dendrocalamus latiflorus</em></td>
<td>Taiwan, S. China</td>
<td>-4</td>
<td>1-5</td>
<td>10</td>
<td>20</td>
<td>200-400</td>
<td>Nov-May</td>
</tr>
<tr>
<td><em>Bambusa oldhamii</em></td>
<td>Taiwan, S. China</td>
<td>-9</td>
<td>0.5-1</td>
<td>6-10</td>
<td>12</td>
<td>400-800</td>
<td>Oct-March</td>
</tr>
<tr>
<td><em>Phyllostachys heterocycla pubescens</em></td>
<td>China, Japan, Taiwan</td>
<td>-15</td>
<td>0.3-1.5</td>
<td>10</td>
<td>16</td>
<td>300-800</td>
<td>Sep-Nov</td>
</tr>
</tbody>
</table>

*Dendrocalamus asper* is a sympodial bamboo best suited to tropical climates. Shoot characteristics vary between cultivars, the most common being a Thai cultivar known as Phai Tong Keo. The shoots of *D. asper* are commonly used for canning but are also suitable for fresh consumption.

*Dendrocalamus latiflorus* is a sympodial bamboo adapted to tropical and subtropical environments. It is commonly consumed as preserved shoots and traditional Japanese pickles. It is also consumed fresh in large quantities in Taiwan.

*Bambusa oldhamii*, a sub-tropically adapted sympodial bamboo, is the favoured shoot species in Taiwan, where it is cultivated on a large scale for shoots for fresh consumption and processing. Compared with other sympodial species it is more tolerant of lower temperatures, produces a smaller plant and lower yields per hectare.

*Phyllostachys heterocycla pubescens* is commonly called “Moso”. Of the four varieties commonly utilised for commercialisation in Australia, Moso is the only monopodial species. It is better suited to temperate climates than sympodial species, but it is highly invasive by nature, requiring intensive management to ensure that it remains contained. In Australia, Moso yields a small winter crop of high quality shoots (around 300 g) from May to August, followed by a crop of larger (1 kg) shoots from September to November. Moso shoots must be dug by hand from under the ground to ensure their quality.

Other species sometimes harvested for shoots in Australia include *Dendrocalamus giganteus*, *Gigantochloa atter*, *Phyllostachys nigra*, *Bambusa vulgaris var. vittata*, *Bambusa balcooa* and *Bambusa arnhemica*.

Their water during the shooting season. Both types of bamboos require shelter from strong winds when immature.

Bamboos tolerate most soil types but prefer a deep, loose, fertile sandy loam. Very dry, rocky or sticky soils are not suitable for commercial production. Bamboos prefer a soil pH close to 7.0. A gentle slope facing northeast is favorable.

**Species**

A large number of bamboo species have been introduced into Australia but few have exhibited the desired characteristics for commercial shoot production.

The main species presently grown in Australia for their shoots are *Dendrocalamus asper*, *Dendrocalamus latiflorus*, *Phyllostachys heterocycla pubescens* “Moso” and *Bambusa oldhamii* (Table 1). These species can be obtained from specialist bamboo nurseries throughout Australia.

**Agronomy**

Many bamboos flower gregariously, that is, a clone of a species flowers at the same time across regions and even countries. Depending on the species, intervals between flowering may vary from a few decades to over a hundred years. The plants of gregariously flowering species typically produce seed and die after flowering. Propagation from this seed is possible but large variation occurs in the resulting plants.

Vegetative propagation of species that are known to have flowered recently is currently the only means to reduce these risks. Techniques of vegetative propagation include layering whole culms, partial and whole culm cuttings, node cuttings, branch cuttings and offset propagation.

**Culinary bamboo shoots**
Bamboo species can be planted at any time of the year but late winter or early spring is the favoured period. Plants are costly because propagation is slow, but recent advances in tissue culture have reduced prices and improved the availability of superior plant material.

Spacing recommendations (Table 1) need to be adapted to individual properties. When determining the distance between clumps, the size of the mature plant and its nutritional needs must be taken into account, as does the management technique to be employed on the plantation.

In areas with high rainfall and rich soils bamboos can be planted at smaller intervals and still obtain their required nutrients while in poor soils spacing may need to be increased.

After establishment, fertiliser should be applied to cover most of the space between plantings to encourage root growth in clumping species and rhizome growth in running species. Regular small applications are more productive than a single large annual application.

Fertiliser should be broadcast at around 300 kg/ha of complete NPK plus trace elements annually. Smaller amounts of fertiliser should be applied during the shoot season as it can cause soft and dark coloured shoots that are more susceptible to bruising and discolouration. Lime can be added as both a fertiliser and a neutraliser for acid soil.

Bamboo shoots contain 90% water and adequate water supply is essential, especially during the shoot season. The equivalent of 2,000 to 2,500 mm/yr of rainfall is the current recommendation for total annual water requirements. A combination of rainfall and irrigation should supply about 200 mm per month for the period commencing 2-3 months before shoot harvest until the completion of harvest. It is common to install drip irrigation in young plantations, graduating to spray irrigation in mature plantations.

A full canopy will smother weeds but in immature plantations it is important to control weeds as they compete with young bamboo for nutrients. Mulching helps to control weeds and improves water retention, thus shoot quality.

Shoots grown without exposure to sunlight are sweeter and lighter in colour. In the absence of an organic mulch, emerging shoots can be covered with soil or black plastic planter bags.

Bamboos produce numerous culms. It is important that dead culms and the thinnest culms are removed as there is a positive relationship between culm size and the diameter of the next season’s shoots. To maximise shoot yield the majority of shoots need to be harvested each year. Depending on species, only 2 to 10 of the larger shoots should be allowed to grow into mature culms in order to maintain clump vigour. A mature clumping bamboo should have 8-12 culms of different ages present after thinning.

**Pests and disease**

Australia remains relatively free of the large number of bamboo specific pests and diseases, although bamboo mosaic virus (BoMV) is present. This virus attacks leaves, shoots and young culms and causes shoots to harden, resulting in poor eating quality. The virus affects the *Bambusa* and *Dendrocalamus* genera and is spread by mechanical means. Its distribution in Australia is presently very limited.

A number of leaf-biting and sucking insects, including aphids, can cause minor damage, especially to young plants. Scale insects are common but cause no obvious damage and are controllable using white oil.

The leaf rolling caterpillar *Crocidophora pustuliferalis* can colonise bamboo species with smaller leaves. Some problems have been encountered with rats nesting around the base of bamboos and damaging the underground rhizomes of the plant.
Harvesting and marketing

Good quality culinary bamboo shoots need to be crunchy yet non-fibrous. Shoot maturity determines fibre formation – younger shoots are less fibrous. Markets prefer shoots that are light in colour with creamy or white flesh. Dark coloured (brown, black or green) shoots are considered to be of low quality. Light coloured shoots tend have less bitter compounds and more delicate flavours. Premium maturity is indicated by the shoot’s height:base diameter ratio, ideally between 2:1 and 3:1. Mature bamboos may be harvested on a three or four day cycle.

Shoots of clumping species are harvested by severing them at the point where the softer shoot tissue joins the woodier rhizome. This point may be 100 mm to 200 mm below the soil surface. Harvesting running species is similar except that the whole shoot is dug from under the ground and the cutting point can be anywhere between 15 cm and 60 cm below the ground surface.

After harvesting, shoots should be pre-cooled as swiftly as possible using iced water baths or evaporative sprays and forced air cooling. Pre-cooled shoots are then washed or brushed to remove any foreign matter before the base is trimmed and any lose culm leaves removed. Trimming is especially important for forced air-cooled shoots as the cut base will dry out and crack during cooling and by trimming 0.5 – 1 cm of flesh off the base the appearance of the shoots is vastly improved.

Shoots are packed in 10 kg polystyrene boxes or waxed cardboard boxes before dispatch to market. The maintenance of the cold chain between the farm and the end consumer is the most important factor in maintaining product quality. Shoots should be cooled to 2°C and stored as close

Key Messages

- A plentiful supply of water (rainfall/irrigation) is essential before and during the shoot season and plantations should not be established if this cannot be guaranteed
- A labour-intensive crop, especially during the shoot season for harvest and culling of culms
- Most bamboo stock in Australia is unlikely to flower in the next few decades
- Prospective growers should contact the Australian Commercial Bamboo Corporation for advice and guidance

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to this temperature as possible, taking care not to injure them by freezing.

**Financial information**

Table 2 details some of the expected costs for setting up one hectare of bamboo for shoot production. The cost and quality of plants varies widely, but tissue cultured plants are generally more even in quality and less expensive. Given the embryonic stage of development of the industry in Australia, it is impossible to provide anything more than a guide to costs and returns.

The area of commercial bamboo in Australia is small but is increasing, from just over 200 ha in 1999 to over 350 ha in 2002. The Australian Commercial Bamboo Corporation is Australia’s largest single bamboo producer organisation. It estimates that in 2002 some 60,000 bamboo plants were distributed among its 69 members, representing an annual production exceeding 2,700 t by 2005. Australia’s actual production could be up to double this figure taking into account harvesting from wild stands.

The price obtained for bamboo shoots depends on the time of season with the highest prices achieved at the beginning and end of the season. In 2003 the average farm gate price for shoots was just under $3.00/kg and the cost of production, including post harvest handling and packing, was between $1.80 and $2.40/kg.

If domestic production could substitute for approximately one third of Australia’s annual imports, between 1,500 and 3,500 t of fresh shoots could be sold on the domestic market. While the development of the domestic market for bamboo shoots will be important to the future of the industry in Australia, the size of the market means that it could potentially be supplied by as little as 150 to 350 ha of plantation bamboo. If the Australian bamboo shoot industry is to grow to a substantial size, its future will therefore lie in the development of export markets. Japan, Taiwan and Singapore should be the first targets for market development by the industry.

### Key statistics

- Australia imports 4,000-10,000 t of canned bamboo shoots annually
- The worldwide consumption of bamboo shoots is estimated to exceed two million t/yr
- It is estimated that Australia’s annual production will exceed 2,700 t by 2005

### Table 2. Set up costs for 1ha of bamboo plantation for shoot production

<table>
<thead>
<tr>
<th>Species</th>
<th>Plants/ha</th>
<th>Price/plant</th>
<th>Plant material/ha</th>
<th>Land preparation</th>
<th>Planting</th>
<th>Irrigation</th>
<th>Labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dendrocalamus asper</td>
<td>200</td>
<td>$25 - $35</td>
<td>$5000-$7000</td>
<td>$450</td>
<td>$200</td>
<td>$3500</td>
<td>$4000-$6000</td>
</tr>
<tr>
<td>Dendrocalamus latiflorus</td>
<td>270</td>
<td>$25-$35</td>
<td>$6750- $9450</td>
<td>$450</td>
<td>$300</td>
<td>$3500</td>
<td>$4000-$6000</td>
</tr>
<tr>
<td>Bambusa oldhamii</td>
<td>625</td>
<td>$15-$25</td>
<td>$9375- $15625</td>
<td>$450</td>
<td>$600</td>
<td>$4000</td>
<td>$6000- $8000</td>
</tr>
<tr>
<td>Phyllostachys heterocycla pubescens</td>
<td>625</td>
<td>$15-$25</td>
<td>$9375- $15625</td>
<td>$450</td>
<td>$600</td>
<td>$4000</td>
<td>$6000- $8000</td>
</tr>
</tbody>
</table>

**Table 2. Set up costs for 1ha of bamboo plantation for shoot production**

Sizeable shoot of *Dendrocalamus asper*, before harvest in northern NSW
About the authors

Steven Keilar completed his PhD at the University of Queensland in 2004, after spending four years from 1999 to 2003 working with members of the Australian bamboo shoot industry to further develop the industry’s future competitiveness.

Dr Ray Collins is Associate Professor in Agribusiness in the School of Natural and Rural Systems Management, at the University of Queensland. His teaching and research focus on new agribusiness enterprises, supply chain management and export development strategies. Over the last 15 years Ray has worked with new rural industries as both researcher and consultant. His contribution to the Australian persimmon industry is sometimes quoted as a model of how a new export oriented horticultural industry can guide its own future. Ray has an active research program involving new product development in Asian markets. Ray is a recipient of the University of Queensland Excellence in Teaching Award, and two International Collaborative Research Awards.

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Introduction

Long white radish (*Raphanus sativus* L.), or daikon, belongs to the mustard family, Brassicaceae. They have been consumed in China since 400 BC and are still one of the most important vegetables in Asia with a production of approximately 20 million t/year.

The radish plant is erect, with a short, non-branching stem supporting leafy rosettes. It has a swollen tap root with narrow, round petioles and the mid-vein is light green in colour. The radish leaf is rich in carotene (pro-vitamin A) and calcium while the root is a good source of vitamin C and some potassium and dietary fibre. The leaf, root and sprout are consumed as a vegetable. Long white radish, which is one of four types of radishes, is the most extensive vegetable crop grown in Asia. The other types are twenty-day radish, leafy radish and sprout radish.

Markets and marketing issues

Most of Asia would be considered as suitable markets for long white radish even in Australia. Japan, for instance, produced 1.36 million t of radish on 42,500 ha in 2002, valued at ¥109 billion (equivalent to A$1.45 billion [A$ = ¥75]) in wholesale markets. Production of long white radish in Japan was reduced from 2 million t in the 1980s to 1.5 million t in the 1990s, 1.4 million t in the early 2000s, and production now...
appears to be declining in most Asian countries as it is a heavy vegetable which brings low prices. However, because of the demand for processing products such as radish pickles, takuan, dried radish and frozen radish, opportunities exist for supplying fresh and processed long white radish to Asia, particularly Japan which, it is believed, imports a large amount of radish in semi-processed forms for the pickle industry.

Long white radish imported into Japan is classified under the code 105 "Salad beetroot, salsify, celeriac, radishes and other similar edible roots (0706.90.090)" which shows that imported quantities of daikon were 3,000-6,000 t of dried daikon per year at approximately ¥190/kg (CIF) during the last seven years from 1995-2002. Japan also imported 1,000-2,000 t of fresh radish mainly from China with very cheap CIF prices at about ¥50 mark in the last three years from 2000-2002. The wholesale and retail prices of daikon in Japan provide an indication of the import prices for daikon (Table 1).

Table 1. Production and importation of daikon in Japan, 1985-2002

<table>
<thead>
<tr>
<th>Year</th>
<th>Production</th>
<th>Importation</th>
<th>CIF prices (fresh) 2,3) , Yen/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area ha</td>
<td>Volume ton</td>
<td>Fresh ton</td>
</tr>
<tr>
<td>1985</td>
<td>66,900</td>
<td>1,856,000</td>
<td>Nil</td>
</tr>
<tr>
<td>1995</td>
<td>53,300</td>
<td>1,609,000</td>
<td>522</td>
</tr>
<tr>
<td>1997</td>
<td>49,800</td>
<td>1,487,000</td>
<td>138</td>
</tr>
<tr>
<td>1999</td>
<td>47,700</td>
<td>1,466,000</td>
<td>815</td>
</tr>
<tr>
<td>2000</td>
<td>45,700</td>
<td>1,419,000</td>
<td>1,018</td>
</tr>
<tr>
<td>2001</td>
<td>44,100</td>
<td>1,413,000</td>
<td>2,028</td>
</tr>
<tr>
<td>2002</td>
<td>42,500</td>
<td>1,361,000</td>
<td>1,740</td>
</tr>
</tbody>
</table>

2) Shokuhin Seisan Yunyu Shohi, 2002.
3) Yasai Yunyu no Doko, 2002.
4) Prices (CIF) for fresh daikon.

Production of dried radish in Japan has increased up to nearly 6,000 t in 2000 but CIF import prices have stayed at around ¥190 (A$2.53) mark per kg (Table 1).

Dried radish is used for cooking, soup, nigiri rice and ‘gobugobu’ pickles. There are three types of dried radish available in Japanese markets, and they are fine sliced (usukiriboshi), long strip or ribboned (kiriboshi) and cross-cut (wagiriboshi).

Frozen radish might be imported into Japan under ‘Other Frozen Vegetables [Code 490, No. 0710.80.090 ] and has been dramatically increased from 61,953 t valued at approximately ¥11.4 billion in 1993 to
154,618 t, valued at ¥27.2 billion (A$363 million) in 2002.

Production requirements

Long white radish is essentially a cold-season vegetable. However, it can be grown year round in Australia.

Producing high quality radish during mid-summer and winter requires great care as high summer temperatures and strong sunlight prompt the roots to develop rapidly in size, and become pithy soon after maturity.

Low temperatures slow vegetative growth, stimulate the forming flower buds and cause bolting in spring. Bolted radish is not marketable as the roots become woody and pithy. Therefore, the best time to grow long white radish is spring and early autumn.

Varieties/cultivars

There are several varieties of long white radish grown in Asia, the main differences between them being size, root shape and root neck colour. The main root shape grown is triangular with a white neck.

When selecting a radish variety, also check shape and colour, since market requirements vary with ethnic groups.

The Chinese and Indo-Chinese require a white-necked (shiro-kubi), thin (5 cm diameter) root growing to 25 cm in length, but the Japanese and Korean fresh market prefers the green-necked (ao-kubi), fat (7–10 cm diameter) radish grown to 30–35 cm in length.

For processing, the root shape is not as important but the flesh must be crunchy, and low in water content for faster drying. It must not be pithy.

Radishes are marketed when the root mass is approximately 300–1000 g, but depending on the type and market, they can be grown to even greater weights; a special Japanese variety called ‘Sakurajima’ (shape 5) can be grown up to 20 kg and a variety called ‘Moriguchi’ (shape 8) can grow up to 120 cm long with a width of 2.5 cm (Figure 1).

There are three other types of radish used in Asia which are:

Twenty-day radish: Most commonly cultivated radish in Australia and other Western countries. There are several varieties, differing in size and shape, but they all produce relatively small roots of approximately 30–40 g and are coloured red, white or red/white. They are very fast growing, maturing in approximately 30 days in summer and 45 days in winter.

Leafy radish: Grown as a leafy vegetable, this radish has large foliage and small roots. The plant is harvested when it has grown 10–15 leaves, each measuring 25 cm in length. The growing method is similar to twenty-day radish.

Sprout radish: A specific variety that grows long, white stems. Seeds are sprouted in moist, dark conditions at approximately 20–25°C and grow to approximately 15 cm over ten days and are marketed after the roots are removed. The Japanese are heavy consumers of sprout radish under the name ‘Kaiware daikon’ with approximately 15,000–20,000
When the seedlings are established 3-4 weeks after sowing, thin them to 20-25 cm apart, side dressing with potassium nitrate after thinning if necessary. White radish needs to be grown 50-60 days in summer and 70-80 days in winter for the fresh market when the fresh root weighs approximately 0.5-1.0kg.

**Pest and disease control**

Weeds are a problem for long white radish as their slow growth in the early stages makes them poor competitors with weeds. Weed control from sowing time onwards is essential, otherwise yield and quality are affected.

Pre-germinate weeds before planting the crop and control them either with knockdown herbicides or by cultivation. It is usually sufficient to hand-weed fast-maturing vegetables like white radish once during their growth.

Radishes are attacked by the same pests as other members of the Brassica family.

The most serious pests found in the New South Wales radish crops are cabbage white butterfly and aphids; nematodes and black beetle sometimes cause root damage.

The most important disease is bacterial soft rot (*Edwinia carotovora*), which is also found on other Brassica species. The bacteria are commonly found in decaying vegetable matter in the soil. They invade damaged tissue, often following other diseases.

Hot, wet weather favours soft rot. A soft, mushy decay develops from the root ‘neck’ (near the ground) and eventually the entire root is affected by a very smelly soft rot. Soft rot can also be a postharvest problem.
The disease is controlled by avoiding damage to the plant during side dressing or harvest, destroying diseased crop residues, and rotating the crop every three or four years.

Radishes are sometimes attacked by yellows (*Fusarium oxysporum*). The fungus survives for long periods in the soil, infecting the plant through roots and growing in the water-conducting tissues. Warm weather favours the disease.

Affected plants lose vigour and the lower leaves on one side of the plant turn yellow; a brown discolouring develops under the skin of the root. The disease is controlled by using resistant varieties, and rotating crops every three or four years.

**Harvesting and packaging**

Fresh market radish varieties are harvested approximately eight to ten weeks after sowing. The roots are mature when they reach a 5-10 cm diameter at the 'neck'.

Radishes are hand-harvested and tied in bunches of two or three roots, or sold in bulk in cartons of five, ten or fifteen kg, or sold individually. Radishes sold on the market have full foliage or are trimmed to leave 10 cm of foliage.

The root should have smooth white skin without blemishes. Internally, root flesh should be compact with no signs of pithiness or hollowness.

Like other vegetables, radishes are susceptible to wilting. If possible, harvest them when it is cool, preferably in the early morning, and keep the produce cool and moist until placed in cold storage at a temperature of 0°C and a relative humidity of 90-95%, but do not freeze the produce, as it can suffer extensive damage when thawing.

These precautions should maintain the quality of the radish and increase its storage life. The radish has a short shelf-life if pithiness develops inside the root.

In hot weather, pre-cool the crop to its optimum storage temperature as soon as possible after harvesting.

This is best done with forced-draught air-cooling. Vacuum cooling benefits produce with a high, surface area-to-volume ratio, where rapid cooling is important, such as leafy vegetables.

Processing radishes are harvested approximately 10-12 weeks after sowing, because processing cultivars need to be grown longer than fresh market types. Roots are thoroughly washed by brush-washer machine or by hand, and are prepared as per market requirements.

To make *takuan*, all plants need to be dried for approximately 3-5 days in shaded areas with good ventilation for the roots to reduce to approximately 50% of their fresh weight.

To make dried sliced radish, the leaf should be trimmed and roots are sliced and dried by either sun or in a drier until they are approximately 10% of their fresh weight. The dried radishes have a strong odour, and packaging them in sealed plastic bags is desirable.

### Precautions with pesticides

Long white radishes are eaten raw or cooked without peeling, so extreme care must be taken if using pesticides. They must be registered and approved for use and applied according to the directions on the product label. Postharvest chemical treatments are generally unnecessary.

### Quarantine requirements

A declaration must be provided to the Australian Quarantine and Inspection Service (AQIS) that the daikon crop has been inspected by an authorised person and is free of burrowing nematode (*Radopholus*).
Financial information

Long white radish can be harvested at different root weights from 300 g to 1,000 g or even up to 1,500–2,000 g depending on the end uses. The production costs therefore vary between time of harvesting, cultivars, seasons, growing locations, packaging and time of consignment. Whilst the break-even for fresh daikon is estimated at around A$0.55/kg (or $0.27 per root), it is understood that break-even for dried daikon is high, estimated at A$5.57/kg (Table 2). This is probably caused by intensively high labour costs.

Exporting of Australian dried daikon to Japan remains possible if the Australian daikon industry reduces its production cost by mechanising production systems, translating its “safe and high quality” vegetables into sales with acceptable margins.

Table 2 shows an enterprise budget for 1.0 ha for Daikon located in Somersby, New South Wales, for a period of 8–10 months.

---

Table 2. Gross margin for Diakon growing on the Central Coast of NSW, 2004

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost (A$)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>55,000 roots</td>
<td></td>
<td>A$0.40/root</td>
<td>22,000</td>
</tr>
<tr>
<td><strong>A. TOTAL INCOME</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Variable costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>8hrs</td>
<td></td>
<td>18.48/hr</td>
<td>147.84</td>
</tr>
<tr>
<td>Diakon seed</td>
<td>2.5kg</td>
<td></td>
<td>400.00/kg</td>
<td>1,000.00</td>
</tr>
<tr>
<td>Planting labour</td>
<td>4hrs</td>
<td></td>
<td>18.48/hr</td>
<td>73.92</td>
</tr>
<tr>
<td>Fertilisers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural lime</td>
<td>4.0t/ha</td>
<td></td>
<td>130/t</td>
<td>520.00</td>
</tr>
<tr>
<td>Fertilisers Multigro</td>
<td>1.5t/ha</td>
<td></td>
<td>495/t</td>
<td>742.50</td>
</tr>
<tr>
<td>Spreader machinery cost</td>
<td></td>
<td></td>
<td></td>
<td>3.88</td>
</tr>
<tr>
<td>Labour</td>
<td>2hrs</td>
<td></td>
<td>18.48/hr</td>
<td>36.96</td>
</tr>
<tr>
<td><strong>Nematode control</strong></td>
<td></td>
<td></td>
<td></td>
<td>85.00</td>
</tr>
<tr>
<td><strong>Weed control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand weed labour (2 times)</td>
<td>10days</td>
<td>8hrs/day</td>
<td>18.48/hr</td>
<td>1,478.40</td>
</tr>
<tr>
<td>Pesticides, machinery, labour</td>
<td></td>
<td></td>
<td></td>
<td>48.14</td>
</tr>
<tr>
<td>Irrigation (water pump &amp; mainten)</td>
<td></td>
<td></td>
<td></td>
<td>219.50</td>
</tr>
<tr>
<td><strong>Harvesting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>59.5days</td>
<td></td>
<td>147.84/day</td>
<td>8,796.48</td>
</tr>
<tr>
<td><strong>Transportation &amp; fees</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Freight to Sydney</td>
<td>2,291.50 ctns</td>
<td>0.50/ctn</td>
<td>1,145.75</td>
<td></td>
</tr>
<tr>
<td>Levies</td>
<td>2,291.50 ctns</td>
<td>0.25/ctn</td>
<td>572.87</td>
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<tr>
<td>Agent commission 10%</td>
<td>2,291.50 ctns</td>
<td>0.10/ctn</td>
<td>229.15</td>
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<tr>
<td><strong>B. TOTAL VARIABLE COSTS</strong></td>
<td></td>
<td></td>
<td></td>
<td>15,100.40</td>
</tr>
<tr>
<td><strong>GROSS MARGIN (A-B)</strong></td>
<td></td>
<td></td>
<td></td>
<td>6,899.61</td>
</tr>
<tr>
<td>Break even for Fresh Daikon</td>
<td></td>
<td></td>
<td></td>
<td>0.27</td>
</tr>
<tr>
<td><strong>For Dried Daikon 1)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drying</td>
<td>357 hrs</td>
<td></td>
<td>7.00/hr</td>
<td>2,499.00</td>
</tr>
<tr>
<td>Loading drying trays (1 min/tray)</td>
<td>250 trays/t</td>
<td>0.06/kg</td>
<td>3,000.00</td>
<td></td>
</tr>
<tr>
<td>Unloading trays &amp; packaging</td>
<td>40 hr/ha</td>
<td></td>
<td>12.00/hr</td>
<td>480.00</td>
</tr>
<tr>
<td>Packaging (50t fresh less 20% loss = 4t dry)</td>
<td>0.30/kg</td>
<td>1,200.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>C. TOTAL VARIABLE COSTS</strong></td>
<td></td>
<td></td>
<td></td>
<td>22,279.15</td>
</tr>
<tr>
<td>Break even for Dried Daikon</td>
<td></td>
<td></td>
<td></td>
<td>5.57</td>
</tr>
</tbody>
</table>

1) Figures in 1997 by Gas drying
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Key messages

• Low capital investment but long term commitment required
• Labour intensive
• High returns are possible

Key statistics

• Japan produced 2 million t of daikon in the 1980s but has declined to 1.4 million t in the early 2000s
• There is a potential market in Japan for semi-processed and processed daikon
• The imported CIF prices of processed daikon in Japan are low, at around ¥190 (A$2.53) per kg

Key references


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Edamame
(Vegetable green soybean)

Introduction

Edamame or vegetable soybean (Glycine max [L.] Merr.) is a traditional food of Japan and China that is now consumed throughout east-Asia and elsewhere in the world with expatriate Asian populations. Traditionally, the whole plant is harvested green when the seeds have reached their maximum size but before any yellowing has occurred. The plants are then transported intact to market to assure customers of the freshness of the product. After purchase, pods are removed from the plant, boiled and consumed as a snack food. To do this a person will squeeze the pod between thumb and forefinger to cause the seed to slide out directly into their mouth. Only the seed is eaten as the pod is fibrous and unpalatable. In Japan, the common use for edamame is as a snack consumed with beer in commercial establishments. Boiled salted pods should be blemish-free, bright green and have a sweet flavour with a slight nutty texture. In other parts of Asia and increasingly in western countries, the seeds are shelled from the pod and used in stir-fries.

Edamame has the same health benefits as are reputed for grain soybean. Notably, a reduced risk of cardiovascular diseases, various cancers, osteoporosis and menopausal symptoms associated with soybean consumption. Importantly, edamame is more palatable to the western consumer than many other soy products.

Until recently, production of edamame for the fresh-frozen market for export to Japan...
was focussed in Taiwan where technologies were developed for mechanised harvesting and processing into a consistently high quality product. More recently, production has moved to China, Thailand and Vietnam following investment and technology transfer from Taiwan.

Markets and marketing issues

There is a limited but high value market to supply restaurants during the Australian summer and autumn with freshly produced edamame. Expansion beyond this will depend on development of an export market to Japan or increased consumption in Australia. Both these areas show potential, but both require market development.

There is potential for year-round production in Australia using a range of varieties and locations from north Queensland to Victoria. The main period of production is likely to occur during the Australian summer and autumn. Production at this time corresponds with a production gap in Japan and very high prices for fresh product. The Japanese government has recently relaxed quarantine restrictions previously in place to protect against fruit fly.

Current Australian production of edamame is of very small volume and entirely used to supply fresh markets. Most varieties of edamame are poorly adapted to Australian growing conditions. As a result, good quality planting seed is difficult to produce and growers find it difficult to achieve good crop establishment and poor productivity results.

Edamame is marketed in one of three forms:

1. Attached, in which whole plants are transported to market after being lightly trimmed of leaves. Japanese customers believe they are able to better determine the freshness of product of this type. In the initial phases of market development in Australia, this is the form that is most likely to succeed in developing niche markets.

2. Detached, in which pods are marketed after plucking from the plant. Detached pods may be marketed fresh or frozen. Frozen beans of this type are the main type imported by Japan.

3. Shelled, in which the seeds are first shelled from the pods. Product of this form is sometimes sold fresh in Chinese markets, but generally product of this type is sold frozen for inclusion in stir-fries and vegetable blends.

Annual consumption in Japan is in the order of 160-180 000 t/year of which around a third is imported, principally as frozen product. Freshness is important, even for the frozen product. Imports of frozen beans into Taiwan are also substantial but largely controlled by Taiwanese owned processors with frozen production from China, Thailand and Vietnam.

Australian prices of around $6 to $10/kg for fresh-attached have been quoted at fresh markets in capital cities. However demand can be patchy depending on whether key buyers realise the availability of the product and on its quality.

Production requirements

Production of edamame is similar to grain soybean in that time from sowing to flowering of the crop is highly sensitive to daylength and temperature. Time to flower sets the size of the plant as little growth occurs after flowering. It is therefore important to use a variety adapted to the latitude and sowing date to ensure that plants grow to the correct size for the market. In general, varieties for southern New South Wales and Victoria need to be of early maturity type and are only suited to sowing dates of late October through to early December. Edamame can be sown from November through to January in northern New South Wales and southern Queensland, and could be produced during the winter season in tropical regions.

Maintenance of the crop in a well watered condition from flowering through to harvest maturity is important to ensure that seeds are large and high in sugar content. Water stress results in smaller seeds which are reputed to have tough texture.

Production of high quality planting seed is a key constraint to production. In many Australian cropping environments, traditional
varieties have uneven ripening within a plant and severe shattering of grain. Often pods at the top of the plant shatter while pods lower on the plant are still green. If desiccated and mechanically harvested, large seed with very low moisture content tends to be mechanically damaged, whilst immature seed with high moisture content tends not to be viable after drying or have low vigour. Attempting to establish a crop with seed of low germination or low vigour results in uneven plant stands and highly variable quality.

Edamame seed is large and of epigeal germination, that is the plant lifts cotyledons from the soil during germination. In order to achieve good establishment, it is necessary to start with high germination seed with high vigour and plant it into a friable seedbed. Hard setting or crusting of the seedbed can result in poor establishment because the cotyledons are prone to being trapped under the crust.

**Varieties**

Traditionally, cultivars with green seed coat and cotyledon at maturity have been preferred by growers because the harvest period can be extended closer to maturity of the plant without experiencing the yellowing associated with maturity. Seed pods should have sparse grey pubescence and contain three seeds per pod, though two seeded pods are acceptable in the market. There should be an absolute minimum of one seeded pods because they are disliked by the consumer, requiring greater effort to shell them. Four seeds in a pod are not preferred because the

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**Table 1. Most popular and emerging varieties and cultivars in Australia**

<table>
<thead>
<tr>
<th>Variety</th>
<th>Synonyms</th>
<th>Area of adaptation</th>
<th>Key characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSB #1</td>
<td>Vesoy #1</td>
<td>NSW</td>
<td>Good quality for fresh market, pods susceptible to bruising so less suited to mechanical harvest and freezing.</td>
</tr>
<tr>
<td>GSB #4</td>
<td>Vesoy #4, CM #1, Chiang Mai #1</td>
<td>NSW</td>
<td>Good quality for fresh market, pods susceptible to bruising so less suited to mechanical harvest and freezing.</td>
</tr>
<tr>
<td>KS #1</td>
<td>Taisho Shiroge, Kaohsiung #1, and many other local names throughout south east Asia</td>
<td>central NSW to southern Qld</td>
<td>Good quality for fresh or frozen market.</td>
</tr>
<tr>
<td>C784</td>
<td></td>
<td>Qld</td>
<td>Good quality and improved agronomic characteristics.</td>
</tr>
<tr>
<td>Tanbaguro</td>
<td></td>
<td>northern NSW to central Qld</td>
<td>Very large black seed with high sugar content and excellent eating quality.</td>
</tr>
</tbody>
</table>
number four is considered unlucky in Japanese culture.

**Cultural practices and agronomy**

Cultural practices, fertiliser and herbicide rates are similar to that of grain soybean, except that plant population should only be around 50,000 to 70,000 plants/ha. Plants should be evenly spaced and a higher standard of seedbed preparation, weed and insect control is necessary as edamame seed tends to be more difficult to establish than grain soybean. Inoculation of the seed with rhizobium strain CB1809 is necessary.

For seed crops, plant populations of greater than 250,000 plants/ha are desirable to maximise seed yield as is sowing during the early part of the planting window for soybean in the region of cropping. The crop needs to be well watered at planting, flowering and early pod fill to ensure good growth and pod set. The crop should be maintained substantially free of sucking and chewing insects. Mild water stress during late pod fill is desirable. Some varieties may need to be desiccated prior to harvest at moisture content of 13-14%. The same desiccant and rates as used for soybean seed is appropriate. The aim of this recommended agronomic package is to maximise seed number and minimise seed size, as smaller seed tends to maintain germination and vigour better during harvest, cleaning, storage and planting.

**Pest and disease control**

Generally, little insect control is necessary before early pod fill. The one exception to this is if more than one in ten plants have caterpillar damage to the growing point. Once early pod-fill has been reached it is important to scout the crop for sucking bugs and chewing insects. Economic thresholds for insect numbers in edamame have not been developed, but are likely to be somewhat lower than the recommendations for food grade soybean in the same region. At this stage, the recommendations for food grade soybean should be used as a guide. Only insecticides registered for soybean can be used and withholding periods strictly observed.

**Harvesting/handling/storage/post harvest/processing**

Two techniques for harvesting have been trialed in Australia. The crop may either be hand harvested as intact plants that are then trimmed of excess leaves or machine harvested using a modified green-bean picker. Hand harvested product is generally far superior in quality to the machine harvested, although this machine harvest quality varies dramatically with the skill of the operator and with adjustment and modifications to the equipment. Hand harvesting is however labour-intensive and therefore expensive. Efficiency of hand harvest is improved by having low plant populations and good agronomy which result in larger plants.

Edamame is best harvested early in the day for peak moisture content, flavour and texture. If machine harvested, it is possible to perform the operation during the night whilst conditions are cool. Flavour quality peaks 3-5 days before seed size is maximised. Research is currently underway to determine methods for practical determination of harvest time. Standards for the fresh attached product are absolute minimum of empty and one seeded pods, pods to be longer than 4.5cm and wider than 1.3cm and greater than 350 pods/kg.

In order to supply fresh edamame to markets with produce over a sufficiently long production season to permit market development, production needs to occur over at least a three-month period from any region of production. Australian markets for fresh produce are often up to 2,000 km by road transport from areas of production. Since freshly harvested edamame commands the highest price in the market, techniques were needed to transport fresh edamame to market in good condition. In CSIRO trials, whole plants were harvested at the R6 or R7 stage and transported intact to market using technology similar to that employed for broccoli, ie packing in ice and transport in polystyrene cool boxes. Customers were delighted with the freshness and quality of the product. Blanching, freezing and transport of edamame is a similar operation as freezing of other vegetable crops.

For non-traditional consumers of edamame, previously shelled product is desirable as hand shelling is time consuming.

Detached type of vegetable green soybean in Toklo wholesale Markets, Japan.
Mechanised edamame shelling equipment has been produced and should be considered in developing non-traditional markets.

**Financial information**

Yields of around six to nine t/ha have been reported, although it appears possible to substantially exceed this level with good agronomic management. Complete crop failures have occurred because of poor quality planting seed or poor quality of harvested product due to insect damage. At this stage it is difficult to produce gross margins of any validity until improved varieties are trialed in several production areas.

**Future outlook**

Once Australian production is underpinned by good agronomic research and improved varieties, harvest, handling and processing technologies, substantial expansion in supply of fresh-attached product and in frozen detached and shelled product is likely to occur. Japanese trading houses have expressed interest in import of fresh-attached type edamame during the January to May production gap in Japan.

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**About the author**

Dr Andrew James is the soybean breeder with CSIRO Plant Industry. He has worked on soybean improvement projects in Australia, Vietnam and Thailand. Dr James currently leads the national soybean improvement program with inputs from state departments of agriculture in Queensland, New South Wales and Victoria, the Rural Industries Research and Development Corporation, the Grains Research and Development Corporation, the Australian Centre for International Agricultural Research, the Sugar Research and Development Corporation and Australian and international industry.

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Japanese ginger  
(Myoga)

**Introduction**

*Zingiber mioga*, commonly called myoga or Japanese ginger, is a traditional Japanese vegetable. Myoga is the most cold tolerant species of the ginger family and is widely cultivated throughout Japan. Myoga is a typical ginger plant with a thick rhizomatous but inedible rootstock. Myoga is grown for spring shoots, or more commonly, for sterile flower buds produced during summer.

Myoga ginger is a perennial, woodland plant from Japan. The plant’s top growth is frost tender and senesces in winter. It regenerates in spring from underground rhizomes and produces dense foliage on robust pseudostems 1.5 to 2 m high. Under Australian conditions, myoga pseudostem growth sunburns without shading.

The flower buds, which are produced at ground level from underground rhizomes during summer are used fresh as flavouring in a wide range of foods including salads, sushi and soups. The Japanese market consumes approximately 10,000 t annually, grown mainly during the summer months of June to September. Winter production of myoga in Japan is produced in heated glasshouses and is called ‘house myoga’. The opportunity exists for Australian grown myoga to be supplied to the Japanese during the ‘out of season’ months in competition with ‘house myoga’. The Australian market offers the opportunity to supply a product which is not widely known but has significant potential.

Since 1990, myoga has been the subject of intensive research and development activity. Production techniques including annual production protocols in the warm coastal regions of central

**MAP**

- Coastal areas in Qld from Cairns to Bundaberg
- Albion Park in NSW
- New Norfolk in Tas

**MAP**

- Suitable for production
  
**MAP**

- Coastal areas in Qld from Cairns to Bundaberg
- Albion Park in NSW
- New Norfolk in Tas
Japanese ginger Queensland have been proven which enable the harvest period to extend to six months minimum each year. Trial marketing has been completed in Japan and in the major cities of Australia. Product quality has been very well received in Japan and Australia and the supply chain to both has been successfully implemented.

**Markets and marketing issues**

The Japanese and the Australian markets are seen as the principal potential markets for fresh Australian grown myoga. The Japanese market is supplied mainly from summer production with plants grown in soil and in ambient conditions.

House myoga or winter production in Japan is expensive to produce and fresh Australian myoga harvested from November to June is competitive with Japanese house myoga.

Trial commercial shipments of Australian myoga have been successfully airfreighted to Japan and distributed in Tokyo and Osaka using an established supply chain specialising in the distribution of Tasmanian grown salmon. The quality of Australian myoga compared highly with local product.

The Australian market has been supplied with myoga grown in New South Wales from January to April. The Sydney market has been the major focus with supplies also going to selected markets in Brisbane, Perth and Melbourne. Apart from Japanese residents, myoga is not widely known in Australia and therefore presents an opportunity to expand its use in western cuisine.

**Production requirements**

Myoga grows naturally in shaded wooded areas in Japan. In Australia, myoga requires shading of 30% to 50% provided by the use of shadecloth. The soils must be free draining preferably alluvial loams or sandy loam.

Plants grown in ambient conditions will produce flower buds for a period of up to six weeks which is not long enough to create a presence in the market or provide continuity of supply to the market. A production method, using forced techniques including chilled root-stock, day length manipulation and minimum night temperatures of 16 degrees, has been proven. The coastal regions of northern New South Wales and central Queensland can provide ideal conditions which allow for sequential plantings to give a lengthened harvest period of at least six months, which both the Japanese and Australian markets require.

Myoga is planted into raised beds of 1.2 metres wide with two rows per bed with 40 cm between the rows and 40 cm between the plants. The beds are covered by an open mulch (pine shavings or similar) to allow the flower buds to emerge from beneath the soil surface into the mulch. The mulch allows diffused light to reach the buds, which produces a pink colour, which the market demands.

Myoga being packed

Myoga grown under 30% to 50% shadecloth
Varieties

Myoga varieties from Japan are not named but are identified only as having been grown in a particular region or as early, mid or late season myoga. The Australian research and development program has identified a superior variety which has demonstrated high yields of highly coloured flower buds in a range of production areas extending from Tasmania to Rockhampton in Queensland. The superior variety performs particularly well under forced conditions.

Cultural practices

The soil should be cultivated to a fine tilth and bedded up prior to planting. The plants should be cooled prior to planting either in the soil from a cool climate (Tasmania) or from plants cooled in a store. The plants should weigh at least 100 g each. The plants are planted on raised beds with 0.8 m between the beds for easy access for harvest and other activity. Wood shaving mulch is applied to a depth of 100 mm over the full width of the bed.

Irrigation can be provided by overhead mist sprinklers or drip tube laid on the soil surface but beneath the mulch. Myoga will not tolerate water logging.

Myoga produces a very vigorous and dense canopy of pseudostems early in the growing season and then goes on to produce a vigorous rhizome ‘mat’ and yields of flower buds of up to 10 t/ha. Phosphorus and potassium should be applied as a mix before planting at the rate of approximately 400 kg/ha and regular applications of nitrogen should be made throughout the growing season at approximately 30 kg of N per hectare each four weeks. Leaf analysis will provide more accurate information to determine nitrogen applications. Excess nitrogen will promote vegetative growth at the expense of flower production.

Shade should be provided by the erection of a structure to carry shadecloth of 30% to 50% with vehicle access provided.

Pest and diseases

The most serious fungal diseases, reported in Japanese literature but not found in Australian grown myoga are *Pythium zingiberum* causing root or rhizome rot and a leaf spot caused by *Pyricularia zingiberi*. Myoga is also known to be susceptible to Cucumber Mosaic Virus (CMV). The myoga plants being grown in the Tasmanian foundation nursery have been tested free from CMV.

Some slug damage can occur after periods of rain but is readily controlled using commercially available repellents. No other pests or diseases are reported in literature or observed in Australian grown myoga.

Harvesting and post harvest handling

Flower buds are picked by hand as soon as they emerge through the mulch layer. If harvesting is delayed much beyond this time the flower buds become deep.
green on their tips and rapidly progress to anthesis. Green buds with emerged flowers are not marketable.

Highest quality buds are large and plump with a distinct pink to crimson colour weighing between 15 and 25 g. Experienced pickers will harvest 10 kg per hour and are able to exercise judgement and only harvest the highest quality flower buds.

Freshly harvested flower buds are transferred to cool rooms as quickly as possible to remove the field heat. The buds are washed in cool water. Washed buds are stored at 4 degrees until they are graded and packed by hand into 75 g or 150 g punnets. Grading is done using Japanese quality standards available on guide charts showing the essential criteria of shape, weight and colour.

Myoga destined for Japan will be inspected for pest contamination by AQIS staff prior to the issue of a phytosanitary certificate that is a requirement of the Japanese import authorities. The myoga packing premises used for export will require AQIS certification.

Packed myoga should be stored at 4°C prior to consolidation in airfreight containers. Myoga destined for the Australian market should also be stored at 4°C prior to delivery.

The graded flower buds are packed into clear clip-top retail packs of 75 to 150 g each and these packs are packed into protective polystyrene outers complete with lids.

Financial information

A financial model has been prepared to examine the feasibility of production and processing myoga in soil as a perennial crop. In the model, production and processing have been treated as a separate business from marketing, which could be handled by another entity.

The financial model looked at the first ten year life of a one ha plantation complete with shade house and irrigation. Yield of the mature plantation in year three was 10 t and the price was established at $A24.70/kg which was based on the weighted average of the price achieved in Japan and Australia. The total accumulated capital investment cost is $A102,750 and the net operating profit is $A56,920 in year three.

The model shows a net present value of $A250,768 and an internal rate of return of 28% with no allowance made for the sale of second grade buds.

References


About the author

Richard Warner has been involved in horticultural production and marketing since 1971. He has managed his own business specialising in production of hops, berry fruits and vegetable seeds. He has chaired a number of agricultural related businesses.

In 1990, in association with Mr Peter Shelley, he commenced trial production of myoga. An intensive research and development program was commenced in 1994 into myoga production and marketing which concluded in 2003 when a student completed her doctorate into myoga production issues.

Richard continues to manage his own business specialising in berry fruit production.

Much of the basic research on the myoga growth model was developed in a research higher degree study by Kristen Stirling at the University of Tasmania. Research has been funded by Agrilink Asia Pacific Pty Ltd and the Australian Research Council through an APA (Industry) grant, and by RIRDC.

Key statistics

- Japanese production is approximately 10,000 t annually grown mainly in the summer months of June to September

Key messages

- 'Out of season' Australian grown myoga has the competitive advantage of being produced under favourable naturally occurring conditions found in coastal Queensland
- The Australian myoga variety has provided excellent yields of high quality buds

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Japanese taro
(Sato-Imo)

David Hicks and Vong Q. Nguyen

Introduction

Sato-Imo, Japanese taro or Japanese potato (*Colocasia esculenta* var. *antiquorum*), is a golf-ball size and shaped starchy root crop belonging to the Araceae (Aroid) family of plants. A fleshy herbaceous perennial with large ‘elephant ear’ like leaves supported on long 1-1.5m petioles, it produces an over-wintering corm mass which includes a large mother corm subtended by a great number of smaller daughter corms. The large numbers of small corms and the ‘nuttiness’ of the flavour are what distinguish this crop, from other taro varieties that produce much larger mother corms with several daughter corms (*Colocasia esculenta* var. *esculenta*, large-corm taro or Pacific taro). The following information refers only to the Sato-imo types known commonly as the *antiquorum* or small-corm varieties.

Japanese potato can be used similarly to ‘Irish’ potatoes and can be prepared as a nutritious substitute or interesting replacement. In Japan, sato-imo has cultural significance as a traditional food which is widely consumed. It is an intensive crop, introduced to and produced in the Northern Rivers region of New South Wales, coastal Queensland and the Darwin region, which yields large volumes per unit of land.

Other known producers are China, Japan and Samoa. Production in Japan was 124,000 t in 2002. Japan is the only currently known importer, and, while peak consumption is during the Japanese winter, there is a
continued period of demand which is counter-seasonally conducive to Australian production.

The challenges facing industry development in Australia beyond competitors, such as China, are quality maintenance during shipment and shelf-life, development of the domestic market and cooperative coordination of export activities.

The RIRDC funded project UCQ-13A involving the Northern Rivers Agricultural Development Association (NORADA), and lead by Central Queensland University (CQU) with New South Wales Agriculture, is presently in the advanced stages of identifying market opportunities and addressing production requirements and practices. The following information is an outcome of that project.

**Market and marketing issues**

The principle market for sato-imo, and the focal basis for which the research project was established, is the counter seasonal export market opportunities in its fresh form in Japan (Table 1).

During the months of May through to July inclusive, the volume of supply has an annual sharp decline, whilst the price for this period has a corresponding sharp increase (Table 2). This suggests that there is still a demand during this period. Estimates for fresh imports from Australia into Japan are targeted at 2,000 tonnes based on 10% of Japan’s annual import volume.

Processed-fresh products including pre-peeled and packaged sato-imo are also worth exploring. Further, Japan imports 50,000 t of pre-peeled frozen product annually which may have longer term implications for export opportunities.

Significant hurdles remain for developing the export market, particularly guaranteeing a high enough return price to make the venture profitable. Japanese importers are over familiar with cheap imports from China during their production season, even though air-freighted trial shipments of the Australian product have been recognised as superior in quality.

**Table 1. Production and importation of Sato-imo in Japan, 1985-2002**

<table>
<thead>
<tr>
<th>Year</th>
<th>Production 1)</th>
<th>Importation 2)</th>
<th>CIF Prices (Fresh) 2,3), Yen/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area, ha</td>
<td>Volume (t)</td>
<td>Fresh (t)</td>
</tr>
<tr>
<td>1985</td>
<td>28,500</td>
<td>225,300</td>
<td>Nil</td>
</tr>
<tr>
<td>1995</td>
<td>2,400</td>
<td>147,500</td>
<td>26,863</td>
</tr>
<tr>
<td>1997</td>
<td>1,400</td>
<td>163,900</td>
<td>6,025</td>
</tr>
<tr>
<td>1999</td>
<td>20,000</td>
<td>148,100</td>
<td>10,322</td>
</tr>
<tr>
<td>2000</td>
<td>18,800</td>
<td>138,300</td>
<td>20,345</td>
</tr>
<tr>
<td>2001</td>
<td>17,800</td>
<td>129,200</td>
<td>20,254</td>
</tr>
<tr>
<td>2002</td>
<td>17,100</td>
<td>123,900</td>
<td>24,887</td>
</tr>
</tbody>
</table>

Table 2. Consignment and prices of Sato-imo at the Tokyo Central market, Japan (Average of 5 years, 1998-2002)

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume, t</td>
<td>1133</td>
<td>1213</td>
<td>1014</td>
<td>826</td>
<td>679</td>
<td>556</td>
<td>550</td>
<td>929</td>
<td>1778</td>
<td>2011</td>
<td>1867</td>
<td>2594</td>
<td>15249</td>
</tr>
<tr>
<td>Price, ¥/kg</td>
<td>182</td>
<td>194</td>
<td>193</td>
<td>179</td>
<td>249</td>
<td>356</td>
<td>326</td>
<td>267</td>
<td>233</td>
<td>196</td>
<td>170</td>
<td>180</td>
<td>209</td>
</tr>
</tbody>
</table>


due to the morphology of the plant, is the fact that in a crop of small-corm taro, a maximum of approximately 30-40% of corms per plant are suitable as export quality.

For the domestic market, most Japanese sato-imo is sold through niche markets and Asian grocery stores. It has not been seen in the larger mainstream chain-store outlets; which is a problem of marketing. There are suggestions that the product be re-branded for the Australian domestic market as “Japanese potato”, to distinguish it from the large-corm varieties and the term taro altogether.

Production requirements

Temperature and water availability have the most important influence on production. The growing season from germination to corm formation will need to be between 6 and 9 months, with an average temperature during growth of between 25–30°C. Sato-imo is frost sensitive, however, lower temperatures after corm formation are favourable to suppress shoot growth from the new corms.

A full sun aspect with protection from wind via windbreaks is an advantage, this is a species that readily transpires water and in strong winds can be damaged. Water will be the major limiting factor to production and any naturally occurring precipitation should be augmented with irrigation.

Preliminary observations indicate good water management practices will provide optimum yields.

Sato-imo will accommodate a wide range of soil types, though it thrives best in soils with high fertility and good structure. It will tolerate waterlogging, though higher yields have been observed in soils with good drainage. A longer growing season is necessary for poorly draining soils. Soil pH should be in the range of 5.5–7.5.

Varieties/cultivars

Considerable attention has been given to nomenclature. Based on more recent genetic and morphological variation studies, proponents of a revision of taro classification argue that the use of the two varietal taxonomic sub-groups, var. antiquorum and var. esculentum, is unreliable, and that the preference is to treat Colocasia esculenta as a single polymorphic species, differing at the cultivar level only. However, the debate

is currently unresolved and to prevent confusion the prevailing commercially-accepted taxonomic breakdown into *antiquorum* and *esculenta* will be recognised here.

An alternative grouping convention is to refer to small-corm and large-corm cultivars. This is a way of referring to relative corm size and morphology and is not based on taxonomic or genetic relatedness.

The only recognised *antiquorum* cultivar currently available in Australia is thought to be *Ishikawa wase*. Confirmation by DNA fingerprinting, of the varietal identification is an objective of the current research project.

There are 10 other cultivars, favoured by different markets within Japan, in the process of importation into Australia. These include *Dodare*, *Tono-imo* and *Takenoko-imo*. The strict quarantine measures imposed upon importers require a laborious route; any new varieties may require up to 2-3 years before release.

### Cultural practises/agronomy

Preparation of land should begin with deep ripping the soil followed by ploughing and mound formation. The use of double or single beds or mounds, 1.5 m in width or one standard tractor wheel width, will assist in harvest and alleviate any drainage problems on heavier soils. Incorporation of half the nitrogen, all the phosphorous, and one quarter of the potassium requirement is recommended prior to mounding. Any minor nutrient, trace element or pH adjustment, recognised by a soil test, should also be addressed at this stage.

Any corms in good condition can be used as propagation material. Mother corms or quarter-cut mother corms, sealed with dolomite or ash and allowed to dry, have provided the highest yields. Planting in single or staggered double rows, within the mound 30 cm apart and 10 cm deep, on central coast and in northern NSW, is from September to November.

Sato-imo is a gross feeder of nutrients; they should be applied as 3-4 split applications. Initially, nitrogen is required for shoot growth at a rate of 150 kg/ha, phosphorous at 80 kg/ha and potassium 100 kg/ha. Subsequent side dressings should be at the rate of 75 kg/ha nitrogen and 100 kg/ha potassium. A final application of potassium at 50-100 kg/ha as potassium sulphate, is required for corm formation. Too much nitrogen at this stage can result in elongated corms and promotion of new shoots from developing corms. Logically, the absolute quantities will depend upon data from prior soil analyses.

Weeds are a severe problem to the taro grower during the early stages of growth before canopy cover over the soil is achieved. Glyphosate can be used between mounds and rows using a hand-held backpack type sprayer. Care should be taken to avoid spray drift onto crop plants. Cultural practices such as using hay mulches, hill ing-up using a disc plough and hand weeding are also effective. A number of chemical herbicides are currently under test for registration application.

Rotation practices should be observed. It is preferable to use a site once only; many very small corms will be missed during the harvest and will sprout during the following season. Effectively acting as weeds, these invaders will compete for available resources and compromise the quality and quantity of yield.

A maximum of two yearly rotations is recommended, as yields have been observed to be lower in subsequent plantings.

### Pest and disease control

This is a crop relatively free of pests. *Heliothis* sp. and cluster caterpillars can cause minor damage to leaves and emerging shoot tips. Chemical control at this stage cannot be recommended, as no products are registered for use. Soil borne larvae such as cane grubs and African black beetles, which can attack and spoil corms, can be kept in check using cultural measures and rotation.

The most serious problem of the taro family of plants is the fungal organism *Phytophthora colocasia*, which causes the disease taro leaf

<table>
<thead>
<tr>
<th><strong>Table 3. Classification of sato-imo in the Japanese market</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corm Size</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td><strong>Early cultivars</strong></td>
</tr>
<tr>
<td><strong>Normal cultivars</strong></td>
</tr>
</tbody>
</table>

Note: Early cultivars such as Ishikawa Wase and the same are produced and delivered to the market from May to August. The normal cultivars are other sato-imo varieties that are supplied to the market in another period of time from September to April.

blight (TLB). This fungus has not yet been officially recorded in Australia, though symptoms which superficially resemble TLB on some plants, have been observed.

**Harvesting and packaging**

Corms are harvested when the shoots die back over winter, usually from mid-May through to July. Corms should not be stored in the ground as re-shooting and quality problems can occur. A slasher can be used to remove standing canopy in areas where it is still present at harvest time. A potato digger is used to lift the corms and initially separate the clump. Yields of between 10-100 t/ha have been reported, though on average 18 t of marketable export quality corms have been reported by growers.

It is necessary to perform the first of two gradings in the field to reduce labour inputs. All mother corms, misshapen, damaged and very small corms are separated from the marketable product. The marketable product is then washed and any remaining roots and soil debris removed. This process may be undertaken on 2-3 occasions. A second and third grading based upon size and then shape is performed. [Note that the grading in Table 3 is the standard for the Japanese domestic fresh market. Individual import companies may have different specifications depending on their clients’ requirements].

Three size grades *viz*. small, mid, and large ranging from golf-ball to small tennis ball are acceptable. The shape must be either evenly

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost (A$)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sales</strong></td>
<td>2,500</td>
<td>10kg</td>
<td>27.00</td>
<td>67,500</td>
</tr>
<tr>
<td><strong>Variable costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cash</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>8hrs</td>
<td></td>
<td>18.48/hr</td>
<td>207.58</td>
</tr>
<tr>
<td>Taro corm</td>
<td>20-25 onion bags</td>
<td></td>
<td>50.00/bag</td>
<td>1,250.00</td>
</tr>
<tr>
<td>Planting labour</td>
<td>32hrs</td>
<td></td>
<td>18.48/hr</td>
<td>591.36</td>
</tr>
<tr>
<td><strong>Fertilisers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural lime</td>
<td>2.5/ha</td>
<td></td>
<td>130/t</td>
<td>325.00</td>
</tr>
<tr>
<td>Fertilisers CK44</td>
<td>24bags</td>
<td>40kg/bag</td>
<td>0.53/kg</td>
<td>508.80</td>
</tr>
<tr>
<td>Spreader machinery cost</td>
<td></td>
<td></td>
<td>3.88</td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>2hrs</td>
<td></td>
<td>18.48/hr</td>
<td>36.96</td>
</tr>
<tr>
<td><strong>Nematode control</strong></td>
<td></td>
<td></td>
<td>85.00</td>
<td></td>
</tr>
<tr>
<td><strong>Weed control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tractor cultivation (6-8x / season)</td>
<td>25hrs</td>
<td></td>
<td>18.48/hr</td>
<td>462.00</td>
</tr>
<tr>
<td>Tractor cultivation machinery cost</td>
<td>6 times</td>
<td></td>
<td>5.50</td>
<td>33.00</td>
</tr>
<tr>
<td>Hand weeding labour</td>
<td>5days</td>
<td>8hrs/day</td>
<td>18.48/hr</td>
<td>739.20</td>
</tr>
<tr>
<td>Pesticides, machinery, labour</td>
<td></td>
<td></td>
<td>48.14</td>
<td></td>
</tr>
<tr>
<td>Irrigation (water pump &amp; maintenance)</td>
<td></td>
<td></td>
<td>219.50</td>
<td></td>
</tr>
<tr>
<td><strong>Harvesting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carton 10kg</td>
<td>2,500</td>
<td></td>
<td>2.00/ctn</td>
<td>5,000.00</td>
</tr>
<tr>
<td>Slashing tops machinery cost</td>
<td>2hrs</td>
<td></td>
<td>10.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Slashing labour cost</td>
<td>2hrs</td>
<td></td>
<td>18.48/hr</td>
<td>36.96</td>
</tr>
<tr>
<td>Per carton cost for all harvesting</td>
<td>2,500</td>
<td></td>
<td>15.00</td>
<td>37,500.00</td>
</tr>
<tr>
<td><strong>Transportation &amp; fees</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freight to Sydney/Melbourne</td>
<td>2,500</td>
<td></td>
<td>1.00/ctn</td>
<td>2,500.00</td>
</tr>
<tr>
<td>Levies</td>
<td>2,500</td>
<td></td>
<td>0.25/ctn</td>
<td>625.00</td>
</tr>
<tr>
<td>Agent commission 10%</td>
<td>2,500</td>
<td></td>
<td>0.10/ctn</td>
<td>250.00</td>
</tr>
<tr>
<td><strong>B. TOTAL VARIABLE COSTS</strong></td>
<td></td>
<td></td>
<td>50,442.38</td>
<td></td>
</tr>
<tr>
<td>GROSS MARGIN (A-B)</td>
<td></td>
<td></td>
<td>17,057.62</td>
<td></td>
</tr>
<tr>
<td>Break even</td>
<td></td>
<td></td>
<td>52.02</td>
<td></td>
</tr>
</tbody>
</table>

1 Phillip Wilk & David Hicks, 2004. Small –Corm Taro growing in New South Wales (Agfact, in press)
round or oval. Mixing of the six grades is unacceptable. No cut surfaces should be present, although a single scar from an adjoining smaller corm is acceptable. Corms should be surface-dried, before marketing in sturdy 10 kg cartons.

Storage of corms is possible at between 7–15°C in a dark well-ventilated room for up to 8 weeks without quality compromise. It is essential that corms be surface dry before storage to reduce the incidence of fungal infection.

Attention must be given to ensure propagation material is retained for the following season. Conditions for storage would be similar and the material should have been semi-washed and cleaned of soil and roots prior to storage.

**Quarantine requirements**

The prospective exporter of sato-imo to Japan is required to provide a phytosanitary certificate for the absence of the nematode *Radopholus similis*.

The volume of waste corms which are unmarketable and surplus to the propagation material requirement must be adequately disposed of.

These corms have the potential to become an invasive weed species. Current disposal methods have been burial, or as cattle stock feed.

Concerns remain over the longer term effects on stock of the calcium oxalate residues in the uncooked corms.

Other investigations are being undertaken for value adding processes to utilise product that does not meet fresh export quality standards.

**Financial information**

The high labour inputs required for postharvest practices determine a high variable cost per hectare. Based on the averages of a minimal machinery and a machinery assisted operation, the gross margin for 1ha of sato-imo is restricted to $17,057.62 for 1,800 cartons sold at a seasonal mean of $27 per 10 kg carton (Table 4). With a greater understanding of the production system, there is scope for improving the efficiencies of postharvest processes and reducing labour inputs through mechanisation and recognised techniques. Further, experimentation has revealed that yields can be increased through adoption of the production requirements.

However, the limited size of the underdeveloped domestic market demonstrated a sensitivity to oversupply in the 2003 season. Initial returns of $35 per carton were reduced to $19 per carton during peak supplies. Confounding the analysis of the market returns was a poor understanding of the quality requirements for this product by a large number of growers.

Export shipments would require a greater return to cover the costs of transport and logistics. A 12 t container trial shipment during 2003 received positive responses on the quality compared with Chinese imports and locally grown product. However, the high cost of airfreight made the product uncompetitive from a price perspective.

Further trial shipments via sea-container during 2004 will be a critical factor to the development of a Sato-imo industry.

Table 4 (on previous page) shows an enterprise budget for 1.0 ha for Sato-imo *Ishikawa-Wase* located in North Coast, NSW, for a period of 7–8 months.

**Key messages**

- Export demand in Japan
- Domestic market development potential

**Key statistics**

- Market volume estimated at 5000–7000 t annually

**References**


Japanese taro

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**Introduction**

Kabocha (*Cucurbita maxima*), and Japanese pumpkin (*Cucurbita moschata*) are members of the cucurbit or pumpkin family. They are small (1.5 to 2.0 kg), generally dark skinned pumpkins with strongly coloured flesh and nutty flavour. Kabocha is grown in Australia for the domestic market, and small amounts are exported fresh (from Tasmania) and processed (from the Australian mainland) to Japan. Within Australia, kabocha is also known as Buttercup Squash, Ebisu, Delica and Early Potkin. In Japan, kabocha is known as Kuri Kabocha, or nutty pumpkin.

Kabocha and Japanese Pumpkin in Australia (Morgan and Midmore 2003) gives a comprehensive summary of current knowledge and reports of varietal trials conducted across Australia from 1998 to 2000. It includes descriptions of varieties, production methods used in those regions where the trials took place and yields of kabocha. It concluded that kabocha can be grown around Australia throughout the year.

**Markets**

Japan is the largest importer of fresh kabocha with 154,183 tonnes imported in 2002 (Figure 1, JETRO 2003). Japan requires kabocha between September and April to supply its off season. 60% of its total kabocha import is supplied from New Zealand (NZ) during this period. Tasmania has exported 1000 tonnes per annum over recent years, which is less...
than 1% of Japan's total kabocha imports. Tasmanian kabocha is exported between March and May. The price is set by kabocha imported from NZ, however quality Tasmanian imports have received higher than average prices. DPIF Tasmania has estimated that exports of 10 000 tonnes are achievable. Other exporting countries include Mexico, Tonga/Fiji and New Caledonia.

Japanese quarantine regulations with regard to fruit fly prevent fresh kabocha being imported from mainland Australia. Frozen pumpkin pieces and purees have been exported from the mainland, and kabocha is currently being processed. Fresh kabocha is also consumed domestically. Average prices for fresh kabocha are $0.40 per kg.

Production requirements

Kabocha has been grown commercially around Kununurra and Carnavon, WA; on the North West coast of Tasmania, north of the Great Dividing Range in Victoria, in various locations in Queensland and in Griffith, NSW. It has been successfully trialled in several other locations. A summary of approximate harvest dates in various locations around Australia is given in Table 1.

Kabocha grows best in mild to warm conditions, with 20 to 30°C days and 15 to 20°C nights. Soil temperature should be greater than 10°C, and frosts cause severe damage. Optimal pH is 6.0 to 6.4, although kabocha will grow between pH 5.5 and 7.2. Kabocha will grow in a range of soils from fine sandy loam to light clay. Irrigation is generally required for growing kabocha. Kabocha requires a 90 to 130 day growing season.

Varieties

Delica and Pacifica are two of the better known hybrids of kabocha. Delica is also known as Ebisu. It is a flat globe shape, deep green in skin colour and with thick yellow flesh.

Tetsukabuto is thought to be an inter-specific cross of \( C. moschata \) and \( C. maxima \). It is darker skinned, nearly round in shape and has darker orange flesh. It yields more highly and also has better quality than the traditional varieties Delica and Pacifica. However, Tetsukabuto needs to be planted near \( C. moschata \) or \( C. maxima \) to set fruit.

Ken's Special is an Australian selection of \( C. moschata \), or Japanese pumpkin, which yields similarly to Delica. Orange skinned kabocha varieties Golden

Table 1. Seasonal harvesting dates for kabocha and Japanese pumpkin production around Australia. From Morgan and Midmore, 2003

<table>
<thead>
<tr>
<th>Location</th>
<th>J</th>
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<td>Tasmania</td>
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<td>North WA</td>
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<td>+</td>
<td>+</td>
<td>+</td>
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<td>+</td>
</tr>
</tbody>
</table>
| South WA          | + | + | + | + | + | + | + | + | + | + |   |+

E: early; M: mid; L: late; +: all varieties.
Debut, Golden Orbit and Uchiki Kuri are also available.

South Pacific Seeds and Yates stock some of the better known varieties. Fairbank’s Selected Seed Co currently stocks Kurijiman and Uchiki Kuri. Tetsukabuto is a release of Takii Seed Company, Japan. Tasmanian production is mainly Delica and Kurijiman, and the seed is imported from Japan.

Agronomy

Requirements are similar, but not identical to pumpkins traditionally grown in Australia. Seeds germinate within 5 to 7 days, and can be transplanted at the first true leaf stage 6 to 14 days after emergence. Direct seeding is preferable if conditions are suitable. Irrigation is required if rainfall is inadequate. Drip tape is preferred as kabocha is sensitive to powdery and downy mildew, which thrive in humid conditions. Generally, raised beds with black plastic mulch and drip tape are used for production.

Crop densities of approximately 1.1 plants/m² have been reported to give greatest yields of marketable sized fruit. This is equivalent to 1.5 to 1.8 m spacing between rows and 0.3 to 0.8 m between rows. At higher densities, total yields increase mainly due to a larger number of smaller fruit. High levels of nitrogen are required early for plant growth, up to 180 kg N/ha. High calcium is applied later in the crop growth to improve fruit quality. Actual requirements will depend on the soil type and history.

Average marketable yields have been estimated at 15 to 22 t/ha, but yields from 10 to 50 t/ha have been reported. Yields vary greatly between varieties. Minimum weight of kabocha for processing is 0.5 kg and fruit must be sound. Skin blemishes and sunburn can result in up to 30% of the harvested crop to be rejected for fresh export. Sunburn was a problem for fruit harvested late summer in south Queensland, and it can also result when the canopy is destroyed by disease.

Harvest and postharvest

More than one harvest is usually required commercially. Fruit are mature when the stem dries and splits. Skin hardness and growing degree days can also be used as indicators of maturity. The stem should be carefully cut to minimise damage and access by stem rots. Good quality kabocha has dark skin of an even colour, with little evidence of the earth mark. This is the pale area where the fruit sits on the ground. Skin blemishes such as warts also detract from kabocha 'Delica' (Photo: Murat Top)
Kabocha should be stored between 10 and 15°C at low humidity and with adequate ventilation. Chilling injury will occur if the fruit are stored at less than 10°C for a few days.

Kabocha harvested from warm climates such as Queensland are more susceptible to chilling injury than those grown in Tasmania. Kabocha should keep between 3 and 4, and sometimes up to 6 months. Postharvest rots are predominantly caused by *Fusarium* spp. Curing at 30°C and high humidity for 2 to 3 days before storage reduces rots.

Washing fruits in sodium hypochlorite reduces incidence of rots, as does careful handling to minimise wounding. Sunburn has also been correlated with increased rots.

Processed kabocha is cut into small pieces of varying sizes, with or without the skin and frozen. The processed flesh can also be sold as a paste or puree.

### Financial information

Establishment costs for kabocha include tractors with appropriate soil preparation equipment, bed formers, irrigation and spray equipment.

Depending on the market being used, curing equipment may be required.

Production costs include fertiliser and irrigation costs, and pest and disease control plus the labour required to carry out these activities.

Estimates of yield at 15 t/ha and price $400/t put gross sales at $6,000/ha (Hassall and Associates 2003).

Gross margins calculated in 1998 have been reported for Tasmania at 15 t/ha yield; they were $1,351/ha at $250/t, and $2,101/ha at $300/t (in Morgan and Midmore, 2003).

More recent figures are not available. It is prudent to establish markets and potential prices at the time of harvest for the desired location before planting.

### Key references


### Key messages

- Kabocha can be grown around Australia
- New varieties have higher yields
- Tasmania exports fresh kabocha to Japan

### Key statistics

- Japan imports 140,000 t of fresh kabocha yearly
- Average yields are 15 to 22 t/ha
- Australian domestic price for fresh kabocha is 40c/kg
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About the author

Melinda Gosbee (B. Sc. (Agr.), PhD) worked as Senior Horticulturist with the Northern Territory Department of Business, Industry and Resource Development. She worked with the Asian vegetable growers around Darwin and studied postharvest problems of Asian vegetables and other produce.
Lotus

Vong Q. Nguyen and David J. Hicks

Introduction

Lotus (Nelumbo nucifera GAERTN.; Nelumbium speciosum Willd.), also called Sacred Lotus and/or Indian Lotus, originates in Asia, Persia, India to China and in North Eastern areas of Australia.

Lotus is one of the oldest plants in the world. Archaeologists in China found seeds of the Lotus with estimated ages of 7,000 years. Seeds, 1288±271 years-old found in China have been germinated, one of the oldest demonstrably viable and directly dated seed germinations recorded.

Culturally, lotus is a potent symbol of fertility, religious significance, holiness and even immortality in different cultures. Oriental medicine also has a marvellous range of uses for lotus and no part of the plant is neglected.

Lotus is a perennial aquatic crop that is grown and consumed throughout Asia. The young flower stalks, seeds and rhizomes are all edible. The flower is used in religious ceremonies and the flower receptacles (pods) are used for ornamental purposes. However, the largest market exists for rhizomes which are a vegetable with enormous potential for a large-scale production in Australian horticulture to supply domestic and overseas markets. Lotus rhizomes form from the terminal roots of the lotus root system. One rhizome carries usually three “sausages” and is creamy-white in colour.

Lotus is cultivated in many countries in the world, especially in Asia, such as India, China, Japan, Korea, South-East Asia, Russia and some countries in Africa. Lotus grown in Europe and America is mainly for ornamental purposes, rarely for foods.
In China, the growing area of lotus is estimated at more than 133,400 hectares with an average yield of 22.5 t/ha. China has a capacity to produce up to 3 million tonnes of lotus rhizomes per annum. In Japan, lotus is grown throughout the country mostly for ornamental purposes, particularly in the Buddhist temples and/or national parks.

Production of lotus rhizomes is however concentrated in few prefectures on the Central and Southern parts of Japan such as Ibaragi, Tokushima, Aichi, Saga, Yamaguchi, Niigata and Okayama. In 1985 Japan produced 73,800 t lotus rhizome on an area of 6,090 ha but reduced to 56,900 t on 4,490 ha in 2002 (Table 1).

Lotus is currently an infant industry in Australia. The industry needs to put more effort into research on variety, growing techniques, post-harvest storage and handling and market development.

The Australian lotus industry can penetrate into overseas markets, particularly Japanese, if we can open up a trading system directly with supermarket chains.

A case study of lotus rhizomes in the Asian market including Taiwan and Japan, has shown that the Japanese market appears to be more favourable for Australian lotus during June, July and August, which coincides with the lotus rhizome harvest period in Australia. If Australia could provide just 1% of the Japanese wholesale market, we would earn A$8 million for our horticultural industry.

A research project on lotus has been implemented at the New South Wales Agriculture’s Gosford Horticultural Institute, in cooperation with the University of Western Sydney, Hawkesbury to research and develop this new crop for Australia domestic and export markets.

Growers intending to access Japanese markets will be required to provide a phytosanitary certificate for the nematode Radopholus similis.

**Markets and marketing issues**

From 1995, Japan imported, 1,347 t fresh and 14,887 t salted Lotus rhizomes for the first time, mainly from China.

In 2002, Japan imported only 11,504 t salted lotus rhizomes from China, worth 739 million Yen (A$10 million). There was however, no importation of fresh lotus rhizomes both in 2001 and 2002.

Production of lotus in Taiwan has declined over seven years to about 550 t in 1993. This may reflect the arduous nature of competition with China in Japanese markets where almost all Taiwanese lotus is destined. South Korea produced 9,261 t of lotus rhizomes on 291 ha in 1995. It is the fourth largest crop area in this country.

Lotus rhizome is a new crop to Australia. It is estimated that domestic demand for lotus rhizomes is approximately 1,000 t annually and valued at approximately A$6 million. At present, Australia is able to provide only 100 t in the fresh form, the rest being imported mainly in frozen and dried forms. Requirements for flowers and pods are unknown, but thought to be potentially high.

Of the several countries in Asia where lotus is cultivated and consumed, the Japanese market offers the best opportunities for the Australian lotus industry. Japan has a market of approximately 70,000 t of lotus rhizomes annually, valued at approximately A$800 million. Domestic production in Japan is still falling due to increased pressure on agricultural land, which has resulted in importation of up to 18,000 t of lotus rhizomes valued at more than A$18 million in the mid ‘90s. In 2002, although production was only 56,900 t, no fresh lotus was imported and Japan was forced to reduce its importation of salted lotus from China because of a problem with chemical residues (Marubeni, pers. comm.) (Table 1).
Table 1. Production and importation of lotus in Japan, 1985-2002

<table>
<thead>
<tr>
<th>Year</th>
<th>Production</th>
<th>Importation</th>
<th>CIF Prices (Fresh) 2,3, Yen/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area, ha</td>
<td>Volume, ton</td>
<td>Fresh, ton</td>
</tr>
<tr>
<td>1985</td>
<td>6,090</td>
<td>73,800</td>
<td>1,347</td>
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<tr>
<td>1995</td>
<td>5,360</td>
<td>65,100</td>
<td>2,007</td>
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<tr>
<td>1997</td>
<td>4,920</td>
<td>53,300</td>
<td>2,007</td>
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<tr>
<td>1999</td>
<td>4,790</td>
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<tr>
<td>2000</td>
<td>4,660</td>
<td>58,900</td>
<td>1,425</td>
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<tr>
<td>2001</td>
<td>4,560</td>
<td>58,800</td>
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<tr>
<td>2002</td>
<td>4,490</td>
<td>56,900</td>
<td>nil</td>
</tr>
</tbody>
</table>

2) Shokuhin Seisan Yunyu Shohi, 2002.  
3) Yasai Yunyu no Doko, 2002.  
4) Prices (CIF) for Salted lotus.

Production requirements

A high degree of dedication from the grower, and commitment of utilised resources make lotus a relatively difficult crop to grow. Growing lotus should be thought of as a system. This includes positioning of ponds in relation to water storage, movement and recycling. Determination of harvest method and soil type in use prior to any pond design would also be an advantage. Considerable capital investment is essential for the construction of ponds. Potential growers should consult an earth working organisation and the incumbent local council before any commitment is arranged.

The site for ponds needs to be relatively flat, expansive, and close to a reliable source of large volumes of fresh water. Farm dams are not suited to lotus production, though can be utilised as a water reservoir for production pond requirements.

Lotus requires a warm temperate to sub-tropical environment with average day time temperatures of 20-30°C. However, a temperate climate produces better quality rhizomes than a tropical climate (Marubeni, pers. comm.). A high incidence of solar radiation providing intense sunlight and long day hours are needed for successful growth. Protection from wind is recommended. Appropriate soil can be transported into the ponds if the on-site soil is unsuitable. Optimal soil is a soft silty loam, free from particulate matter. Attention to soil will assist in harvesting ease. Lotus is highly frost resistant.

Varieties/cultivars

There are many lotus varieties available in the world but they have been classified into three categories according to use, namely flowers, fruits (seeds) and rhizomes. They are different in flower colour, starch content and growing water levels. Some varieties may exhibit one or more of the three characteristics but generally each is classified by the strongest feature. Often, rhizome varieties will have relatively few flowers, which are generally white, and flowering and seed types have no appreciable rhizome, if at all. Many tropical varieties do not form a significant rhizome due to the absence of a cold period in which the plant must produce a storage organ for survival. In China, at the Wuhan Institute of Botany alone, 124 lotus cultivars are available for research. Cultivars currently grown in Australia and distributed through domestic markets include Quangdong, Brisbane, Vietnam Red, Paradise and Green Jade. Of these, only Quangdong is moderately acceptable for rhizome production, the other four being better suited to flower production.

Cultural practices/agronomy

Lotus is grown in specialised shallow ponds with a soil depth of 1m and surface water of 10-20cm. The size or number of ponds will depend upon amount of available water and land in the grower’s operation. Planting is conducted in September to October by using seed or rhizomes. The propagation by seed is unusual since seeds are highly heterozygous and the progeny may not be true to the original variety. If propagating by seed, the best and most simple method is to make a small hole on the seed skin and soak in water at 25°C, with 12 hours light. Change the water daily until the seed germinates 5-8 days later. Transplanting occurs...
6-8 weeks from sowing when the seedlings have 2-3 leaves and a few roots. If propagation is by rhizome, there needs to be care about the rhizome sections with at least 2-3 intact nodes. The section is planted on a 15° angle to horizontal and spaced 1.5-2 m apart within 2.5-3 m spaced rows. The direction of the growing tip should be along the longer axis within the row. The water level during planting should be 5 cm and increased with leaf emergence and rising temperatures.

Fertiliser requirements are high. Nitrogen (N) at a rate of 300 kg/ha, phosphorous (P) at 80 kg/ha and potassium (K) at 350 kg/ha is applied as split applications. The total amount of P is incorporated into the dry pond, with half the N and K, prior to planting. The additional side dressings, applied at 2, 4, and 6 months after planting, will have a high to low concentration gradient for N and low to high for K. Fertiliser should be of technical grade to assist in solubility. The E.C. can range from 2.5-3.2 µS/cm as the plants develop, pH is optimal between 5.8-6.5 though higher and lower pH is tolerated.

Weed control is difficult within the closed pond system, treatments to weeds will often affect the crop plants. Most weed control will require physical removal, this should be practiced prior to planting, especially for soil rooted aquatic weeds. Floating weeds should only be a problem during the initial month of growth before a canopy of lotus leaves is achieved. Salvinia (Salvinia molesta) and alligator weed (Alternanthera philoxeroides) infestations should be removed immediately. Some weeds, such as the Azolla sp. are not considered a weed in parts of Asia. The fern fixes nitrogen, which is passed onto the plant when the fern dies, and it has a thermoregulating effect on pond water temperature by creating a blanket across the pond surface. Fertiliser requirements may have to be adjusted to compensate for the load of any weeds present.

Diseases of lotus are few. Leaf spotting organisms have been identified as powdery mildew (Erysiphe polygoni), Cercospora sp., and Ovularia sp. Control is achieved using copper based fungicides. Lotus streak virus produces streaks on roots and chlorotic ringspots on leaves and requires removal of infected plants. Rhizome specific diseases are caused by Fusarium oxysporum ssp. nelumbicola and Pythium elongatum. Correct water management by adjusting water levels should help to control Fusarium, the disease incidence is attributed to high temperatures and low rainfall. An infected pond should be rotated in the following season.

Pest and disease control

Lotus is host to a number of minor pests, most of which do not occur in Australia. The most important pest is Heliothis sp. caterpillars which skeletonise leaves. Aphids, two-spotted mites and mealy bugs will also be a minor pest on under-canopy emerging leaves. Control recommendations can only be cultural and biological until registration of appropriate control measures is established.
Harvesting and packaging

Harvest is performed 7-9 months after planting, during winter months, after leaves have died off. Rhizomes are removed from the soil by either drying the pond and using a backhoe with a modified fork appendage, or manual removal assisted by recirculating pond water with a high pressure portable pump/canon. The first method is quick but with high waste and quality compromises. The second is labour intensive, performed in cold ponds and requires a soft enough soil to be conducive. The quality of the second and third methods is very high and waste is low. Yields are expected to be in the range of 8-12 t/ha and will be dependent upon variety, location and cultivation practices.

Lotus requires laborious preparation prior to marketing conducted within a shed set-up for this purpose. Rhizomes should be even in size and colour (unblemished cream) with a distinct constriction between rhizome flesh and internode. Select rhizomes are cut to length on the 4th segment of a rhizome chain. Optimum segment sizes are between 15-20 cm long and 5-8 cm in diameter. Side shoots, petiole remains and ‘daughter’ rhizomes should be removed. The chain is then washed with detergent to remove soil residues prior to removal of roots and side meristem buds followed by another rinsing wash. Rhizomes should be surface dried before grading according to size, and storage at temperatures between 3-7°C or marketing in 5 or 10kg styrofoam boxes.

A cool-storage area proportionally sized to the operation scale is essential.

Postharvest losses are high due to rhizome sensitivity to damage. Discolouration is immediate upon physical damage and the probability of disease infestation to damaged tissue is increased. Postharvest diseases include grey mould, Anthracnose and black spot caused by the fungal organisms Botrytis cinerea, Colletotrichum sp and the bacteria Pseudomonas sp. There are no known control measures for these diseases on this crop other than prevention.

Financial information

Working in field trials at Gosford Horticultural Institute and, in discussions with Tai-Cheung Agricultural Development Pty. Ltd., it is understood that high gross margins for Australian lotus rhizomes, estimated at A$2.76/kg (Table 2), would never be competitive with China, whose CIF prices have only ever achieved 30-35% of the Japanese wholesale market prices (Table 1). The possibility of exporting Australian lotus to Japan remains to be seen. There could be interest from Japan because of low chemical residues if Australian lotus are sold at a lower acceptable price.

Table 2 shows an enterprise budget for 1.0 ha for lotus rhizome located in Gosford, NSW, for a period of 9-10 months.

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<th>Item</th>
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<th>Unit</th>
<th>Cost (A$)</th>
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<td>40,000</td>
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<tr>
<td>Less commission</td>
<td>12%</td>
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<td></td>
<td>4,800</td>
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<tr>
<td><strong>A. TOTAL INCOME</strong></td>
<td></td>
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<td><strong>35,200</strong></td>
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<tr>
<td><strong>Variable costs</strong></td>
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<td></td>
</tr>
<tr>
<td>Cash</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Certified rhizomes</td>
<td>650kg a)</td>
<td>6kg</td>
<td>3,900.00</td>
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<tr>
<td>Compost</td>
<td>10t</td>
<td></td>
<td>$200/t</td>
<td>2,000.00</td>
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<tr>
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<td>15m3 a)</td>
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<td>$55/m3</td>
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<tr>
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<td>$376.85/t</td>
<td>753.70</td>
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<td>Pesticides</td>
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<tr>
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<td>$50/hr</td>
<td>500.00</td>
</tr>
<tr>
<td>Contract harvest (hand pick)</td>
<td></td>
<td></td>
<td>$20/15kg</td>
<td>13,333.33</td>
</tr>
<tr>
<td>Carton</td>
<td>666</td>
<td></td>
<td>$1/ctn</td>
<td>666.00</td>
</tr>
<tr>
<td>Water</td>
<td>1500kl a)</td>
<td></td>
<td>$0.3/litre</td>
<td>450.00</td>
</tr>
<tr>
<td>Cash (sub total)</td>
<td></td>
<td></td>
<td></td>
<td>22,628.03</td>
</tr>
<tr>
<td>Non Cash</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Family labour</td>
<td>50 days</td>
<td></td>
<td>$100/day</td>
<td>5,000.00</td>
</tr>
<tr>
<td>Non cash (sub total)</td>
<td></td>
<td></td>
<td></td>
<td>5,000.00</td>
</tr>
<tr>
<td><strong>B. TOTAL VARIABLE COSTS</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>27,628.03</strong> a)</td>
</tr>
<tr>
<td>GROSS MARGIN (A-B)</td>
<td>$/ha</td>
<td></td>
<td></td>
<td>7,571.97</td>
</tr>
<tr>
<td>Break even</td>
<td>$/kg</td>
<td></td>
<td></td>
<td>2.76</td>
</tr>
</tbody>
</table>

a) Less from the 2nd year
a) Family labour not included in gross margin calculation but is important
a) Cost of packaging, transportation and family labour are not included
Lotus

Key messages

- High capital investment and long term commitment required
- Labour intensive
- High returns are possible

Key statistics

- A potential market estimated volume requirement of 2000 t annually
- Japan has a market of 70,000 t/year. It produces about 57,000 t and imports about 13,000 t per annum

References


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About the authors

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Dr David J. Hicks is the Research Officer for NORADA and is employed through NSW Agriculture as a research horticulturist conducting production trials in the Northern Rivers region. He has over 7 years experience in research and extension with Asian roots crops, and is currently completing his PhD in mineral nutrition studies of lotus at the Centre for Horticulture and Plant Sciences, UWS Hawkesbury.
Acknowledgement is given to T. K. Lim, the author of this chapter in the first edition of this publication.

Introduction

Luffas, Asian melons and snake beans are tropical or sub tropical Asian vegetables. The term Asian is used in the sense that they are used widely and traditionally in Asian cuisine. The Asian melons and snake beans are yet to be widely adopted in the diet of Australians of European descent. The melons and snake beans are consumed as immature fruits, either in stir fry, soups or curry. Mature smooth luffa can also be dried and the remaining fibres used as a luffa sponge, however the production of sponges is not discussed here.

There is a lot of variation in the naming of these vegetables, particularly the types of *Benincasa hispida* (Table 1). This is due to different local and cultural names for the vegetables, and the fact that some melons are harvested immature (weight about 1 kg) and mature (about 4 kg).

The words ‘gourd’ and ‘melon’ are used almost interchangeably. It is important to establish the correct identity of the product under discussion, preferably with a picture.

These vegetables are mainly produced in the Northern Territory (NT) during the winter months, and other states in warmer seasons, and are marketed domestically. The luffas, long melon and hairy melon have similar production techniques on trellises, and will generally be discussed together. Snake beans also grow on a trellis; however winter melon is grown on the ground. Bitter melon, the most commonly grown Asian melon, is presented in a separate chapter of this volume.
Table 1. Common names of the luffas, Asian melons and snake beans.
The names used in this chapter are underlined.

<table>
<thead>
<tr>
<th>Common names</th>
<th>Scientific names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinqua, angled luffa/loofah,</td>
<td>Luffa acutangula (L.)</td>
</tr>
<tr>
<td>ridged luffa</td>
<td></td>
</tr>
<tr>
<td>Smooth luffa, loofah, dishcloth</td>
<td>Luffa aegyptiaca (L.) Syn. Luffa cylindrica.</td>
</tr>
<tr>
<td>gourd</td>
<td></td>
</tr>
<tr>
<td>Winter melon, wax melon, dong</td>
<td>Benincasa hispida cv. group Unridged Winter Melon</td>
</tr>
<tr>
<td>gwa, tung gwa</td>
<td></td>
</tr>
<tr>
<td>Hairy melon, fuzzy melon,</td>
<td>Benincasa hispida cv. group Fuzzy Gourd</td>
</tr>
<tr>
<td>winter melon (NT), mo gwa</td>
<td></td>
</tr>
<tr>
<td>Long melon, wax gourd</td>
<td>Benincasa hispida cv. group Wax gourd</td>
</tr>
<tr>
<td>Snake bean, Long bean, Yard</td>
<td>Vigna unguiculata cv. Group Sesquipedalis</td>
</tr>
<tr>
<td>long bean</td>
<td></td>
</tr>
</tbody>
</table>

Markets and marketing issues

Within Australia, most Asian vegetables are sold in Sydney and Melbourne. This is largely due to the greater population of Australians of Asian descent in these cities. Distribution is both within and outside the major produce markets. Domestically, prices of the melons and luffa vary between $1.00 and $3.00/kg, the average being approximately $2.00 (Table 2). Prices are lowest during the winter months when supply from the NT is high. Average snake bean prices are higher at $2.50, and winter melon somewhat lower.

These vegetables are widely consumed and produced by Asian nations. Currently, they are not exported from or imported into Australia. Any product exported from Australia would compete with low prices from locally grown produce, making the available margin for transport costs small. In addition, snake beans are highly perishable, and a tightly controlled cool handling chain would be necessary.

Production requirements

All of these vegetables are sub tropical or tropical in nature, and are sensitive to frost and water logging. The main production area is around Darwin during the dry season, with harvesting from May to October. They are also grown in northern Western Australia, and in the Northern Rivers district of New South Wales from January to April. Some production of snake beans occurs around Sydney, Melbourne and Brisbane over the summer months. Considerable areas of the East and West Coasts with a sub tropical or tropical climate and available water would be suitable for production of these vegetables.

Optimum temperatures for growth of 25 to 27 °C have been recorded. These plants tolerate higher temperatures well, however growth is slowed when temperatures drop below 18 °C. Irrigation during the dry season is essential in the NT. Regular irrigation during dry periods in other climates would likewise be necessary. Snake beans also require warm temperatures above 25 °C for production, and growth slows markedly at temperatures lower than 15°C.

These vegetables can be grown on a wide variety of soil types, however production is better on well-drained soils rich in organic matter. A pH of 6.5 is commonly reported.

Table 2. Northern Territory production of selected Asian vegetables in 2001 and 2002, and price range.

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>2001</th>
<th>2002</th>
<th>Price range ($/kg)</th>
<th>Average ($/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luffa (smooth and angled)</td>
<td>72</td>
<td>130</td>
<td>1.00 – 3.00</td>
<td>1.80</td>
</tr>
<tr>
<td>Winter melon*</td>
<td>0.50 – 2.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long melon</td>
<td>218</td>
<td>435</td>
<td>1.00 – 3.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Hairy melon</td>
<td>125</td>
<td>188</td>
<td>1.00 – 3.00</td>
<td>1.50</td>
</tr>
<tr>
<td>Snake bean</td>
<td>483</td>
<td>1207</td>
<td>2.00 – 4.50</td>
<td>2.50</td>
</tr>
</tbody>
</table>

*The 4 kg winter melon is rarely grown in the NT. Prices vary greatly depending on quality of the product and seasonality of supply. These figures should be taken only as an indication.

**Varieties**

Sinqua is 20 to 50 cm long, and 5 to 8 cm diameter, slightly tapered and dark green. Several ribs or ‘angles’ run the length of the fruit. Smooth luffa has no angles, and a much more fragile skin. It is mid green in colour with longitudinal darker stripes. It is shorter than sinqua with a maximum length of 40 cm. Luffa varieties are different for vegetable or sponge production, it is important that the right one is selected. Luffa varieties imported from Asia may be daylength sensitive. Luffas weigh approximately 0.5 to 1.0 kg.

Hairy melon are cylindrical light green fruit, 20 to 25 cm long and 8 cm wide, and are covered with a layer of fine hairs. Long melon is a similar colour and also finely haired, but is 30 to 40 cm long with a slightly narrowed neck. Its skin is more delicate than hairy melon, and must be grown on a trellis. Long and hairy melon weigh 1 to 1.5 kg. Winter melon, or wax melon, is round to oval shaped, 20 to 30 cm wide and 30 to 40 cm long, green with a whitish waxy bloom. It weighs 4 to 6 kg.

Snake beans look like a slim round bean but are 30 to 40 cm long. A purple tipped variety called Green Pod Kaohsiung has been used in the Darwin area, but other varieties are also grown. Quarantine regulations prevent bean seed being imported into Australia.

It can be difficult to source the seeds of these vegetables from within Australia. Local seed companies may source seed from Asian seed companies on inquiry. Known-You Seed Company, Taiwan and East-West Seed Company, Thailand are two which have seed for these type of vegetables. Market agents may also be able to source the type of seed for the product they require.

**Agronomy**

The luffas, hairy, long melon and snake bean are grown on trellises, which are in turn placed on raised beds or ridges. These can be covered in mulch to improve growth where necessary. Trellises are usually 2 m high, with wires at 50 cm from the ground and then 20 cm intervals, with 100 mm nylon netting. Overhead trellises are commonly used for the melons, particularly sinqua, to prevent wind rub damage to the fruit. These are similar in construction but have additional horizontal spans.

Row spacing is generally between 1.5 to 2.0 m, depending on the row spacing required for machinery access. Sinqua and luffa are planted 0.4 to 0.6 m apart, while hairy melon and long melon are slightly further apart at 0.6 to 0.8 m between plants. Snake beans are planted 0.4 m between plants. Winter melon is grown on the ground, using a raised bed prevents water logging. Spacing is again 1.5 to 2.0 m between rows, and 0.6 to 0.8 m between plants.

Seed can be sown directly into the ground, although transplanting seedlings can be more efficient. Irrigation is necessary.
for all these crops. The use of drip tape, micro sprinklers or drippers under the trellis is more efficient than overhead watering, which may increase fungal disease. Fertiliser application should be determined depending on the soil type and history. Adequate basal fertiliser is essential to establish vigorous vine growth prior to flowering. Nitrogen application is reduced during fruit set to promote flowering and fruit development.

Reported yields of these vegetables vary, and should be interpreted with caution (Table 3). This variation can be due to the stage of harvest, variety, climate and skills of the farmer. It should also be remembered that these crops are generally grown in small areas, less than 0.5 ha, and that this harvest is over several weeks.

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Yield range (t/ha)</th>
<th>Average yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luffa (smooth and angled)</td>
<td>4 to 12</td>
<td>7</td>
</tr>
<tr>
<td>Winter melon</td>
<td>18 to 22</td>
<td>20</td>
</tr>
<tr>
<td>Long or hairy melon</td>
<td>8 to 10</td>
<td>9</td>
</tr>
<tr>
<td>Snake bean</td>
<td>6 to 30</td>
<td>8</td>
</tr>
</tbody>
</table>


**Pest and diseases**

Pests of the melons can include leaf feeding beetles, mites, cucumber moth, Helicoverpa spp., aphids and thrips. However, pest damage to these crops is relatively minor. Fruit fly and whitely can be a problem, and the cucurbits are susceptible to virus, so aphid control is important. Common diseases include powdery mildew and downy mildew.

Nematodes, particularly root knot nematode (*Meloidogyne* spp.) can affect all these crops. Use of an off-season green manure crop, such as sorghum, reduces the population of nematodes in the soil and provides some control. Crop rotation with non-susceptible crops also prevents the build up of nematodes in the soil.

Bean fly is the major pest of snake beans in the NT. Other pests include thrips, caterpillars and mites. Fusarium root rot of snake bean vines is a major disease concern. Control of this disease is through using clean planting material, increasing the organic matter in the soil and preventing spread of the disease through farm hygiene. Snake bean can also be grafted onto a resistant cowpea rootstock. The Department of Business, Industry and Resource Development, NT is currently evaluating snake bean varieties for resistance to Fusarium. Parrots can also be a serious pest of snake beans.

Pesticides are rarely registered specifically for Asian vegetables within Australia, however some off-label permits are available. Check with the local state department of agriculture and primary industry for current permits. Biological and ‘soft’ insecticides such as potassium soap are also available to control some pests.

**Harvesting and storage**

Sinqua and luffa are harvested 9 to 13 weeks after sowing. Winter melons are slow growing and are harvested at a more mature stage 90 to 100 days after sowing. Hairy melon is harvested 3 to 4 weeks after fruit set, which is about 90 to 100 days after sowing. Harvest for snake beans commences at 6 to 8 weeks after sowing. Snake beans are harvested while immature, before the seeds within the pods are fully developed. Beans need to be harvested several times a week, if not daily, over the production period. Depending on the health of the vines, beans can be harvested for up to 8 weeks from first production.

Most of the melons can be stored at 12°C for up to 3 weeks, Sinqua growing on an overhead trellis

Smooth luffa
however sinqua stored at 5°C has been found to have a longer shelf life. Mature winter melon can be stored below 12°C for up to six months. Smooth luffa is quite sensitive to water damage, so care should be taken with washing and drying. The melons are sold in 10 kg cartons with no liners. Sinqua is often packed in a longer carton because of its greater length.

Snake beans need to be cooled rapidly after harvest to 8 to 10°C and stored at this temperature. Packaging to prevent water loss is necessary for beans to remain crisp. Generally, beans are packed in 10 kg cartons with a plastic or perforated plastic liner. Beans will last up to 2.5 weeks when stored at 5 to 10 °C. Snake beans, like all beans, have a very high respiration rate and heat will build up in packaged beans if they are not adequately cooled.

Financial information

The major risks for growing the Asian melons are associated with learning a new crop. Firstly, getting the right seed is vital and can be easily mistaken owing to the confusion with names. Harvesting at the right stage and correct postharvest handling for each type of melon is also critical.

Diseases such as Fusarium can also dramatically reduce yield of snake bean. Marketing any of these products is also an area where inexperienced growers can flounder, so be certain of the market and requirements before planting. Prices can vary greatly within and between seasons depending on supply. Most growers produce several types of vegetables to minimise that risk.

Equipment requirements include land, a tractor and some type of bed former, trellis materials, irrigation and spray equipment, and some sort of cooling and storage facility after harvest. Production costs include fertiliser, pesticides, irrigation and labour for these activities. Harvest and packing costs, including both labour and materials, are also a large proportion of production costs.

References


Key messages

- Establish a market before planting
- Get the right vegetable!
- Cool beans after harvest

Key statistics

- Average yield of luffas: 7 t/ha
- Snake bean average price $2.50/kg
- Long melon and snake beans are produced in greatest quantities
- Supply, and price, varies greatly between seasons

Disclaimer

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Introduction

Taro (Colocasia esculenta L. Schott) belongs to the monocotyledonous family Araceae, which includes the well known ornamental plants Philodendron, Dieffenbachia, Caladium and Anthurium. This taro species has two forms, the 'large corm' taro which is the subject of this chapter and 'small corm' taro (Colocasia esculenta L. Schott var. antiquorum) also known as Japanese taro which is dealt with in another chapter. Large corm taro is characterised by a larger central or main corm and usually 5-10 smaller side cormels or suckers. Small corm taro has a relatively smaller central corm and very numerous (>50) well developed side cormels. Other plants referred to as taro include White Taro (Xanthosoma sp.), Giant Taro (Alocasia sp.) and Giant Swamp Taro (Cyrtosperma sp.).

Taro is an ancient crop grown throughout the humid tropics and parts of the subtropics for its edible corms and leaves (blade and petiole). The corms are usually boiled, steamed or baked but they may also be fried to make
chips – both fries and crisps. The leaves and corms must be cooked properly before consumption otherwise the calcium oxalate present can cause irritation. The same is true for other crop plants such as rhubarb.

Large corm taro has been growing in Australia for about 100 years but it is only in last 10 years or so that a significant industry has emerged which is based mainly on the wet tropical coast of north Queensland. Smaller production areas are located near Darwin, the Atherton Tableland, central and southern Queensland and northern New South Wales. The rise in importance of taro can be partly attributed to the very large increase over the last 20 years or so in the ethnic Asian and Pacific Islander population, who are the main consumers (Table 1). Pioneer taro growers, the Rural Industries Research and Development Corporation, the Queensland Department of Primary Industries and Fisheries and Central Queensland University and have also fostered the development of the taro industry. Recently the favourable nutritional properties of taro have been raising a lot of interest with non-traditional consumers.

Australian production is conservatively estimated at 1,000 t/yr with a wholesale value of about $3.5 million to the 150 or so growers. Thus at yields of 20 t/ha Australian production could be achieved off just 50 ha. A further 3,000 t or so is imported – mostly from Fiji. Small quantities of frozen peeled taro pieces are also imported from several countries including Thailand, Malaysia and Fiji.

Growing taro is currently physically demanding but as mechanisation of cultural and harvesting practices increases, then working with the crop will become more attractive. Because taro is a relatively new crop to Australia, growers need to be innovative to make advances in crop management and to secure a fair remuneration from the supply chain for their efforts. Much is still to be accomplished before taro becomes a mainstream crop.

Australia is fortunate in not having the major pests and diseases which have a severe impact on productivity in many other countries. These include the devastating taro leaf blight (*Phytophthora colocasiae*), taro beetle (*Papuana sp.*) which damages the corm and the virus diseases bobone and alomae. The challenge for Australian producers is to significantly improve their efficiencies of production so that they can be more competitive with imports in the domestic marketplace and increase their prospects for export to New Zealand.

### Marketing issues

The main taro product traded is whole fresh corms. Sale of fresh leaves is of very minor importance currently in Australia. Much of the north Queensland production is marketed in Sydney.

---

**Table 1. Number of migrants from selected Asian/Pacific countries resident in Australia, 30 June 1976 and 30 June 2001.**

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of residents</th>
<th>Weighted increase* 1976-2001 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>June 1976</td>
<td>June 2001</td>
</tr>
<tr>
<td>Vietnam</td>
<td>2500</td>
<td>154831</td>
</tr>
<tr>
<td>Malaysia</td>
<td>19900</td>
<td>78858</td>
</tr>
<tr>
<td>Philippines</td>
<td>5800</td>
<td>103942</td>
</tr>
<tr>
<td>Hong Kong &amp; Macau</td>
<td>8900</td>
<td>67122</td>
</tr>
<tr>
<td>China</td>
<td>20100</td>
<td>142780</td>
</tr>
<tr>
<td>India</td>
<td>39200</td>
<td>95452</td>
</tr>
<tr>
<td>Sri Lanka</td>
<td>15600</td>
<td>53461</td>
</tr>
<tr>
<td>Indonesia</td>
<td>9500</td>
<td>47158</td>
</tr>
<tr>
<td>Fiji</td>
<td>5900</td>
<td>44261</td>
</tr>
<tr>
<td>Singapore</td>
<td>9100</td>
<td>33485</td>
</tr>
<tr>
<td>Papua New Guinea</td>
<td>15400</td>
<td>23616</td>
</tr>
<tr>
<td>Other Pacific Islands</td>
<td>4700</td>
<td>30744</td>
</tr>
<tr>
<td>Cambodia</td>
<td>500</td>
<td>22979</td>
</tr>
<tr>
<td>Thailand</td>
<td>Not determined</td>
<td>23600</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>157100</td>
<td>922289</td>
</tr>
</tbody>
</table>

| % of Australian Population | 1.1 | 4.9 |

Source: Australian Bureau of Statistics

* Increase 1976 – 2001 as % of overall increase for the selected countries
** 1976 value taken as zero for computational purposes
and Melbourne with some being shipped as far away as Perth. The volume that goes through the Brisbane wholesale market is quite small due to the existence of taro locally grown by Vietnamese and Pacific Islanders in backyards in the Brisbane region. This taro is sold directly to both the public and to Asian retail outlets.

Currently there are three main exporters of taro from Fiji to Australia. Each sends one shipping container every two weeks. These exporters have their own supply chain to distribute the taro which bypasses the central markets. Some smaller exporters send taro whenever it is available but they do not have an efficient distribution network with a considerable amount finding its way to the central markets where it creates havoc with sales of domestic product.

We believe that the future is positive for taro in Australia. However, much will depend upon putting in place a strong supply chain and a sound marketing strategy. Taro is consumed as a staple starchy food by the Asian and Pacific Islander ethnic communities in Australia. Thus consistent year-round supply is desirable – not just when it is easiest to grow (over the wet season). Merchants in the central markets have indicated that they could sell a great deal more taro (3-4 times has been quoted) if growers could deliver consistent supply (volume) and consistent quality (grade standards). Thus coordination of supply of product to the marketplace would appear to be crucial to achieve significant increases in sales. In particular, the Australian industry must ensure that they do not oversupply the market from April-July when imports from the Pacific Islands are greatest. Profits are not necessarily just made by getting high yields relative to inputs but by matching good yields with good market prices.

It is interesting to note that in the Pacific, the Australian market is not seen to be assured in the long term. Indeed Australia is seen as a potential future rival in the New Zealand market which currently takes about 6,000 t/yr. Under the existing circumstances, costs of production in Australia are still too high compared to Fiji but an event such as an outbreak of taro leaf blight in Fiji and enhanced industry mechanisation in Australia could tip the balance.

About 400 million people around the world include taro in their diet and in much of the Pacific, West Africa and the Caribbean it is a staple food crop (Table 2). However, in Australia most of the consumption is by Asian and Pacific Islander communities which represent less than 7% of the population. Thus per capita consumption is only 0.2 kg/yr compared with about 60 kg for potato (Solanum tuberosum). One key to an expanding Australian industry is to increase consumption by the remainder of the population. Capturing these new markets will partly involve the interaction of producers and researchers with hotels and restaurants to promote and create awareness with the public. Special features of taro that could be exploited are:

- taro chips (fries and crisps) are better for you than potato chips because taro absorbs a great deal less cooking oil during the frying process
- taro has a low glycemic index (GI factor) i.e. it provides slow sustained release of energy to the body. Thus it is a desirable food in the treatment and prevention of the blood sugar disorders diabetes and hypoglycemia which are rampant in the western world
- most importantly it is very delicious when properly prepared.

Taro is a major staple food crop in much of the Pacific. Both corms on the left and young leaf on the right are consumed.
Table 2. Proportion of world production of 9 million t of taro among regions and countries and consumption statistics 2001.

<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>% total world production</th>
<th>Taro consumption (kg/person/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>Nigeria</td>
<td>43.6</td>
<td>33.4</td>
</tr>
<tr>
<td></td>
<td>Ghana</td>
<td>18.8</td>
<td>85.5</td>
</tr>
<tr>
<td></td>
<td>Cote d’Ivoire</td>
<td>4.1</td>
<td>22.6</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>Asia</td>
<td>China</td>
<td>17.2</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>2.4</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Oceania</td>
<td>Papua New Guinea</td>
<td>1.9</td>
<td>35.0</td>
</tr>
<tr>
<td></td>
<td>Fiji Islands</td>
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Source: FAO

Wholesale prices received for Australian taro in the central markets range from $2-$6/kg but are generally $3-$4 – the price received being largely governed by supply. Imported fresh taro usually retails from $4-$6/kg. It is interesting to note that when the wholesale price falls below about $2/kg virtually any amount of taro can be sold. Thus consumption could be greatly increased without substantial damage to grower returns if lower cost efficient production could be implemented.

**Production requirements**

Taro can be grown over a range of climatic conditions but is best adapted to a warm humid environment. Cooler temperatures, water stress and overcast conditions will lead to delays in the crop reaching maturity. Best growth occurs at daily maximum temperatures of 25-35°C. It can be grown in subtropical environments with average temperatures of 20°C, but must be frost-free during the growing cycle. Excessive wind can cause damage to the large leaves. Highest yields for taro are obtained under full intensity sunlight but taro is more shade tolerant than most other crops. Taro can be grown on a wide range of soils but best results are obtained on deep, well-drained friable loams with pH 5.5-6.5. Soils with high water holding capacity are advantageous during dry weather. Taro is a water loving plant and is very sensitive to water stress which causes drastic effects on yield. Irrigation is essential for high yields of quality corms. Taro can withstand prolonged waterlogging and in certain parts of the world some varieties are actually grown like paddy rice.

**Varieties**

The main variety grown in Australia is Bun Long. This variety is a soft cooking type which is favoured and mostly consumed by the ethnic Asian community. Smaller quantities are also produced of 'Pacific' taros such as Pink Samoan and Taro Niue (Tausala ni Samoa) which retain a firmer texture after cooking and are preferred by Pacific Islanders. Imports to Australia are mostly firm textured varieties and largely Pink Samoan and Taro Niue. There are no fresh corm imports of Bun Long. Fresh ‘Pacific’ Taro grown in north Queensland is superior in quality to imported taro from Fiji because:

- it is fresher
- it does not require fumigation
- it is carefully handled to minimise mechanical damage.

Thus if ‘Pacific’ taro could be produced at a competitive price then an Australian market three times greater than for Bun Long would open up to producers.

There are several thousand varieties of taro existing around the world and each country has its favoured varieties. Thus there

Dirt and roots are removed from individual corms prior to packing.
are opportunities to further develop niche markets. The best varieties for expanding the non-ethnic market in Australia may not necessarily be the main ones currently grown. Producers must also realise that each variety will have its own particular set of advantages and disadvantages e.g. Taro Niue is more tolerant of dry conditions and suffers less damage from rats compared to Bun Long but the crop cycle is longer and yields are lower. The calcium oxalate content also varies with different varieties.

Commercially produced varieties in Australia have been demonstrated to be susceptible to taro leaf blight overseas, so it would be advisable to begin a program of importation of taro leaf blight resistant germplasm to examine agronomic characteristics and potential marketability. A genepool reserve of resistant varieties in the possession of growers will prevent the overnight collapse of the industry and long lead-time to re-establish should the disease enter and become rampant.

Taro farms have abundant quantities of planting material. Contact Taro Growers Australia (07 40672078) for potential suppliers.

### Agronomy

Taro is grown as an ‘upland’ crop in Australia, not as a paddy crop. Land preparation usually consists of weed removal and cultivation to obtain a friable soil texture with deep ripping usually beneficial. Mounding of rows is recommended on the wet tropical coast. In tropical locations field planting can occur at any time of the year so long as the ground is dry enough for land preparation.

Provided there is an ample supply of irrigation, production and harvest can be scheduled for most of the year. However, on the wet tropical coast plantings are mostly made prior to the wet season which extends from January to June so that the crop is largely rainfed. The crop duration in north Queensland is from 7-12 months depending upon time of planting and variety grown. Subtropical regions must grow the crop over the warmer part of the year, usually establishing plantings in early spring and harvesting in the autumn and winter months.

Taro is propagated vegetatively by sets which consist of the lower 30-40 cm of the leaf stalks together with the top 1-3 cm of the corm. Suckers (side cormels) including their attached undeveloped corm may also be used as planting material. However, larger sets give higher yields. Plantings are often made by hand in planting holes 10-15 cm deep but mechanical planting or at least opening furrows with a tractor greatly speeds up the planting operation. The corn that will eventually be harvested grows upward from the corn portion of the planting piece. If plantings are too shallow this will result in corms developing above the ground surface which are more likely to be damaged by insect pests and rodents. This can be partly overcome by hilling up the rows as part of the weed control strategy.

Planting densities are from 12,000 to 25,000 plants/ha either arranged in single or double rows (e.g. 1.5 m x 0.6 m in single rows → 12,000 plants/ha and 1.5 m x 0.50 m x 0.50 m in double rows → 25,000 plants/ha). Irrigation is essential for optimum yields and is usually delivered by solid set sprinklers above the crop or by drip irrigation.
Fertiliser requirement will depend upon the particular soil conditions. Soil testing prior to planting is recommended to reduce some of the guesswork of rates of fertiliser to apply. Likewise plant analysis of leaf tissue comparing levels to tentative optimal levels will help fine-tune fertiliser requirements. The usual experience is that taro responds to regular applications of nitrogen and potassium fertiliser. Sugar mill byproducts such as mill mud are useful sources of nutrients for the taro crop. Mill mud should be incorporated well prior to planting at rates from 15 to 40 t/ha. Otherwise a basal dressing of a balanced fertiliser should be incorporated in the bottom of the planting furrow. Cover crops of forage sorghum grown during the fallow period and then incorporated before planting have been very beneficial to growth of taro crops. As well as contributing organic matter to the soil they can also help break some pest, disease and weed cycles.

Weeds can take over and substantially reduce yields if not controlled during early crop development. Ensuring strong healthy growth of the taro plants to improve competitiveness is a key. Weeds are generally not a problem once the taro’s leaf canopy has closed. Weeds are usually controlled by cultivation, mulch, mowing/slashing or combinations of these. Some herbicides are used but the crop is very sensitive to several herbicides. Weeds may re-establish in a mature crop but this is not really an issue if hand-harvesting. However, weeds must be controlled during this latter stage if the crop is to be mechanically harvested or ratooned.

Taro is most commonly produced as a single plant crop but it may also be ratooned for a second crop. Such ratoons have lower costs of production compared to the first crop but management, particularly weed control, crop nutrition and plant density must be just right. However, the size of ratoon corms is seldom as large as the plant crop. Also if a ratoon crop is desired, mechanical harvest will not be possible in the plant crop.

Pesticide control
Taro is a crop with generally few pest and disease problems in Australia. This makes it one of the easiest crops to grow organically. However, because taro is only a niche market there is no particular consumer demand for taro grown organically. Nevertheless as the non-ethnic market grows this may be a useful marketing angle.

Various species of rats cause the most damage in taro crops by feeding on the corms. This can lead to downgrading of a large percentage of corms because rather than eating the whole corm they nibble on many. Rats are best controlled by good farm hygiene as well as controlling surrounding vegetation and weeds to reduce their other food sources and shelter. Strategic baiting and trapping is also practised. Feral pigs and wallabies can also cause significant plant damage if not controlled.

Outbreaks of cluster caterpillar (Spodoptera litura) and hawk moth larvae (Spingidae) are common but they are readily controlled with the use of sprays such as Dipel® (Bacillus thuringiensis). Various grasshoppers and cane grubs cause damage to leaves and corms respectively from time to time.

Taro also suffers at times from bacterial corm rots. There is still much to be learnt on this subject but it appears that crop stress such as foliar damage and leaving the crop in the ground for too long once maturity has been reached tends to increase the problems experienced. The virus, dasheen mosaic virus is present in plantings but it is not known just what impact it has on yield.

A particular concern to the industry is the threat of taro leaf
blight, taro beetle and exotic virus diseases entering Australia via illegal imports of taro planting material and via insufficient enforcement of AQIS guidelines for the import of taro corms for sale/consumption in Australia. There is evidence of shipments being contaminated with soil and the corms having viable ‘eyes’ that can be propagated from. By comparison no imports of new varieties via quarantine have been permitted in recent years because of the possible incursion of exotic virus diseases.

Harvesting and postharvest handling

The crop is mature for harvest when the leaves become smaller, the leaf stalks shorten and the main harvestable corm pushes out above the soil surface and is about half exposed. If the crop is left in the ground too long after this stage the eating quality of the corms can deteriorate and as mentioned there is more likelihood of rots occurring.

Harvesting is a very laborious task with mature corms usually pulled out by hand. Some mechanical harvesters have been developed but these are not yet in common use. The corms are then transported to the packing shed where the tops are trimmed and roots and dirt removed from the corm. Corms are usually graded according to size or weight. Taro Growers Australia has recently prepared a set of grading and packing standards. Corm weight of 1-2 kg is preferred for Bun Long. ‘Pacific’ taros are best in the 1.5-2.5 kg range. Corms are then packed into fibreboard cartons holding 15-20 kg, palletised and freighted by road or rail to the capital cities which can take 2-3 days from north Queensland. Harvested corms should not be stored for lengthy periods at ambient temperatures as deterioration occurs. Cool storage can be used to extend storage life.

Crop yields are extremely variable with the full yield potential seldom reached which is partly due to grower inexperience. Yields >50 t/ha have been reported from Hawaii but in north Queensland yields are more usually 15-25 t/ha.

A taro chip (crisp) factory is about to be established at Babinda, north Queensland. Projected product sales from this venture forecast a need for about 100 t/yr of fresh corms of Bun Long by the fourth year of operation which is 10% of current Australian production.

Tender young taro leaves are usually prepared for market by packing in low density polyethylene bags. They can then be stored at 10°C for up to two weeks without discolouration and major weight loss.

Financial information

Taro is a relatively new crop to Australia hence there is limited market, production and economic information available. Growers of taro usually have plantings of between 0.5 and 2.5 ha. Also taro is usually grown in conjunction with other crops to spread risk. Taro is a good complementary crop for an orchard which can ensure positive cash flow between fruit harvests.

The costs of producing and marketing an average yield of 20 t/ha are $40,000 with labour costs comprising 50% of the costs while gross incomes amount to approximately $70,000/ha.

Key references

CTAHRR (1997) Taro – Mauka to Makai. College of Tropical Agriculture & Human Resources University of Hawaii at Manoa


Key messages

• Main market – Asian and Pacific Islander communities
• Easy to grow organically
• Very labour intensive crop
• Irrigation essential
• Improved competitiveness by enhancing production efficiencies
• Market growth via consistent quality, supply and promotion

Key statistics

• Australian production 1,000 t/yr
• Imports 3,000 t/yr
• Exports nil

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Philippe Petiniaud
was a key player in the formation of the grower association – Taro Growers Australia and has been the association president in the three years since its inception. Philippe, as director of NQ Taro Growers Proprietary Ltd., is currently developing a taro chip factory at Babinda. He has been growing taro organically for six years on his property at East Russell near Babinda, north Queensland.

Peter Salleras
has been growing taro for 20 years along with a range of tropical fruits on his property at East Feluga, near Mission Beach, north Queensland. Peter is also vice-president of the FNQ Rambutan Marketing Group.
Acknowledgement is given to Melanie Barber and Michele Buntain, the authors of this chapter in the first edition of this publication.

**Introduction**

Wasabi (*Wasabia japonica* Matsumara) is a perennial herb belonging to the Brassica family, which includes broccoli, cabbage and mustards. The plant grows naturally alongside mountain streams in the highlands of Japan.

Wasabi paste is prepared by grating the fresh stem of the wasabi plant, to form a hot, spicy green condiment served with traditional Japanese dishes such as sushi, sashimi and soba noodles. Ready-to-use wasabi pastes are also popular and dried powder is used to flavour foods ranging from rice crackers to ice cream.

Wasabi is in short supply in Japan due to a decline in traditional farm labour, urban encroachment on production sites and pollution of some rivers and streams. Wasabi is becoming increasingly popular in many other countries with the inclusion of Asian food in cultures formally dominated by European cuisine.

Wasabi is grown commercially in gravel beds filled with fast-flowing water or in soil, in a manner similar to other Brassica crops. The requirement for shade and cool growing conditions determines the suitability of a site for wasabi production.

The major advantage of producing wasabi in Australia is the ability to supply product year round. Mild summer and winter temperatures...
in the cool temperate zones of Tasmania and southern Victoria mean that there is no constraint to production caused by extreme temperatures.

**Markets and marketing issues**

In Australia, there is potential not only to supplement the demand for wasabi in Japan, but also to provide fresh wasabi for the increasing number of people enjoying Japanese cuisine throughout the Asia-Pacific region.

Markets in Australia, south-east Asia and the Pacific islands will be targeted initially, while increased product volume will provide the opportunity to export to Japan. Current Japanese production is around 5000 tonnes fresh weight per annum, but fresh product is unavailable in the coldest months (December–February).

Fresh wasabi was not available in Australia prior to 2000. Processed products imported to Australia often contain European horseradish. Evaluation of wasabi from trial wasabi crops grown in Tasmania has confirmed a large domestic market based in Sydney and Melbourne, and export opportunities to south-east Asian and Pacific regions with expatriate Japanese populations keen to obtain fresh and processed pure wasabi products.

Since 2000, a supply of fresh Tasmanian wasabi with a farm gate value of $AUD 100/kg has been available to selected clients in Sydney, Melbourne and Hobart. Fresh stems are airfreighted either directly to the restaurant or to a distributor servicing a number of Japanese restaurants.

Yields of 10 t/ha have been realised and are estimated to double, in line with those achieved in Japan, as crop husbandry practices improve. Fresh Tasmanian wasabi is currently a soil-grown product, traditionally considered suitable only for processing. Market evaluation indicates that discerning domestic consumers are willing to pay up to $AUD 380/kg for water-grown wasabi. Consequently, the introduction of water-grown wasabi production systems, and improvements in the quality of planting stock, have been development priorities for the industry in the last 3 years.

While there is a high demand for fresh quality stems, a major market also exists for processed product in the form of pastes, pickles and powder. Wasabi flavoured cheese produced in Tasmania uses dried wasabi powder from Tasmanian crops and has met with great success in Australia, USA and Japan. This is the first in a range of value added wasabi products to be produced in Tasmania.

**Production requirements**

Wasabi is a cool climate crop requiring shaded conditions, plentiful irrigation water and readily available oxygen at the root system. The ideal root temperature range of 12–15°C may be a constraint when choosing a site to grow the crop. While wasabi tolerates air temperatures ranging from mild frosts to 30°C, root temperatures below 12°C cause declining growth rate. Growth ceases altogether at 5°C. The plants exhibit signs of stress and become more susceptible to disease if the root temperature exceeds 18°C.

In Japan, shade is provided from deciduous trees complemented by temporary shade structures during the summer months. In Tasmania, permanent structures, built to withstand windy conditions and using 80% shade cloth, have been constructed. While crops have been produced successfully under black shade cloth, light colours have the advantage of reflecting light, thereby keeping the internal environment of the shade house cooler.

For soil grown crops, excellent drainage is essential. Soils with an open friable structure, such as sands or light loams, are preferred. Raised beds assist with drainage and soil pH should be in the range 6.5 - 7.5. Soil preparation includes the incorporation of base nutrients

![Wasabi growing under shade cloth](image)
similar to those required for other leafy vegetables. Foliar boron and sulphur sprays may be beneficial during the second year of growth.

For water grown crops, the semi-aquatic plants are anchored in gravel beds through which fresh water flows continually. Water must be free of pollutants and have an oxygen concentration of 10-12 mg/L. A delivery volume of 180 L/sec/ha is recommended. Plants generally scavenge nutrient requirements from the fast-moving water while foliar sprays provide supplements.

Areas most suitable to wasabi production in Australia are those with a maximum summer temperature below 30°C and access to abundant water. This confines production to isolated pockets in the southern-most part of the continent (see map).

### Varieties

‘Daruma’ variety has been selected for soil-grown wasabi crops in Tasmania. Its rhizome is thick and green, and has excellent flavour. Leaves are heart-shaped and deep green in colour. ‘Daruma’ produces many side-shoots, lending itself to vegetative propagation. This practise should be continued for a maximum of 2 - 3 generations to prevent build up of disease.

‘Mazuma’ is the preferred variety for semi-aquatic production. Plants produce short, thick rhizomes with excellent flavour. Mature leaves are round and dark green while emerging leaves and petioles have a distinct reddish colouration. The use of tissue-cultured plants of ‘Mazuma’ variety in Tasmania aims to minimise disease risk.

‘Midori’ variety is also suited to semi-aquatic production. By comparison with other cultivars, the rhizome grows quickly and is pale green in colour. The leaves are heart-shaped and bright green. Growers in Victoria have conducted trials with this variety.

The use of high quality planting stock is essential to minimising disease risk in wasabi production. Although Japan continues to provide the largest gene pool for wasabi varieties, it is anticipated that local production of disease-free tissue-cultured plants will replace the need to import commercial quantities of planting stock from Japan.

### Agronomy

Tasmania’s temperate climate allows wasabi to be planted and harvested year round, providing a distinct advantage for supplying fresh wasabi to the market. Mature stems are harvested 18 – 24 months after planting.

**Soil Culture.** Soil preparation includes application of a base fertiliser N:P:K (12:12:12). Application rates are determined by paddock history but should be similar to those for other Brassica vegetables. Boron must be included pre-planting with additional foliar applications made one year after planting. Beds can be prepared by building ‘potato mounds’ along which plants are sown in zigzag manner. Alternately, raised beds 1 m wide are prepared with plants spaced at 300 mm intervals.

A shade house structure is required to provide 80% shade in the summer months. The shade structure must be sufficiently robust to withstand windy conditions in the local environment. Extension of the shade cloth down the walls to the ground protects plants from wind and grazing predators and ventilation openings reduce the incidence of mildew. Light colour shade cloth is beneficial in keeping the shade house cool.

Rainfall should be supplemented during dry summer months with irrigation water applied gently from overhead micro-sprinklers or drippers at a rate of 30 mm/week.

**Water culture:** Bed preparation is determined by the topography of the site and the water source available. Bed types for stream and spring fed systems have a finished slope of 1-2% and require 80% shade in the summer.
(1) **Stream fed sites** consist of gravel-filled terraces through which water is diverted from an adjacent watercourse. The topography of the site will determine the depth and length of the terraced beds. Bed depth may range from 400 – 900 mm. Drainage pipes incorporated into a coarse gravel layer at the base of the beds ensure that water moves downward throughout the whole root zone of the plant allowing fresh water to rapidly replace that depleted of oxygen and nutrients. A layer of fine gravel overlays the coarse gravel layer to a depth of 100 – 200 mm. This provides anchorage for both the plant and water borne nutrients. The gravel beds are filled with water covering the gravel to a depth of 10 mm. Water should be delivered at a rate of 180L/sec/ha and plants spaced at 300 mm intervals.

(2) **Spring fed sites** are usually identified by the occurrence of coarse gravel or sand from which spring water seeps. The rate of delivery of the spring water will determine the size of the wasabi beds at these locations. A flattened area is prepared at the spring source with gravel mounded in rows running parallel to the flow of water. Plants are placed at 300 mm intervals along the water’s edge. The water flow rate should be controlled to provide a surface speed of 120 – 150 mm/sec.

**Pest and disease control**

Maintaining cool temperatures for wasabi culture is a valuable tool for controlling pest and disease problems.

Insect pests that attack Brassica vegetables such as Diamond Back Moth and White Cabbage Butterfly are occasional visitors to wasabi production sites. The most detrimental organisms in Japan are fungi, such as *Phoma* species, *Fusarium* species, *Pythium* species, and bacteria such as *Corynebacterium* species.

Black streaks on the leaf stalk and dark brown circular spots on the leaves are indicative of *Phoma* infection. Chronic wilt symptoms and rotting at the base of the plant are indicative of *Fusarium*.

The effects of these organisms can be minimised by taking precautions such as the use of disease-free planting material when establishing new production sites, maintaining good plant nutrition and immediately removing and destroying plants displaying disease symptoms.

Copper sprays can be used as a protective fungicide in the summer months to control *Fusarium*, though care must be taken to avoid run-off to streams and rivers. Trials are currently being conducted in Tasmania to identify fungicides suited to a pre-planting control treatment for other fungal organisms.

**Harvesting, handling and post harvest treatments**

Wasabi stems reach a marketable size of 80 - 150 mm long, weighing 60 – 180g approximately two years after planting. As side shoots develop from the main stem following flowering, harvest should commence prior to flowering in the second year.

Whilst mature stems may be harvested individually, more often the whole plant is harvested and graded as:

- premium stems suitable for the fresh market (farm gate price $100/kg)
- smaller stems, leaves and petioles suitable for processing as prepared wasabi paste or dried powder (farm gate price $20/kg)
- fresh leaves (wholesale price $75/kg).

An individual plant weighs approximately 3 kg and can produce 4 - 14 stems for the fresh market, 2 kg of smaller stems, leaves and petioles and 100 g of premium quality fresh leaves.

Wasabi stems should be bright green in colour and evenly tapered,
narrowing at the root. Uneven taper indicates that the plant has been subject to environmental stress during growth.

Trimming is a critical part of wasabi stem presentation. Excessive trimming suggests that soil or diseased material has been present. Stems should be trimmed immediately above the root and petioles trimmed to a length approximately one third the length of the stem. Wasabi stems are cleaned under cool running water. This procedure is considerably easier for wasabi grown in water culture.

Stems for the fresh market should be kept moist, cooled to 4°C immediately after harvest, packaged in chilled polystyrene boxes and delivered to the market within 24 hours. Restaurants and households can keep wasabi stems fresh for up to two weeks by wrapping in a moist towel and storing in the refrigerator.

Stems weighing less than 60 g, or those that are bent or broken, are used for processing. These should be kept chilled prior to mincing or drying. Leaves that are not suitable for the fresh market may also be dried and ground to add authentic colour and flavour to processed wasabi products. Leaf petioles can be made into wasabi pickles.

Leaves 100 - 150 mm in diameter are suitable for the fresh market. Premium leaves should have no discolouration or physical damage and be packed in breathable plastic bags, cooled to 4°C and delivered to the market within 24 hours.

Financial information

A crop of wasabi becomes commercially viable with 0.5 ha under production, half of which is planted and harvested each year.

Soil culture. To date the average yield of fresh stems for a Tasmanian wasabi crop is 10 t/ha, with secondary stem leaves and petioles contributing a further 20 t/ha. An average price of $35/kg is estimated for the different component products of the plant. The crop production cycle is between 18 months and 2 years. This calculates to a gross income per crop cycle of $262,500 (30,000 kg/ha x $35/kg x 0.25 ha), or equivalent annual gross income of between $131,250 - $175,000 per 0.25 ha.

Establishment costs for a wasabi crop in soil culture including planting stock, soil preparation, irrigation and shade-house construction are estimated at $90,000/0.25 ha. These costs are incurred for each 2-year crop cycle as the site is relocated to provide a rotational break. Access to a suitable shade tolerant, disease breaking crop would allow a reduction in establishment costs as the same site could be reused without the need to re-locate the shade house. A 0.25 ha site is estimated to require a basic packing shed ($15,000) and harvest and processing costs of $10,000 per cycle. Sharing with nearby growers could reduce overhead costs for packing shed facilities and harvest times could be coordinated to ensure continuity of supply to markets.

Water culture. Although the yields are similar for soil and water grown wasabi, market evaluation indicates that water-grown wasabi for the fresh stem market has a value three times that of soil grown stems, bringing the gross income for 0.25 ha to $393,750 for a 2-year rotation. Establishment costs are higher for this type of system when the recommended disease-free, tissue-cultured planting stock is used ($170,000). However, because the site is permanent, the capital costs of shade house, gravel bed and drainage can be amortised over more production cycles. Capital costs can be reduced by linking shade houses on adjacent sites. Variable establishment costs can be reduced for subsequent crops by using side-shoots for crop establishment.

Once established, variable costs of production, including gravel bed restoration, replanting, foliar fertiliser application and harvest costs are estimated to be approximately $30,000 per 2-year crop cycle. However, actual costs may be significantly different as there are no Australian figures currently available.
Key references


Key contacts

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Angela is project leader for the jointly sponsored DPIWE and RIRDC Tasmanian wasabi project and has travelled to Japan and the USA to compare methods of traditional and modern wasabi cultivation systems. The project aims to establish wasabi production and marketing in Tasmania as a sustainable agricultural enterprise.

Key statistics

- Japanese market demand exceeds supply
- Potential market for Japanese cuisine in Asia Pacific region
- Australian market evaluation predicts $100–380/kg for fresh stems from Tasmania
- Current Tasmanian production of 0.2t/ha projected to increase 500-fold by 2015

Key messages

- Requires water, shade and cool temperatures
- High value, low input crop
- High initial capital investment
- Two-year production cycle

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## Essential oils

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**Blackcurrant bud oil**

**Rob McEldowney**

**Introduction**

An extract for use in flavours and fragrances can be extracted from the dormant buds of the blackcurrant bush *Ribes nigrum* L. It has a distinctive aroma with fresh top notes and an intense catty characteristic overlying a strong fruity background.

The extract can be obtained through solvent extraction using either a purified hydrocarbon solvent like hexane or liquid CO₂. The product is generally traded as a ‘concrete’ which is solid at room temperature due to the presence of plant waxes, or refined to an alcohol soluble product known as an ‘absolute’, which is liquid at room temperature.

The buds required for extraction have traditionally been sourced from the annual prunings from fruit plantations with the buds stripped by hand. Consequently the availability of buds has largely depended on the fortunes of the fruit industry at any given time, resulting in severe supply and price fluctuations.

In the mid 1980’s a group of Tasmanian producers, in response to difficulties with their local fruit market, turned to bud production, establishing dedicated high density blackcurrant plantings set up for mechanical harvesting.

**Markets and marketing issues**

The principal market for blackcurrant bud extract has been in flavouring where it is used to reinforce and modify natural or artificial blackcurrant flavours, but it has also found applications in perfumery and cosmetics. The product has been marketed since the early 1960’s as Bourgeons de Cassis, reflecting the traditional production area, the Grasse region of France.

Buds were also imported from other European sources for extraction by a small number of specialised facilities. However, since the supply of buds was only ever a sideline to fruit production, volumes generally fell short of demand. This market opportunity was identified by the School of Agricultural Science at the University of Tasmania and Essential Oils of Tasmania Pty Ltd (EOT) who worked with Tasmanian producers to pioneer economic production systems using mechanical harvesting.

More recently, similar systems have been established in France, under contract to the main suppliers.

As with all essential oil products the quality of the oil, as defined by composition and organoleptic criteria, is critical. Tasmanian production is based on different cultivars and unique extraction systems, giving a product which is different to the established quality. While this invariably makes the marketing process more difficult initially, it does provide a competitive advantage in terms of...
future sales, if the new quality can become established. The market dynamics are expected to change in the near future as new plantings set up for mechanical harvesting come online in France.

Production requirements

Blackcurrants require very specific conditions in terms of microclimate and soil type. Production is most likely to be in the temperate areas of Australia where long days and cool nights favour accumulation of essential oil. However, it would be possible to produce in other specific regions such as highland sub-tropical and tropical areas.

A wide range of soil types can be used provided drainage is good. This is important both for plant performance and longevity, but also to enable access for mechanical harvesters during winter. A neutral pH is ideal but crops can be successfully grown on soils down to pH 5.

Blackcurrants are not deep rooted and have a reasonably high irrigation requirement during the vegetative growth period through summer. Vigorous extension growth has to be maintained to give the necessary bud numbers for economic oil production and the right structure for mechanical harvesting.

Topography limitations are largely dictated by machinery requirements with mechanical harvesters limited to slopes of less than about 10%.

Aspect is not critical - although the crop needs full sun, bud production does not require the same level of sun penetration as a ripening fruit crop.

Varieties/cultivars

Tasmanian bud production has been based on the variety White Bud, a local selection of the English variety Baldwin. More recently selections with particular oil chemotypes have been isolated from the general White Bud population and cultivated to enable different quality criteria to be met. White Bud is not the normal variety used for bud oil in Europe resulting in the Tasmanian product differing from traditional sources.

Cultural practices/agronomy

Blackcurrant plantations for bud production are established at about 4 times the density of fruit plantings. A total of around 50,000 cuttings per hectare are mechanically planted during the dormant period. The cuttings are generally 150-200 mm long, with 6 buds and the cuttings are placed so that no more than 2 buds remain above ground level. Cuttings should be prepared from one year old canes and planted at row spacings to suit the equipment required to manage and harvest the crop.

Good soil moisture must be maintained until the cuttings strike roots – the period after bud burst is the most critical because it generally precedes root development by several weeks.

Irrigation requirements remain reasonably high throughout the growth period. As a guide, approximately 30 mm per week should be budgeted on for the period from bud burst in September until leaf drop starts in April.

A high nutrient status must also be maintained to ensure constant, rapid extension growth. Recommendations for basal fertilisers should be based on soil analyses but on reasonably fertile soils an annual application of around 35 kg/ha of P and 80 kg of K can be expected. Crops in Tasmania have shown responses to additional potash applications around November (100 kg/ha of muriate of potash).

Regular nitrogen side dressings are vital with at least 100 units of N generally recommended in the period through to early autumn. Sulphur is also an important nutrient and it has implications in terms of the chemical composition of the oils produced.

At the end of the growth cycle, a well grown bud plantation will have canes at least 80-100 cm long with up to 30 buds per cane. Recycling of nutrients is encouraged as much as possible – only a relatively small weight of buds is removed from the field at harvest with all the remaining growth mulched and returned. Production can be expected to steadily increase for the first 3-4 years, as the cane density builds up to mature levels, starting with about 50 kg of buds/ha in the first year and levelling out at about 250 kg of buds/ha at full plantation density. Crops on well-selected sites with good management can be expected to produce for at least

Key messages

- Careful market analysis required
- Determine product quality criteria
- Select cultivars and extraction technologies

Blackcurrant bud oil
10 years. Some rejuvenation may be required to counter excessive cane density and soil compaction as crops age.

Good weed control is extremely important to avoid competition and from harvesting and quality considerations. Since propagation is via unrooted cuttings, establishment is relatively slow and poor weed control in the first season will result in crop failure. Depending on the weed spectrum, sites should go through an extensive weed control program before planting, including broad range knock-down herbicides, cereal cover crops and fallow periods. Even after that, follow-up spot spraying is often required after the crop has been planted. There is an opportunity for further perennial weed control during the dormant period in winter after the crop has been harvested.

There are few herbicides registered for blackcurrant plantations and all relate to fruit production situations. Minor use permits are required from the Australian Pesticides and Veterinary Medicine Authority (APVMA) for any non label chemical use.

Pests and diseases

The main disease of blackcurrants in Tasmania is Septoria leaf spot (Septoria ribisi), which can cause premature leaf drop, greatly reducing vigour and bud development. It is evident as angular light coloured spots with a greyish centre and purplish margins. Gooseberry mildew (Sphaerotheca murs-uvae) can also cause problems sporadically, particularly when conditions have been warm and humid after the crop canopy has closed over. The symptoms of mildew appear as pale yellow patches on the upper surfaces of young leaves with areas of powdery white fungus on the underside. This can develop into a powdery white covering over the whole leaf with subsequent leaf breakdown and stunting of growth.

Insect pests include aphids and mites. Outbreaks of the Sow Thistle Aphid (Hyperomyzus lactuca) can occur in spring and early summer causing distortion of the growing tip. The Two Spotted Mite (Tetranychus urticae) causes bronzing of the leaves and premature leaf drop during severe infestations, resulting in a loss of vigour and reduced yield.

The Currant Borer Moth (Synathedon tipuliformis) which can cause severe damage to fruit plantations can be present in bud crops but does not have any economic impact.

Harvest/storage/processing requirements

Development of mechanical harvesters has been crucial to the success of the Tasmanian blackcurrant bud industry, allowing it to become established against competition based on hand harvesting. The equipment used by EOT was designed locally and developed over a number of years. This machine cuts the canes, strips the buds and then chops the canes to a fine mulch in a single pass. Buds are frozen to –20°C for storage until they are extracted.

EOT extracts the buds using highly refined hydrocarbon solvents, with most product sold as an absolute. The extraction process has a strong bearing on the yield and composition of the end product.

Financial information

It is not possible to give precise financial details for production of blackcurrant bud extracts because of the diverse nature of systems and circumstances. Indicative costs for field operations can be quoted but the major financial considerations relate to harvest and extraction infrastructure.

With field production costs, the Tasmanian experience has been that establishment, including land preparation, preparation of cuttings and planting, amounts to about $2,000/ha, provided planting material is available at cost. Thereafter, annual growing costs are of the order of $1,500/ha. As already noted, bud production can be expected to start at around 50kg per hectare in the first year increasing to 250 kg/ha in year 3–4 when the plantation reaches a mature density.

Figures relating to the cost of developing and operating proprietary harvesting equipment cannot be quoted. Similarly with extraction, a major component is the capital cost of equipment. Various forms of solvent extraction are used and the equipment required is expensive and needs specific expertise to operate. Since the market for blackcurrant bud extracts is limited it is unlikely that a dedicated plant could be economical. It is likely that any new blackcurrant bud producers would need to have access to a suitable solvent extraction facility processing other commodities as well.

Key references

Blackcurrant bud oil

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Boronia oil

**Introduction**

*Boronia megastigma* Nees. is endemic to Western Australia and is found in the south-west of that State where it grows as a woody under-storey shrub one to two metres in height on moist or seasonally wet sandy soils of acid to neutral pH. The genetic resources of *B. megastigma* for essential oil product have been investigated by Plummer and Considine (1997).

Flowers are initiated in autumn and continue to differentiate and develop during the winter, bearing a profusion of strongly scented brown, purple and yellow flowers in early spring. Flowers contain the oil or extract which is used in commerce.

The purified extract is known as Boronia absolute and has been available on the world market since the 1920’s (Geunther 1949). Since the mid 80’s the largest volume of commercial production has been produced in Tasmania and a small volume in New Zealand. In the late 90’s a small area of intensive commercial production commenced in Western Australia. Prior to this, flowers were collected from wild stands in Western Australia. The product has application in scale through increased production may accommodate the price decrease required for fragrance application.

The major application for the product is in flavours, for example in beverages and dairy products at low concentrations it imparts the character of fruit, esters, tutti frutti and honey. Other applications include the enhancement of natural flavours in fruit essences such as raspberry, strawberry, plum, peach and meat products such as salmon.

The product is purchased by end users, dealers/traders and flavour and fragrance companies. This latter group may compound a

**Markets and marketing issues**

The principal markets are in Europe and the United States of America with potential in Japan, South Korea and South East Asia. Where the product is used in natural perfumes, it has a distinctive powerful odour which is typical of the fresh flower and makes an excellent addition to quality bouquet perfumes. The odour is strongly persistent with natural green freshness and floral undertones of rose, jasmine and freesias and a character of ripening hay and a woody tea like background. The use of boronia absolute in perfumery is restricted because of price. Economies of

**Key messages**

- Composition and organoleptic profile are highly specific for particular applications
- Do not plant without a production contract
- Plant material, extraction and harvesting will be supplied with the contract

**Key statistics**

- World production approx 200kg
- Tasmania is the major producer
- Western Australia is a minor producer
particular essence or fragrance to apply to end use products.

The current world production is approximately 200 kg of absolute and the price ranges from $3,000 – 6,000/kg depending on sample size and purchase contract. There is a steady increase in demand which is essentially associated with new applications for the product.

**Production requirements**

**General**
Suitable climates exist in parts of Western Australia, Victoria, Tasmania and New Zealand. The current limitation to production is the rate of expansion of market opportunities.

**Climate requirements for flowering (Roberts 1989)**
Boronia will survive a range of climatic conditions from its native environment on the edges of swamps, to the extremes of dryness associated with a Mediterranean climate. In Tasmania, the plant has survived periods of heavy frost and snow. However best production occurs in a maritime climate in the South West of Western Australia, North, North East and East coast of Tasmania and Southern coastal regions in Victoria.

Boronia remains vegetative at temperatures in the high 20°C. Competition from young developing leaves for available assimilates is the likely cause of flower abortion. In autumn ideal weather conditions for maximum flower number are approximately 10°C night temperature, day temperature 15°C with 10 hour day length and full to 50% sunlight. It appears that prevailing temperatures may restrict the climatic range for commercial boronia flower production. Boronia flower buds that initiate and develop under non optimal conditions may eventually reach maturity, the structures being a transition between buds and leaves.

Flower initiation and development of flowers in boronia is sensitive to photon flux density, night temperature and photosynthetically active day length. There is no single obligatory stimulus for induction. For example, lowering the night temperature from 15°C to 6°C has a greater promoting effect on flower initiation than the effect of decreasing the day length from 16 h to 10 h. The combination of low night temperatures, short days and full sunlight results in the highest number of flower buds. The conditions that produce the highest number of flower buds are also the most suitable for their differentiation and development. [Roberts and Menary (1994) a]

**Soil**
Boronia has reasonably specific soil requirements. The soil should have a pH of between 4 and 5, however trials have shown the plant will grow in soil with a pH of as low as 3.5 and as high as 6.5. The soil should have a high organic, low clay content with high production being obtained on well drained acid sands. The natural vegetation on this soil is usually a coastal heath or bracken fern. A previously uncultivated area is preferred. It is recommended that a total soil analysis be undertaken prior to planting to measure pH and levels of macro and micro nutrients.

Two methods of soil preparation are practised. One involves minimum tillage the other normal seedbed preparation with deep ripping to remove old roots which may be a source of Armillaria infection.

**Varieties**
Current commercial varieties grow to a maximum height of approximately 1.5 m. The leaves are linear, shiny, 10–20 mm long and usually with three leaflets, up to 5 leaflets may occur if the nitrogen supply is high. Buds are usually initiated on the current laterals, these can be distinguished
from that of previous season’s growth by the lack of rough bark and from the general light reddish brown to green appearance of the stem.

Both flower and vegetative buds are formed in the axils of leaves. These flower initials may continue to develop under ideal conditions or revert to vegetative structures if adverse conditions prevail. The maximum number of flowers per node is three.

A typical timetable of visual events during flowering in *B. megastigma* under flower inducing conditions in autumn is given in Table 1. This means that flowers can take 4-6 months to develop, the time being directly related to temperature and sunlight.

Propagation of commercial plant material can be undertaken from short lateral cuttings and through tissue culture. Cutting material is collected in summer from rapidly growing plants and these produce roots quite readily under mist with a rooting medium of bark and coarse sand. Tissue culture plants can be produced from sterile meristems grown in shoot proliferation medium. Shoots are subsequently transferred to a rooting medium. The latter technique is used to produce mother plants from which cuttings can be taken for mist propagation.

Commercial varieties for oil production have been selected from seed populations. They have been selected for agronomic, oil bearing and disease resistance characteristics. These improved varieties are only available through a licence agreement with current owners.

### Cultural information

#### Shelter

Until 2 years of age, the young bushes are very prone to wind damage. Adequate shelter should be provided through the planting of trees as shelter belts.

#### Irrigation

Irrigation is not essential but is recommended for high productivity. *Boronia* is able to withstand long periods of drought. Once established the plant appears to be able to produce flowers without summer watering.

However trials have indicated that on young plants, a high survival, better establishment and better growth rates are achieved if irrigation is applied. Drip systems using low volumes of water at around 8 to 10 L/plant/week have been successful.

#### Cultivation and weed control

Mowing between the rows to reduce competing vegetation is important. For particular weed problems it may be necessary to seek minor use permits from the Australian Pesticides and Veterinary Medicines Authority (APVMA). It should be emphasised that the use of herbicides increases the danger of chemical contamination in the oil. Their use is minimised through careful land preparation prior to planting and careful sanitation during the production phase.

A plant density of 1 - 3 plants/m² has been used depending on cultivation, site and harvesting methods employed.

#### Pruning

Heavy pruning is practised after harvest to stimulate new growth or potential sites for flower production in the following autumn. The pruning cut should be 2-3 nodes above the previous year’s growth.

### Table 1. Time taken to flower development in *B. megastigma*

<table>
<thead>
<tr>
<th>Event</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days from initiation to appearance of buds</td>
<td>30-40</td>
</tr>
<tr>
<td>Days to flower stalk elongation</td>
<td>55</td>
</tr>
<tr>
<td>Days to flower stalk curvature</td>
<td>75</td>
</tr>
<tr>
<td>Days to petal exposure</td>
<td>125</td>
</tr>
<tr>
<td>Days to flower opening</td>
<td>160</td>
</tr>
</tbody>
</table>
Fertiliser

Preliminary trials on fertiliser responses have shown that slow release fertiliser such as IBDU and Osmocote are appropriate for boronia to prevent high concentrations of nutrients in the root environment. The nutrient combination used should be high in nitrogen, low in phosphorous and moderate in potassium. Applications of fertiliser should occur after harvest to stimulate summer extension growth.

Nitrogen should be applied at rates between 15 and 80 kg/ha depending on soil type and variety.

Recent trials [Roberts and Menary (1994)a] have shown that ammonium nitrate is a suitable nitrogen source to keep a balance between the two forms of nitrogen, NH₃ and N⁰, and so prevent major pH changes.

Nitrogen is normally applied in October/November and the level of total nitrogen in January/February should be 1.5%. Samples should be taken in early January to check these levels and if necessary apply nitrogen to rectify any deficiency. Magnesium, sulphur and molybdenum deficiencies have occurred and these elements should be present in the fertiliser. It is preferable to apply molybdenum as a foliar spray where the soil pH is below 5.5.

Yield and composition

A yield of 2t of flowers/ha can be expected from selected varieties. The extract yield from fresh flowers varies between 0.3 and 0.6% depending on variety. The conversion from crude extract to absolute yield is approximately 50%.

The major chemical components in the absolute are β-ionone, dodecylacetate, methyl jasminate and heptadec-8-ene. (Davies & Menary 1984 and Weyerstahl et al 1995)

Pests

Psyllids (Mensah 1990)

Psyllid (Ctenarytaina thysanura) insects were first identified on boronia plants in 1932 in New Zealand and have been a major problem in the Tasmanian boronia industry. Infestation will kill boronia seedlings or lead to reduced vegetative growth and flower and oil yields. An economic analysis of insect control to benefits achieved established a cost benefit ratio of 1:9. Known insect control programs were therefore regarded as ineffective and expensive.

Damage

Psyllid feeding leads to a reduction in the number of new nodes formed by the plant and eventually growth ceases and the tip of the terminal bud is killed.

The psyllid produces honey dew in the course of feeding and this honey dew settles on the plant causing the development of sooty mould which lowers the photosynthetic ability of the plant.

Their feeding causes yellowing of leaves and consequently leaf loss, and in young plants the whole plant may die while in mature plants it leads to stunted growth and loss of flower yield.

The percentage of oil extracted from the flower is reduced as much as 30% as the psyllid feeding affects the accumulation of oil in the glandular cells.

Population dynamics

The insect lays its eggs in the leaf axil of the terminal shoots of boronia plants but in winter, most of the eggs are laid in the flower bracts, sepals and petals.

Population sampling of insects over a number of generations revealed that natural enemies such as parasites were responsible for mortality at certain stages in the life cycle of the insect.

Integrated pest management program

Application of a systemic insecticide when there are 10 or more adults in young leaves will reduce the numbers of psyllids without affecting the parasites.

Nuvacron 40® (monocrotaphos) was used @ 0.02% ai. until 1999. However, registration has now been cancelled and the product withdrawn from sale. No registered insecticide is currently available for the control of psyllids.

About the author

Bob Menary is a Visiting Research Professor, School of Agricultural Science, within the University of Tasmania and has 20 years research experience in developing boronia as a commercial crop. This includes detailed investigations of physiology and development, cultivar development and propagation, nutrition, harvesting, processing and marketing.
Black scale (Enggar 1995) and brown scale

Black scale insects (*Saissetia oleae*) and brown soft scale insects (*Coccus hesperidum*) have become serious pests to some boronia plantations in Tasmania. Black scale has only one generation per year, commencing in January.

The immature insects settle on both sides of the leaves and stems over the entire boronia bush, and migrate to the woody stems in late autumn and winter, before reaching adult stage. Adult scales are rarely found on leaves.

Black scale is most vulnerable at the immature stage (first stage nymphs) to attack by parasites, insecticides and also high temperatures during summer.

Brown soft scale has three generations per year, appearing in summer, autumn and spring.

The distribution of the scale, both immature and adult, tend to be on the top half of the boronia plant on leaves and stems although, in spring and summer, the scale prefers to settle on leaves rather than stems.

Parasitism of brown soft scale populations only reaches 19% but does contribute to keeping the population at low levels.

Factors influencing scale populations

Plants damaged through cultural operations are more susceptible to infestation because the bark forms a wound callus which provides an ideal establishment site for scale. The callus also protects the scale from white (summer) oil.

Some weeds act as alternative hosts to immature black scale insects, such as *Rumex acetosella* (sorrel), *Trifolium repens* (white clover), *Stylidium graminifolium* (trigger plant), *Leontodon taraxacoides* (hawkbit), *Hypochaeris radiata* (flat weed or cat’s ear) and *Solanum nigrum* (black nightshade). These should be controlled to reduce infestation.

Pruning reduces scale insect populations but prunings must be destroyed to avoid reinfestation.

Results and recommendations for a successful pest control program

White oil (summer or petroleum oil) is the most effective agent in the control of both types of scale insects. Apply to the entire plant (both tops and sides) at the immature stage of the insects’ life cycles in the last two weeks in February and repeat four weeks later. Apply white oil to run-off in large volumes at low concentrations (1.0% - 1.2%) and at low tractor speed (eg. at 4 km/h rather than 8 km/h).

Browsers

Sound cultural practices should ensure adequate fencing is provided to restrain animals, such as rabbits, bandicoots, sheep and cattle.

Cutworms

Cutworms will ringbark young seedlings during the first few months. Successful control can be achieved if the ground to be planted is cultivated 12 months in advance and left to fallow.
Diseases

General
Sanitation is the best form of control. Ensure disease free stock is purchased, production and handling areas are clean, machine and foot sterilisation is maintained. These and other common methods of sanitation are stressed as a means of preventing infections. Boronia is seriously affected by root rotting diseases. Phytophthora and Armillaria root rots appear most damaging to boronia when grown in contaminated areas. Rust is a problem if commercial varieties are not resistant to the disease. Boronia clones are resistant to Phytophthora but may succumb under unfavourable water logged soil conditions.

Boronia rust
Boronia rust (*Puccinae boroniae*) is a major problem in the field. Tilt® is registered for control of the disease.

Harvest, handling, storage, post harvest treatments and processing

General considerations
Harvesting is carried out between late August and late October. Localised climatic influences will either produce a compact flowering period or a lengthier flowering period depending on day/night temperatures, day length and sunlight. During years 1 and 2 harvesting is carried out by hand or with a mechanical aid. Hand pickers are unlikely to harvest more than 1 kg/hour under these conditions. Hand held combs are used to rake the flowers into containers.

Mechanical harvesting
Mechanical harvesting is practised in Tasmania. The equipment is solely owned and operated by Essential Oils of Tasmania. The mechanical aids used for harvesting in Western Australia are owner operated. There is also one such operator in Tasmania. Flowers are harvested when 80% of the flower buds are open. (McTavish & Menary 1997)

Very strict requirements are placed on the levels of leaf matter contained in the harvested product. The leaf contains waxes and impurities which change the composition of the floral extract.

Flower handling
Freshly harvested boronia flowers will remain in a chemically stable condition if the field heat is removed by refrigeration and flowers are then stored at -18°C.

Extraction
Flowers may be extracted with liquid C02 or a hydrocarbon solvent (such as hexane). The initial crude extract is then converted to an absolute which is the alcohol soluble fraction.

Financial information
The cost of establishment of boronia is approximately $20-$22,000/ha.

Boronia crops are established from nursery speedlings which are produced by vegetative propagation. Planting material is the major cost of establishment as plant densities of 1 to 3 plants/m² are practised. Each unit may vary in price from 50¢ to $1.00.

On farm costs are fertilisers, pesticides, irrigation, slashing or mowing, pruning, harvesting and cold storage. A total average cost of production is $10,000/ha. Flowers may be purchased by a processing company with solvent extraction facilities.

Gross income to growers for flowers is approximately $24,000/ha. The gross margin for boronia flower production would compare favorably with some vegetable crops, eg. potatoes, or poppies and pyrethrum.

The yield, cost of establishment and maintenance can vary widely depending on location, associated farm activities and previous land use history. Virgin land is the preferred option to minimize disease, encourage biological control of insects, minimize weed infection and improve longevity. Under these conditions a commercial life span of at least 10 years could be anticipated.

No plantings should be undertaken unless a production contract is in place with a reputable company involved in the international essential oils trade and preferably a member of the International Federation of Essential Oils and Aroma Trade.

Boronia oil
Key references


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Chamomile
(German chamomile)

Introduction

The common name chamomile covers many species from many genera. In particular it covers two different crop types: English, Russian or Roman chamomile (Chamaemelum nobile (L.) All., formerly Anthemis nobilis L.) and German or Hungarian chamomile (Matricaria recutita (L.) Rauschert., formerly Matricaria chamomilla L.). Both belong to the daisy family, Asteraceae and are native to Europe. The latter species is the subject of this chapter.

German Chamomile is a herb producing small, white daisy flowers. It has been used in folk medicine throughout history and its flowers are currently used in the production of three commodities: a) a medicinal tea that is renowned for its calming properties, b) steam-distilled essential oil which is used in the flavour, fragrance, pharmaceutical and cosmetic industries and c) a solvent extract of the flowers used primarily in the cosmetic and pharmaceutical industries.

Growers wishing to diversify into German chamomile production should first forge links with wholesalers of these products. To be successful, potential growers will need to give detailed attention to producing a quality product over many seasons, thereby establishing a reputation for consistency in quality and reliability of supply.

Perhaps the major constraint for the industry is the small size of the local market. Although both the local and export markets are expanding, there is a significant risk that oversupply will greatly reduce the price received for the products, in turn greatly reducing the return to individual growers.

An additional risk is that chamomile is a prolific seed producer. Its weed potential both in other crops and the environment should be considered before chamomile is sown.

Markets and marketing issues

Markets consuming significant quantities of chamomile products are in Europe, Latin America and USA. The oil of Matricaria chamomilla is registered with FEMA (Flavor and Extract Manufacturer’s Association) as
GRAS (Generally Recognised as Safe) and therefore can be traded as a flavour compound in the USA.

All three chamomile products, i.e. dried flowers, oil and extracts, are both imported and traded within Australia. Increased production of chamomile in Australia has potential both for import replacement and for export.

Products will generally be traded through an agent or wholesaler who will pool together the supply from a number of small producers. In Tasmania, a collective growers’ group trades directly with a production company which pools and packages the products and in turn distributes the products via agents to the manufacturing companies. By forming regional co-operatives, growers are able to smooth out some of the fluctuations in supply caused by environmental events. As a region, they then gain the reputation for reliability that is critical to trading such products on the world market.

The dried flowers are used to produce herbal teas both alone and in mixed blends. The market requires that these flowers have specified levels of the pharmaceutically active compounds (principally α-bisabolol and chamazulene) and that the product is free from weeds and other debris, including insects and insect parts.

The essential oil is a deep blue or bluish green liquid, which turns green and finally brown upon exposure to air and light. The blue colour is caused by the chemical component chamazulene. Chamazulene is not present in the intact flowers but is produced by the distillation process. The blue essential oil is used primarily in the pharmaceutical and cosmetic industries, although a small amount is used in flavouring.

Again, the two important pharmacological components are chamazulene and the bisaboloids.

Chamomile is cultivated in Europe, particularly Germany, Slovakia, Hungary, Czech Republic, northern Africa, Asia, Argentina and USA. Within Australia, there is established production in localised regions from Victoria through to southern Queensland, and the beginnings of an industry in Tasmania. The Australian market will have to compete with the low wage conditions from some of these producers.

The major risk to the Australian chamomile industry is oversupply of the small local market.

Production requirements

When selecting an appropriate site for a chamomile crop, growers should note its potential as a prolific weed and ensure that it can be contained and controlled within the proposed production area.

Chamomile is a native of Europe between the Northern Hemisphere latitudes of 45-50°. It is therefore likely to do well in the Southern Hemisphere at similar latitudes, although it is currently being produced as far north as southern Queensland, which has a latitude of 33°.

Germination appears to be inhibited by high temperature and crops establish better under cooler conditions (18°C-20°C). Higher yields are obtained when the plant undergoes a vegetative phase prior to flowering. Since it is a quantitative long day plant, with flower initiation inhibited by day lengths less than 14 hours, those latitudes with short spring days are preferable.

Chamomile can tolerate heavier soils but prefers a well-drained sandy or sandy loam. It will tolerate a wide range of pH and is possibly quite salt-tolerant. Research into the production of chamomile on saline Tasmanian soils is proposed for the future.

Chamomile seed is extremely small and must be sown close to, if not directly upon the surface, therefore the ability to apply frequent low intensity irrigation in the first days and weeks after sowing is imperative.

Once established chamomile crops become somewhat drought tolerant but irrigation is required to produce high yields. It requires warm to hot weather for best
yields and dry weather at harvest, particularly for the production of dried flowers. Free water on the surface of the crop will both decrease the efficiency of harvest and increase the cost of drying the flowers. Free water on the surface of the crop also reduces the efficiency of distillation and solvent extraction.

**Varieties/cultivars**

As detailed in the introduction German chamomile is of the species *Matricaria recutita* (L.) Rauschert. Within this species are several chemotypes, which are defined by the ratios of the pharmalogically active components in their essential oil. For example there are those which produce chamazulene (blue colour) upon distillation and those which are chamazulene-free. The other important group of compounds are the bisaboloids. Chemotypes are defined by the relative concentrations of α-bisabolol, α-bisabolol oxide A and α-bisabolol oxide B. Each end user will have different requirements for these active ingredients and an appropriate variety for any new producer will need to be selected after consultation with the proposed wholesaler or agent.

Two cultivars appropriate for use in the production of medicinal dried flowers are Bona and New Bona. These produce essential oil of similar chemical composition. Both were developed through a breeding program conducted by Dr. I. Salamon, Institute of Agroecology, Michalovce, Slovakia. Seed of these varieties is available from Dr Salamon. Other available seed varieties include Bodegold which may be obtained through Johnny’s Selected Seeds, Maine, USA and Goral which is a tetraploid variety.

**Key statistics**

- Price is highly elastic
- World market small but increasing
- Establishment costs are high

**Key messages**

- Requires short spring days for maximum yield
- End-users require specific chemotypes
- Oversupply of small market is a significant risk
- Potential growers must forge links with wholesalers

**About the author**

Dr Linda Falzari is a researcher with the Essential Oils Group at the University of Tasmania. She has spent the last ten years studying the cultivation of essential oil crops and the production of essential oils and extracts.

Good site preparation prior to sowing is essential. Chamomile, having extremely small seed, needs a well-worked stale seedbed with a fine surface texture. A Cambridge roller will create a sheltered microclimate for the seed as it germinates.

Chamomile needs to be sown early in the spring to ensure optimum germination and crop establishment. This also allows adequate vegetative growth before flowering. Late sowing restricts the ultimate size of the individual plants and therefore the yield of flowers produced, which in turn restricts the volume of oil. Autumn sowing should be considered if the area is adequately drained through the winter. Established chamomile crops are tolerant of light frosts.

Recommended seeding rates vary considerably, from rates of 320g/ha in the USA literature to 1kg/ha in Slovakia. Seed in Australia is expensive and the lower seeding rate of 300g/ha is recommended in the first year. In the following season, the same site may be re-sown at half this rate due to the establishment of self-sown plants. In subsequent years, chamomile may continue to be produced on the same site entirely through self-
seeded plants. Eventually weed control becomes too difficult and the crop must be moved to a clean site.

The seed is sown directly onto the soil surface, hence the value of the Cambridge roller. After sowing chamomile requires irrigation every two days, even if sown into a moist seedbed.

The surface layer must not be allowed to dry out until the plants are established. Germination and establishment takes between 14 and 21 days. After this, small rosettes should become apparent and irrigation can be reduced.

Crop growth in the early stages is particularly slow and a herbicide regimen aiming for early weed control is best.

Herbicide application can cease once canopy closure is achieved, since mature chamomile plants are very competitive and will smother most weeds. Rogue weeding may be necessary, just prior to harvest.

The fertiliser regimen will be dependent upon the prior nutrient status of the site. The aim should be to apply a complete, balanced fertiliser, including micronutrients, at the rosette stage. Nitrogen application will improve yields of both flowers and oil, but care needs to be taken that the crop does not become too soft and vigorous. This would encourage lodging, making harvest more difficult.

The aim is to manage the crop to produce a low canopy, with short straight plants, minimal branching and strong stems. This will improve mechanical harvesting.

Optimum harvest time is determined by a combination of observation of the crop and repeated sampling of the flowers for chemical composition.

The optimum harvest time is when the flowers are fully open, with the white ray petals fully extended and the small, tubular florets of the yellow disc just beginning to open. At this stage, the crop appears white. Pre-harvest sampling should be conducted to ensure that the oil composition is of sufficient quality and that yield is sufficient to warrant commencement of harvest.

Chamomile has a continuous flowering habit and several harvests will produce better yields than a single harvest at mid flowering. These harvests will be spaced about 10 days apart, depending on the weather conditions. The final flowers are left to self-sow the crop for the following season.

**Pest and disease control**

Chamomile is relatively pest and disease free in Tasmania but snails and slugs can be a problem in the very young crop, particularly with autumn sowings.

Weeds are the most serious hygiene issue as contaminants in the final product, be it flowers, oil or extract will detract from the product quality.

Overseas experience shows the following chemicals to be useful, but none are registered for use on chamomile in Australia. Potential growers should seek advice on Minor Use Permits from the Australian Pesticides and Veterinary Medicines Authority (APVMA).

Sprayseed, glyphosate and trifluralin are potential, suitable pre-emergent herbicides. Trifluralin must be applied at least 2-3 days prior to sowing so that it is deactivated before coming into contact with the chamomile seed. Post-emergent herbicides should not be applied until the crop has reached the rosette stage. Those that may be of use are ethofumesate, MCPA, prometryne and chlorthal.
Harvest/handling/storage/post harvest treatments/processing requirements

Flower maturity is a guide to harvest time. The optimum time is approximately when the majority of flowers present are in full bloom i.e. the ligulate florets (white petals) are fully open and 50% of the disc florets (orange centre flowers) are open. Ideally, pre-harvest serial sampling and small-scale distillation or solvent extraction will be used to observe changes in oil yield and composition. Chamazulene will not be present in solvent extracts but the precursor of chamazulene i.e. matricarin may be monitored. Harvest can then be scheduled to maximise yield and optimise oil composition.

Chamomile has a continuous flowering habit and will produce higher yields from multiple harvests rather than a single harvest, provided that the harvester can selectively pick the mature flowers whilst leaving the developing buds behind. The first harvest should be scheduled to remove the first open flowers and harvest repeated at intervals designed to remove later flowers as they open. Three to four harvests can be expected, although each successive harvest will be somewhat smaller than the previous one. Further harvests should be scheduled until the yield falls below the cost of harvesting. The final harvest may be left to self-seed the following season’s crop.

In countries where labour is inexpensive, chamomile is hand-harvested. This permits grading of the flowers during picking, resulting in a high quality product and facilitating multiple harvests. Hand-harvesting is not economical in Australia, except in very small niche markets for organically produced crops. Large-scale mechanical harvest in Tasmania utilises a header with fingers that comb through the crop and a vacuum system for transferring the flowers to a storage bin. A similar system is used in Slovakia.

The harvest is screened to separate uniform flowers of high quality, which are dried for tea. Lower-grade flowers are distilled to produce blue chamomile essential oil or are extracted with solvent. The flowers may be distilled either fresh or dried. Drying adds a further cost to production but will improve the efficiency of distillation. It also allows the crop to be stored and multiple harvests pooled and distilled together.

Drying may take place in the field but the risk of weather damage is often great. Drying facilities usually consist of a shed with a raised, perforated or slotted platform and a fan to circulate dry air from below. This air may or may not be heated. Care must be taken to keep the depth of flowers low to prevent overheating and/or rotting of the flowers as they dry. On-farm bagging of the dried tea is possible, but usually not economical due to economies of scale.

Distillation of chamomile using low-pressure steam is relatively inefficient and relative to other essential oil crops, a long duration of distillation is required to obtain the bulk of the oil. It is recommended that high-pressure steam be used. However, this adds substantially to the costs of setting up the distillation plant and to the skills and training of the plant operator.

Large-scale chamomile production is relatively new in Australia and attainable yields are still difficult to predict. From Tasmanian trials, yields of one tonne of dry flowers per hectare can be expected. Yields quoted in the literature can be as high as seven tonnes of dry flowers per hectare.

Oil yields are even more difficult to predict. Oil yield depends not only on the quantity of oil produced in the plant but also on the efficiency and duration of distillation. Tasmanian trials indicated that oil yields of Bona from 3kg/ha to 4.5kg/ha and Bodegold 1kg/ha to 2.4kg/ha could be expected. Oil yields of up to 15kg/ha are reported in the literature but potential growers would be wise to treat these figures sceptically.

The distilled essential oil of chamomile is relatively stable when stored in full bottles, at 5°C, in the dark.

Dry flowers need to be stored in a dry, rodent and insect free environment.

Financial information

Basic general farming equipment for the establishment of crops is required for the production of chamomile. This includes equipment for cultivating, sowing and application of herbicides and pesticides. In addition, a Cambridge roller is of benefit. A suitable irrigation system, capable of applying low volume of water at frequent intervals is necessary in the establishment phase of crop production.

Chamomile seed is a relatively expensive commodity and adds significantly to the gross margin in the first two years of production. This expense is reduced in subsequent years by allowing the crop to self-seed.

Capital outlay for the post-harvest processing equipment is significant
and usually is best undertaken by a group of growers in order to take advantage of economies of scale. In Tasmania, there is a significant, established essential oils industry. Potential growers in this state may be able to tap into the current infrastructure, significantly reducing the expense of entry to the industry. Without the benefit of an existing facility the cost of a regional distillation plant is in the order of $150,000 – $200,000. If high-pressure steam is required, this expense will rise.

A tentative gross margin is provided in Table 1, however, the price of chamomile commodities is extremely elastic and strongly depends upon supply. The price range for dried flowers may vary from $5/kg to $20/kg. The price of chamomile oil may fluctuate in a similar fashion from $200/kg to $1200/kg. Costs of production are relatively stable.

**Table 1. Gross margin analysis**

The following gross margin is based upon the following assumptions:
1) Flower production = 1000kg/ha dry weight.
2) The harvest is split 50:50 between dried herb and oil.
3) Average oil yield = 0.45% D.W.
4) Harvest x 2 passes x 8 hours/ha each @ $100/hour.
5) Screening for dried herb production - 5 hours/ha @ $20/hour
6) Distillation - 2 batches x 6 hours each at $25/hour steaming cost
7) Drying @ $1.25/kg dry herb weight.

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**Key references**

Falzari, L. M. and Menary, R.C. Chamomile for oil and dried flowers RIRDC, Publication No 02/156 February 2003

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Australia is the home of the eucalypt. All the commercial oil-bearing species of *Eucalyptus* are indigenous. Therefore, the raw material for the production of eucalyptus oil is available, and the soil and climate are suitable for the establishment of plantations of oil-bearing species.

Eucalyptus oil has been produced and traded for over 150 years. Although several different types of oil can be produced, it is only the oils rich in cineole that are now produced in quantity. Eucalyptus oil is used in a wide range of pharmaceuticals, cleansers, flavours, and to a small extent, as an insect repellent. Demand for the oil is currently stable.

The oil is easily produced, but the cost of production in Australia is high compared with other countries, even when produced from natural stands thereby avoiding the cost of establishing the crop.

While the demand is static, the production of eucalyptus oil in other countries, particularly China, has increased to a point where the world demand can be met by countries where labour is cheaper. Furthermore, in China the oil is produced as a by-product of the timber industry, thus also avoiding the cost of establishing the crop.
Key statistics

- World demand for cineole-rich eucalyptus oil—approx. 3,000 t/year
- World production potential from existing trees—over 4,000 t/year
- Australian production is currently approx. 120 t/year. But from 2005 this may increase to 320 t as the pilot plant at Narrogin begins production
- Potential production from WA is 1,000 t/yr

Key messages

- Eucalyptus oil is overproduced
- China can supply world demand
- New use for oil essential

Markets

There are two market categories for eucalyptus oil:

- one for supply of straight oil to the ultimate consumer
- one for oil that will be incorporated in other products.

Eucalyptus oil is sold worldwide. Most oil sold in Europe and North America is used in pharmaceuticals—in a variety of preparations for the alleviation of the symptoms of colds such as inhalations, rubs and cough lozenges. It is also used in mouthwash, toothpaste and embrocations, in confectionery and in the cosmetics and toiletry industry. Much of the oil sold in Australia and Asia is used as a pure oil in household products, in inhalations, to alleviate cold symptoms, and as a cleaner, spot remover, massage oil, etc.

The crude oil produced on the farm or in the forest, is sent or sold to a refiner, who redistills, blends to customers requirements, packages and ships to manufacturers or bottlers. The oil is then exported or distributed through the appropriate chain to the retailer. Nowadays, the straight oil is retailed through pharmacies and supermarkets.

Estimated global demand for cineole-type eucalyptus oil is 3,000-3,500 t/yr. Australian production is about 120 t. However, the Australian production is from a variety of eucalypts, particularly *E. polybractea* and *E. radiata* ssp. *radiata* (cineole variant) (syn. *E. Australiana*), while almost all the cineole-type oil produced in other countries is from *E. globulus*. While all the oils conform to the same standards, the Australian oils are more varied in composition, exhibiting more complex aroma and taste. This enables Australian oils to retain their niche position at the premium end of the market.

World market price for the standard grade *E. globulus* oil is now about US$5.50/kg in container lots (15 t). The price, while varying to some extent, is now fairly stable after a steady decline. The price is now less than it was 15 years ago. Because of static demand and over-production in China, the price is likely to stay low in the foreseeable future, unless a new large-scale use for the oil is found. Although the higher quality Australian oil commands a higher price, the demand is strictly limited.

Production requirements

Oil-bearing eucalypts will grow well in many parts of Australia, but work to date shows that *E. polybractea*, the major source of oil, thrives best on the light sandy soils of the western plains of NSW and just west of Bendigo in Victoria. It grows quite well in rainfall down to 350 mm/yr, but would probably do better in slightly higher rainfall areas.

While irrigation would enhance growth, the potential return does not warrant the cost.

*E. radiata* grows naturally on the Great Dividing Range and the south coast of NSW. It thrives in steep country on a wide range of soil types.

Because it is now essential to mechanise production to be able to produce oil at a saleable price, production from natural stands of *E. radiata* is unlikely. For mechanical harvesting, level to no more than gently sloping land is necessary. Natural forest areas of this type, with good oil-bearing trees as the dominant species, are now rare. This means that plantations, such as those currently being established in WA for salinity control, are required.
Although all the oil-bearing eucalypts occur naturally in Australia, there are now virtually no remaining areas of natural bush suitable for development for oil production. Therefore, future production must be based on plantations of the desired species, or on harvesting of the leaves of trees grown for other purposes, such as salinity control.

The following information on establishment and silviculture relates to mallees in the semi-arid zone of Australia. Other techniques, such as mounding and fertilising, may be essential for the successful establishment of other species in other areas.

Since it is essential to mechanically harvest plantations, planting in straight rows is desirable. For ease of pest and weed control, sufficient space should be left between the rows for machinery access. Thus, site preparation calls for clearing land that slopes no more than gently, and laying out straight rows, across the slope where possible. The rows should then be ripped as deeply as is practicable and, just before planting, the surface layer to about 25 cm on both sides of the rip broken down to allow the use of planting machines. One or two passes with a chisel plough or cultivator should be sufficient to achieve this. Into this ground, 10-20 cm seedlings are planted.

To protect the young seedlings from dehydration, watering at or immediately after planting is essential and watering must continue until the first effective rainfall. In the first few months, the seedlings also need to be protected from livestock.

The equipment required for planting and establishing the young trees is thus:

- a powerful tractor, or preferably bulldozer, with a ripper
- a cultivator
- a planting machine
- either an irrigation system, or a water tanker with an appropriate water delivery and pump and motor filling systems.

A good source of water is essential. Depending on cost, seedlings can be bought from a commercial nursery or raised on site. If they are raised on site, it will require the usual nursery facilities of tubes, trays, watering bays, plastic greenhouses and a watering system. Once planted the trees need to be kept weed free for at least 12 months and protected from insect attack.

Most of the oil-bearing eucalypts do not respond well to fertiliser and thrive in reasonable weather conditions without additional nutrients.

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**Varieties/species**

The most commonly traded eucalyptus oil is that obtained from *E. globulus*. This oil is readily available because of large-scale planting of *E. globulus* primarily for wood. These trees now also produce oil in commercial quantities.

Oil of more character is obtained from *E. polybractea*, which also gives better yields and is suitable for mechanical harvesting. The strong lignotuber developed by this species allows coppice growth to be harvested frequently—at about 18-month intervals. This growth can be harvested at ground level.

Several species are being planted for salinity control, especially in Western Australia (see box). Periodic harvesting of the leaves of these trees will stimulate growth, and therefore transpiration, further helping to lower the saline water table. Species being tried for this purpose include: *E. kochii* ssp. *kochii*; *E. kochii* ssp. *plenissima*; *E. horistes*; and *E. loxophleba* ssp. *lisophloia*. All of these eucalypts are native to Western Australia.

CSIRO’s Forestry and Forest Products Seed Centre in Canberra, and the Department of Conservation and Land Management (CALM) in Perth are likely sources of seed for all species.
Large-scale eucalyptus oil production in WA

WA has the most advanced salinity problem of any of the Australian states – 10% of all agricultural land has been degraded and this is projected to rise to 30% over the next 50 years; virtually every creek and river across the 15 million ha of agricultural land with <900 mm rainfall has become saline. This dire situation has given rise to an ambitious project to develop mallee eucalypts as a farm tree crop, to produce commercial return from oil and wood products, and to help control salinity.

Mallee industry development is based on recognition that the scale on which tree crops will need to be used to make a useful contribution to salinity control is very large (up to 20% of all farm land). To achieve adoption on this scale, tree crops will need to be seen to be economically competitive on their own account.

Mallee industry development was initiated by the Department of Conservation and Land Management (CALM) in 1993. It quickly attracted support from farmers who formed the Oil Mallee Association (OMA) in 1995. This body assumed leadership of the project in 1997. Large scale planting commenced in 1994 and by 2003 more than 10,000 ha had been planted. Operational planting was used to explore establishment and management techniques and a substantial body of knowledge and experience has been built up. Planting is on good quality cropland in unfenced belt layouts designed to better capture surplus water from adjacent crops. CALM and OMA undertook R&D in important aspects such as species selection, genetic improvement, yield prediction, harvest and handling systems and economic analysis.

The early hope was that economies of scale and innovative harvest and extraction systems might make a single product eucalyptus oil industry viable. Preliminary analysis had shown that with such advances, considerable reduction in cost of oil production should be achievable, that this could stimulate development of new large scale industrial products and markets for eucalyptus oil, and therefore provide a feasible basis for a large scale industry. By 1996 it was clear that this industry scenario was not likely to be feasible. R&D turned to finding uses for mallee wood and residues.

In 1998 the new Oil Mallee Company assembled a group of parties to conduct a feasibility investigation of ‘integrated processing’ where mallee feedstocks would be converted within a single processing plant to eucalyptus oil, activated carbon and electricity. The study was funded by Western Power Corporation and RIRDC, and managed by Enecon, a Melbourne based engineering company that holds licences for use of CSIRO activated carbon technology. It showed that integrated processing should be commercially viable. The report by Enecon is on the RIRDC website [http://www.rirdc.gov.au/reports/AFT/01-160.pdf].

A 20% scale demonstration plant has now been constructed at a cost of $9 million at Narrogin, a district with extensive mallee plantings, 200 km south east of Perth. It will test integrated processing on an operational scale. Plant commissioning has been delayed by budget problems but is now expected to commence in late 2004. If testing is successful there is potential to construct some 9 full-scale plants each with the following attributes:

- plant construction cost of $25 million, plants to be located within regional towns
- processing volume of 100,000 green t/year requiring 10,000 ha of mallee crop
- annual production: 1,000 t eucalyptus oil, 3,500 tonne activated carbon and 5 MW electricity capacity
- plant viability was based on a sale price of $A3/kg for oil and payment of a competitive price to growers.

The development of mallee indicates a structural shift emerging in Australian dryland agriculture. It will become imperative to better manage salinity and several new large-scale woody crop industries will be required. Major new research capability is being assembled to address this problem, e.g. the CRC for Plant-based Management of Dryland Salinity [http://www1.crcsalinity.com/index.asp].
First harvest will depend on time of planting and weather, but except during drought the first harvest can be made 18-24 months after planting. Thereafter harvests are at about 18-month intervals. Over-frequent harvesting will adversely affect the trees.

Because the trees are harvested at ground level, soil will be prone to water and wind erosion. This can be prevented by planting pasture or a crop of some sort between the rows but not close to the trees, or by mulching with leaves from which the oil has been extracted. A machine will be needed to spread the leaves.

**Pest and disease control**

Control of weeds in the early planting and regrowth phases is essential. Cultivation is effective in a well laid out plantation where implements can be used very close to the trees. There are also effective herbicides which can be applied close to, or in some cases over, the trees and which do not suppress tree growth. Livestock, feral pigs and kangaroos can cause damage in the early stages of plantations.

The main insect pests of the mallee species such as *E. polybractea* are sawflies and case moths. Case moths in particular can spread very rapidly and defoliate the trees. This tends to occur when there is a substantial amount of leaf, but not in the early stages of growth or regrowth. A good means of control is to harvest the affected area even if it is not due for harvest.

Experience from trial plots indicates that insects and diseases may be a greater problem in establishing plantations in higher rainfall areas, than in the dry areas where *E. polybractea* and other oil-bearing mallees occur naturally.

*E. polybractea* has not responded well to more fertile soil in higher rainfall areas. Although it is likely that some suitable areas could be found, improved leaf growth would be offset to some extent by the increased cost of insect and disease control.

**Harvest and processing**

Eucalyptus oil is extracted by steam distillation. While there are other methods of extracting the oil, this is the accepted method, stipulated by national and international standards. It is a simple and cheap method.

The oil is confined to the leaves which, after harvest, are placed in a container (still) through which steam can be passed. To produce oil economically, these processes must be mechanised. The mallee type eucalypts, with their capacity to coppice vigorously, are ideal for mechanised harvesting as the whole of the aerial part of the tree can be cut off and placed in the still. The amount of non-oil-bearing stem so harvested is insufficient to warrant separation of leaf and stem and so harvesting requires only simple machinery.

By passing steam through the leaf mass in the still, the oil is vaporised; oil and water vapour are ducted to a condenser and there condensed to liquid oil and water which can be separated by flotation. The oil, being of lower density and, for practical purposes, immiscible with water, floats on the top of the water from which it can be separated easily.

The oil can be stored in drums made of high density plastic or steel (preferably but not necessarily galvanised). Although the oil is ‘wet’ at this stage, it can be stored without deterioration for several weeks before further processing.

For most uses, the oil needs to be refined, and this is best done by redistillation under reduced pressure. Thus vacuum stills and pumps will be needed.

The initial steam distillation of the oil from the leaves needs to be done close to the harvest area as...
the cost of transporting leaf more than a few kilometres is too high. Vacuum redistillation is generally not carried out on farm as the cost of the apparatus needed will be too high, unless production on the farm is large or a number of farms share the equipment.

If the crude oil is to be sent on for refining, all that is necessary is to pack it into suitable containers for transport to the refinery. If the crude oil is to be sold as crude oil it should first be dried and filtered. Steam has to be generated for the distillation of oil from the leaf and because of the low value of the oil at present, the cost of steam production must be kept low. The leaf, after the oil has been extracted, is suitable for this purpose. About 20% of extracted leaf is required as fuel, the rest should be returned to the harvested area to minimise erosion and to retain moisture.

Most oil entering the market must conform to the appropriate national standard. Refining ensures that this is so.

**Financial information**

At this stage of the industry's development it is not feasible to set up a viable operation if land and all equipment has to be purchased. However, if land and some standard items of agricultural equipment are already owned, and the cost of establishment of trees is covered by some other project, e.g. trees planted for salinity control, a profitable operation might eventually be possible. The key to success is the market price. If it remains at its present level it will be impossible to produce oil in Australia at competitive prices.

Establishment costs on cleared land, assuming a heavy tractor or bulldozer is already owned, consist of the cost of laying out the plantation, deep ripping and surface cultivation of the rows, planting, watering and weed control. If, as suggested above, these costs are not borne by the eucalyptus oil production, then the specific costs to be covered to enable production are: acquisition of a heavy forage harvester, at least three mobile distilling vessels, a boiler, lids, a condenser and oil separator, a pump and motor for circulating the cooling water plus the cost of housing for the apparatus if it is not already there. A good water supply is essential. The cost of these items, not new, would exceed $100,000 for a modest plant capable of producing about 15 t of oil per annum. At present prices, oil production is not a profitable enterprise if the oil is to be sold to the wholesale market. If retail marketing or a new oil use is being considered, margins may be greater and therefore justify the establishment of a distillation plant.

The world market price is set by China. China is moving towards a market economy and the availability of extremely cheap labour might end. However, unless a substantial new use is found for eucalyptus oil, China can more than supply the world demand, and consequently a dramatic price rise is unlikely.

### Table 1. Gross margin analysis

<table>
<thead>
<tr>
<th>Income</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil yield (kg/ha/yr)</td>
<td>130</td>
</tr>
<tr>
<td>Price ($/kg)</td>
<td>10.50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expenditure</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross Income</td>
<td>$1,365</td>
</tr>
<tr>
<td>Establishment costs</td>
<td></td>
</tr>
<tr>
<td>Ground preparation</td>
<td>$1,100</td>
</tr>
<tr>
<td>Seedlings @ $0.22 ea</td>
<td>$733</td>
</tr>
<tr>
<td>Watering</td>
<td>$800</td>
</tr>
<tr>
<td>Weed control, herbicide</td>
<td>$200</td>
</tr>
<tr>
<td>Establishment cost spread over 8 yrs</td>
<td>$354</td>
</tr>
<tr>
<td>Annual costs</td>
<td></td>
</tr>
<tr>
<td>Weed control</td>
<td>$25</td>
</tr>
<tr>
<td>Leaf/mulch spreading</td>
<td>$30</td>
</tr>
<tr>
<td>Harvest &amp; distillation</td>
<td>$750</td>
</tr>
<tr>
<td>Total variable costs</td>
<td>$1159</td>
</tr>
<tr>
<td>Annual gross margin /ha</td>
<td>$206</td>
</tr>
</tbody>
</table>

1. Yield at 200kg per harvest on an 18 month rotation.
2. Establishment costs for a perennial crop need to be spread over several years – in this gross margin 8 years has been used.
3. Harvest and distillation cost based on theoretical plant producing approximately 15 t/yr. Such a plant is smaller than current commercial plants but represents a minimum sized economic unit. Plant cost approx. $150,000 if mainly second hand equipment used.
Eucalyptus oil

Key references


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Acknowledgement is given to Lee Peterson the author of this chapter in the first edition of this publication.

Introduction

Fennel (*Foeniculum vulgare* (L.) Mill.) is a member of the Apiaceae (Umbelliferae) family. It is native to southern Europe and the Mediterranean region. Other cultivated crops of this family include parsley, coriander, dill, parsnip and carrot.

Fennel is a deep-rooted perennial crop, cultivated for the production of essential oil. The essential oil is produced in canal-like structures formed by glandular cells throughout the plant but the most prominent canals are present in the seed coat. The seeds produce approximately 60% of the oil and 90% of the anethole that is produced in the whole fennel plant.

Since fennel is fundamentally a seed crop, simple grain harvesting and handling equipment can be modified and used for harvest. The crop can be direct headed or forage harvested, depending on the type of oil required and the transportation arrangements available. Post-harvest, the crop...
is steam distilled to release the essential oil.

Australian production of fennel for its essential oil has been limited to Tasmania where production began in 1982. It was first produced for the compound anethole, which was used in many aniseed-flavoured beverages popular in European countries. The original alternative source of anethole was star anise, a member of the magnolia family. Cropping fennel enabled broad-acre production of anethole.

Recently aniseed-flavoured beverages have lost favour with consumers and fennel is now produced for fennel oil in its own right.

Markets and marketing issues

World production of anethole is about 1000t/annum. Most anethole is extracted from star anise, with China and Vietnam being the dominant producers. The production of anethole from fennel oil requires specialised rectification equipment to produce the 99% pure product that the market requires. Unfortunately, Australia was not able to remain competitive with Chinese and Vietnamese production of anethole due to improvements in the continuity and quality of the Asian supply, combined with price reductions and world-wide trends towards decreased consumption of aniseed based beverages.

Tasmanian production of fennel oil declined to about one tonne per annum in the late 1990’s compared with a high of 40t in 1992. Production has now risen to approximately ten tonnes of oil per annum. The present market for fennel oil is the flavour industry where the balance of anethole with other important flavour components is vital. Fennel is now also used in aromatherapy.

Other countries currently producing fennel oil include India, China, Egypt, Argentina, Indonesia and Pakistan.

While anethole sales in the past have been direct with end-users, fennel oil sales are generally handled through the normal essential oil marketing chain of grower via trader, to flavour and fragrance house and finally to end user or manufacturer.

Fennel umbels at fruit set. Inset: Fennel umbel with mature seed

Production requirements

Fennel has been grown successfully on a variety of soil types, from sandy loam to black cracking clay. Although it prefers alkaline soils it will tolerate soil pH’s ranging from 5 to 8.5. Soils must be free draining, particularly during winter, as fennel is a perennial crop. If the ground lies wet for any length of time, root disease and plant death will lead to a patchy crop in subsequent seasons.

The site must be open and sunny, in a cool temperate climate, ideally with an average daily temperature of approximately 20°C.

An advantage of growing fennel is its ability to improve soil structure due to the large amounts of vegetable matter that it returns to the soil and its aggressive deep rooting habit. In addition, in a mixed farming enterprise, fennel provides valuable forage as it can be grazed by stock over winter.

Once established, a fennel plant may grow to over 2m and the volume of vegetative material produced can be considerable. It is crucial to maintain cultural practices during the early development of the crop since accessibility will become very difficult later in the season. Late applications of fertiliser or pesticides must be applied from the air.

Recently production techniques have been modified to reduce the height and bulk of the crop, though this does not negate the need for aerial application of chemicals should they be
needed post-bolting. The new management strategies include grazing the crop for an extended period coming into spring and withholding fertiliser application until after flower initiation. Flower initiation is triggered by day lengths exceeding 13.5 hours when the plant has reached a minimum size of 7-8 adult leaves. At this point nitrogen-based fertiliser is applied and the crop goes on to produce a full yield of seed, carrying the full complement of oil as the traditional growing system. However, this oil is produced from distillation of 60% of the traditional quantity of plant material, significantly reducing the distillation costs.

Irrigation is essential, particularly during flowering and seed development. Flood irrigation is not recommended as this is said to cause root disease problems.

Fennel can be harvested with forage harvesting machinery similar to that used for peppermint. However, the crop does not have to be wilted and is cut at a height that mainly removes seed heads. Direct heading, using regular combine harvesters is also successful. Direct heading of the seed significantly reduces the volume of crop to be processed.

The fennel oil is extracted by steam distillation, a technique requiring specialised equipment and expertise.

**Varieties/cultivars**

The classification of fennel has been disputed by many researchers, but the general agreement today is that there is only one species, *Foeniculum vulgare* Mill. with two sub-species, *piperitum* (Bitter Fennel) and *capillaceum*, which has two varieties, Sweet Fennel and Bulb Fennel.

**Cultural practices/agronomy**

Fennel crops can be established easily by direct seeding in the spring. The target density is 10 plants/square metre. Because the seed is small, best results have been obtained using some form of precision seeder. Seeding rates vary with seed size and germination rates but are generally in the order of 2-2.5kg/ha. Seed must be sown deeply, (20-30mm) as germination is inhibited by light. Good seed to soil contact is essential for uniform germination. In general, germination takes 14 to 21 days and initial development of the seedling is slow. No herbicides can be used until the plant has developed at least three pairs of true leaves.

Recurrent selection programs have been undertaken in India and France to increase seed yield, oil content, oil quality, pest and disease resistance.

The varieties commercially grown in Tasmania are the result of a joint program by the Pernod-Ricard company and the University of Tasmania. The program was initiated by Pernod-Richard in the quest for higher yields of anethole per hectare. A wide range of selections and oil characters is available. The flavour market, in general, demands an oil with a low concentration of the intensely bitter agent fenchone.

Fennel is a typical long day plant and will remain vegetative until the day-length exceeds 13.5 hours, after which the plant initiates flowers and bolts very rapidly.

Fennel can reach maximum yields in the first year of growth and, with careful maintenance, under Australian conditions can maintain that yield for 6-7 years. Productive crops in excess of 10 years of age exist in Tasmania. Australia is lucky in this respect, since, in many other countries, the severity of *Phomopsis* disease outbreaks means that fennel must be grown as an annual crop.

Fennel is a particularly vigorous crop and can produce biomass yields of 40-60t/ha. Fertiliser requirements are therefore relatively high and annual soil analysis is required to monitor changes. Nitrogen applications are critical, especially during flowering. Actual fertiliser rates required depend upon the initial soil fertility but typically 350-400kg/ha N:P:K (3:6:8) is incorporated prior to sowing and followed up with bi-annual side dressings of 50-75kg/ha ammonium nitrate.

To date, no major trace element deficiencies have developed over a 5-year life span.

After two years the crop benefits from deep ripping. This alleviates soil compaction, promotes new adventitious root growth, and lowers shoot density. If the shoot density is not checked, yield can decrease in later years.

Fennel growing at Cressy, Tasmania
Agronomic practices are aimed at promoting maximum seed yield and maximum seed size. Crop uniformity is also important.

Harvest date prediction is not as critical as with some essential oil crops since oil composition is largely determined by variety. The more important factor is the minimisation of seed loss. The umbels on fennel mature at different rates and it is important not to leave the crop too late as the seed set on the earliest maturing umbels will shatter. Forage harvested fennel crops can be harvested earlier than direct heading which requires a lower moisture content for successful seed removal and oil extraction.

Pest and disease control

The major disease problem in fennel is a Cercosporidium fungus. This can be managed with early preventative fungicide applications to reduce the level of inoculum. High humidity during flowering will promote Cercosporidium development, such that heavy leaf loss and damage to the flowers and seed will be sustained. Late infections can be controlled by fungicide application, but usually the operator must resort to expensive aerial spraying to gain access to the crop.

A major disease of fennel in Europe is Phomopsis wilt. Where this disease is prevalent, fennel must be grown as an annual crop. To date this disease is not present in Australia.

Fennel can also be infected by Sclerotinia but infections are not usually severe.

The major yield-reducing pests of fennel are thrips, potato mirids and aphids. Particular care has to be taken with insect pest management during flowering, as bee activity is vital for pollination and subsequent seed set.

Harvest/handling/storage/post harvest treatments/processing requirements

As mentioned previously, fennel can be either forage harvested or direct headed. The stage of maturity at which each harvest type can commence varies, allowing for considerable flexibility in the harvest period and better utilisation of the distillation equipment.

The volumes of crop to be transported to the distillation unit can vary greatly between the two methods: heading allows for crops further away from the distillation unit to be economically processed. Conventional grain handling methods can be used for the handling of headed fennel seed, but as the moisture content is much higher than grain, the product has to be extracted promptly and some handling difficulties may occur. It is important that the seed has the correct moisture content at the time of harvest.

The plant and equipment used for the distillation of other essential oil crops can also be used for the extraction of fennel oil. However, if distillation facilities are used for more than one product, it is imperative that tubs and condensers and separators be cleaned thoroughly between uses as cross contamination of oils may lead to unsaleable products.

Once the oil is extracted and separated, the product is relatively stable for many months provided it is stored out of direct sunlight and away from heat. Poly-lined drums are not suitable for fennel; only galvanised or lacquered drums may be used for its storage and transport.

Financial information

Fennel crops are established by direct seeding and it is important that some form of precision seeder is used to establish the crop at the correct planting density. To date seed costs have been relatively low.

The major advantage of fennel is its robust perennial nature. Proper maintenance has allowed crops in Tasmania to yield more than nine commercial harvests.

As with most essential oils crops the major costs are those for harvest, transport and distillation. On-farm costs are limited to fertilisers, pest and disease control, and irrigation, and slashing of the stubble after harvest. In later years there are some costs associated with deep ripping or inter-row cultivation to maintain vigour.

Contractors can be used for direct heading of fennel, but forage harvesters must be modified if the crop is to be collected in this fashion.
Capital outlay for distillation equipment such as boilers, condensers, separators and tubs is considerable. In general, even with second-hand equipment, set-up costs have been in the order of $150,000-250,000 for a regional facility.

Mobile distillation units were tested in Australia but the strict regulations covering boilers have led to both economic and strategic failure.

The following table is a typical gross margin analysis for fennel oil production. As with most niche crops, the price is highly elastic while the costs are not. Growers should be aware that prices will fluctuate and significantly alter the expected gross margin.

<table>
<thead>
<tr>
<th>Table 1. Gross margin analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year 1</strong></td>
</tr>
<tr>
<td><strong>Oil yield (kg/ha)</strong></td>
</tr>
<tr>
<td><strong>Price</strong></td>
</tr>
<tr>
<td><strong>Gross income</strong></td>
</tr>
<tr>
<td><strong>Materials</strong></td>
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<tr>
<td><strong>fertiliser</strong></td>
</tr>
<tr>
<td><strong>disease control</strong></td>
</tr>
<tr>
<td><strong>weed control</strong></td>
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<tr>
<td><strong>pest control</strong></td>
</tr>
<tr>
<td><strong>Tractor and Plant</strong></td>
</tr>
<tr>
<td><strong>planting</strong></td>
</tr>
<tr>
<td><strong>fertiliser application</strong></td>
</tr>
<tr>
<td><strong>disease control</strong></td>
</tr>
<tr>
<td><strong>weed control</strong></td>
</tr>
<tr>
<td><strong>irrigation</strong></td>
</tr>
<tr>
<td><strong>slashing</strong></td>
</tr>
<tr>
<td><strong>harvest and distillation</strong></td>
</tr>
<tr>
<td><strong>Total variable costs</strong></td>
</tr>
<tr>
<td><strong>Annual gross margin/ha</strong></td>
</tr>
</tbody>
</table>

Key references


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About the author

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Key statistics

- World production of anethole is approximately 1000t/annum
- Australian production is approximately 10t/annum

Key messages

- Market has changed from anethole to fennel oil *per se*
- New techniques have improved efficiency of production
- Small market with risk of oversupply

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Introduction

Lavender is an ancient herb with a long history of use in fragrance, medicinal, culinary and aromatherapy applications.

The Lavenders are members of the Laminaceae family and the genus is divided into three main types, namely the Spica, Stoechas and Pterostoechas groups. It is the Spica group which includes the species of most commercial significance.

The three principal commercial species from the Spica group are the English or True Lavender *Lavandula angustifolia* - P Miller (syn. *L. officinalis* - Chaix), Spike Lavender *L. latifolia* and a number of hybrids of *L. angustifolia* and *L. latifolia* known as *L.x intermedia* or Lavandin.

Australia is currently a net importer of lavender oils and opportunities exist for import replacement provided the required quality criteria can be met. It is important to appreciate that a diverse range of lavender products are traded and production systems need to be selected carefully to ensure the desired outcome. To this end, a number of factors need to be considered including the planting stock, the production environment and processing infrastructure.

Production in Australia is set to increase with a large number of new operations throughout the country at the early development stage. However there are good opportunities for more new...
ventures that can target specific market niches.

**Markets and marketing issues**

Lavender products offer a range of market opportunities and most commercial operations would endeavour to capitalise on more than one revenue source. Oil and herb production complement one another well and the crop in full flower is visually spectacular, making an attractive tourist experience, particularly when augmented by suitable interpretation information covering the various aspects of production, extraction, uses and history of lavender.

The price that can be obtained for lavender oil is largely dictated by oil quality and there are various categories defined by international standards.

The highest value oil is produced from True Lavender (*L. angustifolia*) for use in perfumery. This is frequently referred to as Oil of French Lavender or French Fine Fragrance Lavender.

Most oil production is from the Lavandin hybrid cultivars which have a more vigorous growth habit and higher oil yield, but suffer the disadvantage of high levels of camphor creating limitations for cosmetic and perfume use. Because of this, the use of lavandin oils is generally restricted to general fragrance applications and blending.

Accurate global production figures are difficult to obtain but appear to be of the order of 1,200 t/yr of Lavandin oils compared to about 200 t/yr of True Lavender. Most comes from Europe, with increasing production in the United States. France was once the main supplier but production, particularly of True Lavender, has declined markedly over the last 20 years. There is now a concerted effort to reverse this situation.

Australia currently produces a little over 2 t/yr of lavender and lavandin oils and imports around 32 t/yr.

There is increasing interest in the use of lavender oil for therapeutic purposes and this area could provide significant growth opportunities. There is evidence, often anecdotal at this stage, for a range of effects including calmative, relaxant and sedative responses, as well as antimicrobial and wound healing properties. There is now a considerable amount of research being undertaken to test lavender efficacy claims.

For therapeutic use, products have to be listed on the Australian Register of Therapeutic Goods. At this stage, only oils from *L. angustifolia* are registered.

**Production requirements**

Lavenders will grow under a wide range of climatic conditions. However, since the native habitat of the Spica lavenders is the sub alpine region of Southern France, this group is generally best suited to temperate conditions. This is particularly so with True Lavender which is only found naturally at higher altitudes where, for high quality oil production, maximum

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**Key messages**

- Identify market opportunities
- Cultivar selection critical
- Good soil drainage required

**Key statistics**

- Australian production of True Lavender and Lavandin is approximately 2t/yr
- Australian imports of True Lavender and Lavandin are approximately 32 t/yr
- Global production of True Lavender is approximately 200 t/yr
- Global production of Lavandin is approximately 1,200 t/yr

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Hanging bunched lavender to dry
temperatures should not exceed 30°C, and the temperature preferably has a wide diurnal variation. Spike lavender which originates at lower altitudes and the lavandins are the preferred species for warmer locations although *L. angustifolia* can be grown in the highlands of subtropical areas such as south east Queensland. Most lavenders tolerate cold winter conditions and are frost hardy although late frosts in November or December, once flower buds have started to develop, can severely deplete spike numbers and oil yield.

Lavender is generally considered drought tolerant and well-established plants can withstand dry periods. However adequate moisture through spring and early summer when crops are harvested is important for maximum productivity, and a reliable autumn break is required to allow good regeneration after harvest and to maintain plant vigour and longevity.

An ability to irrigate via either sprinkler or trickle systems is an advantage particularly during establishment and later to counter dry periods and to allow good timing of nitrogen side dressings.

Once a suitable soil type has been identified there are a number of other site characteristics which need to be considered. A slightly undulating topography can be an advantage in helping to avoid any risk of waterlogging during extremes of rainfall, in which case it is recommended that rows are planted on the contours to minimise erosion. On the other hand excessive slopes should be avoided on larger scale plantings since access for mechanised harvest and transport systems is required.

Aspect is not critical given the maximum degree of slope likely to be employed but full sun is necessary for good flower development, hence any shading for significant parts of the day should be avoided. For this reason, proximity to trees can be a problem, and certainly any containing essential oils such as the Eucalypts must be avoided due to the added problem of potential oil contamination from fallen leaves.

Exposure to wind should be considered, especially during the flowering period. Lavender is quite robust but like any essential oil crop risks significant volatile loss if exposed to strong wind in the period leading up to harvest.

**Varieties/cultivars**

The choice of cultivar is critical for any lavender enterprise and should be selected to suit the locality and the products required. Vegetative propagation is necessary to maintain cultivar characteristics since seedling stock results in a high degree of variability, which is reflected in both the morphology of plants and the composition of any oil produced.

The requirements for oil production are very specific and the selection of cultivars generally involves a long and detailed process to ensure the resultant oils fit the chemical and organoleptic criteria of the market. Even established commercially available cultivars should be tested for any site-specific variation that might arise from differences in soil types, microclimate, aspect and management techniques.

The difficulties associated with cultivar selection can be exacerbated by poor nomenclature standards within the industry, with no formal varietal certification currently available. There are some reference collections in Australia to assist in identification, for example, the Yuulong Lavender Estate near Ballarat which holds the National Collection of Lavenders for the Ornamental Plant Conservation Association of Australia with some 120 varieties of the genus *Lavandula*.

**Cultural practices/agronomy**

Lavenders originate in France in areas which have predominantly calcareous, stony, free draining soil types. Consequently, areas for plantation lavender must have very well drained soils, preferably within a pH range of 6 to 8. Lavender requires moderate phosphate and potassium levels. Adequate potassium is important for flower development but higher levels can be deleterious. Calcium applications are important in non-calcareous soils. Lavender
responds to nitrogen side dressings in spring resulting in increased spike density and oil yield. However, excessive nitrogen can be counterproductive if too much vegetative growth is promoted since it can affect oil quality and the added bulk will increase distillation costs.

Good weed control is vital since lavender is not strongly competitive, particularly during establishment, and weed contamination can be a serious problem for oil production due to the risks of taints and the effect of additional bulk on distillation economics.

Herbicide options are limited with the only chemicals currently registered in Australia being oryzalin and oxadiazon under a general ornamental category.

Perennial weeds must be completely controlled prior to planting with broad range knock down herbicides, with inter-row cultivation and hand weeding generally required for follow up weed control.

The recommended plant density varies depending on the species of Lavender grown.

For *L. angustifolia*, a plant spacing within the row of 50 cm is preferred in order to give full row cover within 2–3 years. On the other hand, *L. latifolia* and *L. intermedia* are generally planted at 80 – 100 cm spacings, depending on the vigour of the particular cultivar. Inter-row spacing should be set to suit the equipment and the practices chosen to manage the crop. Typical row spacing is around 1.8 m to allow tractor access.

**Pest and disease control**

Lavender is generally relatively free of pests and diseases. Aphid damage has been reported and can provide a vector for virus infection, particularly the Alpha Mosaic Virus.

If mulch is used, care should be taken with the selection of materials since some can introduce or encourage insect problems. For example, lucerne mulch has been associated with increased aphid difficulties and the Alpha Mosaic Virus.

The spittle bug (*Philaenus spumarius*) is often found in crops in early summer but causes no economic damage unless the crop is grown for the cut flower market.

Fungal problems are rare although root rot conditions will develop if soil structure and drainage are poor or when roots are damaged by inter-row cultivation practices. Nematode damage has also been demonstrated but tends to become significant only when other plant stressors exist.

**Harvest/handling/processing requirements**

The scale of lavender enterprises starts with fairly modest operations producing fresh and dried flowers and associated products, with and without oil production, giving annual revenues less than $20,000.

At the other end of the scale are businesses which encompass all aspects of the industry, employing 10 or more staff with 7 figure revenues.

The infrastructure required at the different levels of production naturally varies tremendously.

For the larger oil producing ventures, the harvest has to be mechanised to be able to handle the volumes involved. As an example, Bridestowe Lavender Estate with up to 50 ha under lavender at any one time uses a system which forage harvests the flower heads directly into 250 kg distillation vats trailed behind the harvester.

As each is filled, it is quickly transported to the distillery to be processed in one of three diesel fired water bath stills.

Bridestowe also has mechanised systems for dried flower production. Flowers are dried initially on a large external drying pad, then picked up using a tractor mounted vacuum system before transporting to on-site cleaning facilities where the dried herb is screened and sorted into different product categories.

**About the author**

Robert McEldowney is an agricultural scientist with 18 years experience in the essential oil industry. He has experience in all aspects of essential oil production including development of agronomic systems and harvest and extraction technologies relating to a broad range of crops. He is currently General Manager of Essential Oils of Tasmania Pty Ltd.
Financial information

It is impossible to quantify typical returns from lavender enterprises because the range is so diverse. For operations concentrating on oil production, indicative market prices can be obtained, but in most cases there is some degree of value adding, which is enterprise specific.

Like most essential oils, bulk oil prices are quite variable and depend on the quality of the oil and the supply/demand dynamics at any given time. Indicative figures show a range from as high as $A250/kg for top quality True Lavender (although the bulk of sales are probably nearer to $A150/kg), through to around $A30/kg for Lavandin blends.

To some extent, the price disparity is offset by the productivity of the different lavender types. Again, only indicative figures can be offered but generally commercial Lavandins can be expected to yield up to five times as much oil per unit area as L. angustifolia cultivars.

Establishment costs are site specific and can vary significantly depending on the preparation requirements and the type of irrigation installed, if any. Planting stock will always be a major cost since propagation via cuttings is fairly laborious. With up to 12,000 plants per hectare generally involved, plant costs should be negotiated with the relevant nursery – as a guide figures from $A500 to $A1,000 per thousand plants can be expected, depending on the numbers ordered. When time permits, capital outlay can be reduced by establishing field nursery areas. This allows cultivars to be assessed under local growing conditions and those selected for expansion can be used for propagation stock via either semi-hardwood cuttings or splits planted directly into new areas.

Prospective lavender growers should seek detailed advice from industry representatives.

Key references


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Mint oils

Lee Peterson

Acknowledgement is given Fred Bienvenu, the co-author of this chapter in the first edition of this publication.

Introduction

The two main mint oils that have been produced in Australia are Peppermint and Spearmint oil. Peppermint oil is obtained from the leaves of the perennial herb, Mentha piperita L. whilst there are two types of commercial spearmint oil obtained from the leaves of the perennial herbs, Mentha spicata L., more commonly known as native spearmint, and Mentha cardiaca L., Scotch spearmint.

All are members of the Labiatae family. This family includes many well-known essential oil plants such as spearmint, basil, lavender, rosemary, sage, marjoram and thyme. The mint plants are summer-growing perennials with upright square stems reaching a metre in height at maturity.

The oil is found on the undersides of the leaves, is extracted by steam distillation and is generally followed by rectification and fractionation before use. The major end-uses are in toothpaste and mouthwashes, chewing gum and food flavourings.

Commercial production of spearmint oil has declined over the
last 5 years and only small plots of reference material remain in Australia.

World production is more than 5000 t/year, with the USA accounting for 90% of this and being, in addition, an importer and re-exporter.

The increase in world-wide demand is currently running at about 5% a year, predominantly as a result of Asian market expansion.

The environmental conditions under which peppermint is grown are critical to the quality of the oil produced and limit the areas suitable in Australia to Tasmania and Victoria. Long day lengths with warm to hot conditions and cool nights are required for the right balance of oil compounds to be produced during the growing phase. Most of Tasmania is therefore suitable and in Victoria the agricultural areas adjacent to the alps in the north-east of the State provide the right growing conditions. The environmental requirements for spearmint cultivation are not as narrow as those for peppermint. Nevertheless, as the general growing requirements, management practices and harvesting techniques are the same for both crops, spearmint is grown in the same production localities as peppermint.

Production has been under way in both these regions for many years but recent expansion in the Victorian region has now ceased and is limited to the Corryong region.

Production techniques are based to a considerable extent on U.S. practices and require a high level of capital input and expertise to produce a saleable product.

Markets and marketing issues

Prices in world markets are dictated by conformity with the characteristics of U.S.-produced oils, which differ from region to region. ‘Lower quality’ peppermint oils typically command a market price of about $A30/kg, whereas ‘higher quality’ oils can fetch up to $A60/kg.

The price of spearmint oil fluctuates year to year, with native spearmint at 20–40% lower than peppermint oil and Scotch spearmint 0–10% higher than peppermint oil. Maximum prices are achieved only if the major oil components, carvone and limonene, are in the correct balance with other flavour components.

The buyers’ primary concern is the quality and flavour of the product and the consistency from year to year. This largely stems from the need for a consistent taste in the end-product formulated and delivered to customers.

The world-wide trade in mint oils is generally from growers to traders who may blend or rectify the oils from many growers or even regions to provide a consistent product to the flavour and fragrance houses which then supply pre-formulated product to the manufacturer.

Sales direct to flavour and fragrance houses and manufacturers do occur but require considerable long-term marketing commitment and well established production history.

The level of pesticide residues in the oil is now a key marketing issue. The top end of the market is very discerning and well equipped for residue detection.

Production requirements

Climatic constraint of areas suitable for peppermint oil production has already been mentioned. A major factor in this context is to minimise the production of less desirable compounds, in particular menthofuran.

All mints require a relatively free-draining soil type with a pH of 6–6.5. Areas that lie wet in winter will not perform vigorously and plants may even die. Inundation during the growing season has even greater harmful effects.

The crop has high water demands in the summer. Crops are currently grown under managed flood, high pressure and low pressure irrigation systems. It is the ability to adequately irrigate

A 200 litre drum of export peppermint oil is sufficient flavouring for over 100 tonnes of toothpaste.
which normally limits the growth or expansion of peppermint areas.

Pest and disease management are paramount and efficient broadacre spray equipment is a prerequisite.

Spearmint differs from peppermint in that a healthy crop will regularly produce two harvests each season whereas peppermint usually produces only one harvest. In general, experience has shown that it is better to concentrate on maximising the oil potential for one harvest because of the high costs of harvest and the additional costs of disease management with double harvest.

Harvesting uses conventional forage harvesting technology but distillation of the oil requires specialist equipment and expertise and needs to be regionally based as large volumes of material must be processed.

**Varieties**

*Mentha spicata* L. and *Mentha cardiaca* L. are sterile perennial herbs, and therefore must be propagated vegetatively. *Mentha spicata* L. is characterised by a high carvone content which accounts for 60-70% of the total oil analysis, accompanied by a limonene content of 8-15%. The odour profile of native spearmint is a fresh and green with very high floral topnotes. The body of the oil is warm and herbaceous.

The carvone content of *Mentha cardiaca* L. is also 60 and 70%, but typically it has a higher limonene content of up to 20%. The oil also has a menthone content of up to 2%. This is the prime indicator of Scotch spearmint oil.

The odour of the oil is light, fresh, and diffusive, with an ethereal topnote and a woody, rapid body expansion. The body of the oil is typically very sweet.

*Mentha piperita* L. is also a sterile, perennial herb and therefore must be propagated vegetatively.

Two main selections are currently in commercial usage throughout the industry. Black Mitcham is the original cross. It is highly valued but susceptible to a soil-borne fungal disease, verticillium wilt.

Todd Mitcham is a more wilt-tolerant selection which now forms the bulk of the world’s production.

Both selections are present in Australia where, to date, verticillium wilt has not been detected.

**Agronomy**

Using stolons from a nursery site of 1 ha, a cropping area of 7-10 ha can usually be achieved the following year.

As the mints are a perennial crop, pre-planting weed control is imperative for the long-term viability of the crop. A well-planned fallow and weed eradication program before planting is therefore strongly recommended.

Specialised lifting equipment is used in Victoria and Tasmania to lift plants and remove soil. In Victoria, a specially designed planter is used to place stolon...
fragments evenly in rows. These rows rapidly close over and form a dense canopy in summer. In Tasmania lifted stolons are spread using modified muck spreaders followed by a light discing. Both planting processes work well.

Strong healthy planting material is essential for correct density of established crop.

Fertiliser rates are generally high, as development of the maximum number of leaves and their retention through to harvest is the target. Frequent nitrogen applications are required through the growing season and careful maintenance of soil fertility is needed to ensure the crop remains productive. A commercial crop correctly maintained will yield well for at least 5 years.

Because the mint plant is very succulent, proper timing of all operations is critical for the retention and maximisation of oil glands in the leaves. Oil yield will decrease rapidly if the plant is subjected to either physiological or pathological stress.

**Pest, disease and weed control**

The most significant disease problem encountered with all mint plants is a rust fungus which, if left unchecked, will totally defoliate the plants.

The current method of control is to use the fungicide ‘Tilt’ at strategic times in the life cycle of the rust fungus. The other important factors for control are efficient spray application, removal of any areas that are hard to spray and removal of rogue plants. Scotch spearmint appears to be more sensitive to rust attack than the native spearmint, but both are prone to significant oil loss if the rust is left unchecked.

Pest problems encountered in Australia include cut worms, twospotted mite, brown vegetable weevil and wingless grasshopper.

Weed control programs must be strictly maintained to reduce plant competition but more importantly to eliminate oil contamination. There are a range of herbicides, fungicides and insecticides registered for use in mint crops or under minor use permits, but these should be reviewed annually to ensure that they are current.

**Harvesting, transport and distillation**

The timing of harvest is critical to the quality of the oil. In Tasmania and Victoria an extensive pre-harvest sampling program is employed to schedule harvesting of all mint crops. This sampling examines changes in oil composition from early January onwards.

Mint crops are mown using conventional hay mowers or windrowers. It is very important not to bruise any of the leaves at any time during harvest as this will result in oil losses.

Once the cut herb is wilted it is chopped directly into a distillation vessel, usually referred to as a tub, using a forage harvester. The correct moisture content of the herb is essential for complete and economic oil extraction.

The tubs are then transported to the distillation facility where either wet or superheated steam is passed through the herb and the resulting steam and oil vapour are condensed and separated.

Condensing and separation equipment should be
manufactured from stainless steel and general processing hygiene followed to ensure no contaminants are present.

In general, the most-economic units distil five or more tonnes of herb at a time. The time for oil extraction varies depending on the type of steam source, the herb weight and the moisture content.

Most distillation units are diesel-fired but wood-fired units are used in Tasmania with success.

Once the oil is separated, the product is relatively stable for many months provided it is stored out of direct sunlight and away from heat. Epoxy-lined and galvanised drums are the commonly used storage and transportation units.

**Financial information**

The costs of establishing a mint crop are considerable because propagation is vegetative, as described above. In general, a minimum area of 5 ha is needed within an existing essential oil distillation region of radius 30 km. For a distillation region to be viable a minimum of approximately 80 ha is necessary.

Capital outlay is considerable for dedicated equipment such as boilers, condensers, separators, tubs, and planting equipment. In general, even using second-hand equipment set-up costs have been in the order of $150,000-250,000 for a regional facility. Table 1 shows the gross margin analysis.

**Key references**


Aretander (1960) Perfume and Flavor Materials of Natural Origin – Aretander


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**About the author**

Dr Lee Peterson is an agricultural professional with extensive expertise in many aspects of agricultural production gained over a period of 20 years in industry, consulting and research. Considerable experience in the development of new crops and production systems with a particular emphasis on essential oils combined with expertise in a wide range of annual and perennial cropping systems provide Lee with a unique range of skills.
# Mint Gross Margin

## Enterprise Output

<table>
<thead>
<tr>
<th>Yield:</th>
<th>65kg/ha mint oil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price:</td>
<td>$40.00/kg</td>
</tr>
<tr>
<td><strong>Total Enterprise Output</strong></td>
<td><strong>2,600</strong></td>
</tr>
</tbody>
</table>

## Variable Costs

### Materials:

- **Planting material - stolons**: 400kg/ha @ $100/ha = 100
- **Fertiliser**:
  - 0:7:12: 400kg/ha @ $325/tonne = 130
  - **Ammonium Nitrate**: 400kg/ha @ $500/tonne = 200
  - **Cartage**: 800kg/ha @ $13.50/tonne = 11
- **Weed Control**:
  - **Terbacil**: 1.5l/ha @ $88.00/litre = 132
  - **Spot spraying**: 0.2l/ha @ $88.00/litre = 18
- **Disease Control**:
  - **Propiconazole**: 2.5l/ha @ $85/litre = 213

### Tractor and Plant:

- **Land Preparation**:
  - 4hr/ha @ $5.26/hr = 21
- **Stolon Collection - 2 operations**:
  - 2hr/ha @ $8.09/hr = 16
- **Stolon Spreading - 2 operations**:
  - 2hr/ha @ $8.09/hr = 16
- **Stolon Discing-in**:
  - 1.5hr/ha @ $5.26/hr = 8
- **Harrowing**:
  - 0.8hr/ha @ $5.26/hr = 4
- **Rolling**:
  - 0.5hr/ha @ $5.26/hr = 3
- **Fertiliser Topdressing - 4 operations**:
  - 2.4hr/ha @ $2.83/hr = 7
- **Weed Control - 2 sprays**:
  - 1.2hr/ha @ $2.83/hr = 3
- **Disease Control - 2 sprays**:
  - 1.2hr/ha @ $2.83/hr = 3
- **Mowing for Harvester**:
  - 1hr/ha @ $2.83/hr = 3

### Contract Operations:

- **Soil Analysis**:
  - 1analysis @ $30.00/field = 2
- **Hire of Potato Lifter**:
  - @ $55.00/ha = 55
- **Hire of Muck Spreader**:
  - @ $45.00/ha = 45
- **Harvesting & Distillation***:
  - @ $650/ha = 650

### Irrigation:

- **Running costs**:
  - 300mm/ha @ $19.70/25mm = 236

## Total Variable Costs

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Variable Costs</strong></td>
<td><strong>1,976</strong></td>
</tr>
</tbody>
</table>

## Gross Margin - Establishment Year

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GROSS MARGIN</strong></td>
<td><strong>624</strong></td>
</tr>
</tbody>
</table>

---

Table 1. Gross margin analysis
**MINT GROSS MARGIN (cont.)**

**Year 2 to end of productive life.**

<table>
<thead>
<tr>
<th>ENTERPRISE OUTPUT</th>
<th>$/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield:</strong></td>
<td>65kg/ha mint oil</td>
</tr>
<tr>
<td><strong>Price:</strong></td>
<td>$40.00/kg</td>
</tr>
</tbody>
</table>

Total Enterprise Output: 2,600

**Total Variable Costs: 1,469**

**GROSS MARGIN - Successive years: 1,131**

*Fuel cost only.  
**Land preparation is assumed to consist of one disc ploughing, two tyne cultivations and one harrowing  
***Harvesting costs will vary with district and farm. Raking & baling may require night operations to ensure premium quality, thereby increasing costs.  
****Combined in single application.

**Key messages**

- Environmental/climatic conditions critical for saleable product
- Capital costs high due to specialised machinery and extraction facilities needed
- Field expansion costly and slow

**Key statistics**

- World production 5000 t/year
- World consumption increasing by 5% per year
- Australian production 15 t
Parsley oil

Linda Falzari

Introduction

Parsley, from which parsley essential oil is produced, has the species name *Petroselinum sativum* Hoffm. (formerly *Apium petroselinum* L.) or *Petroselinum crispum* (Mill) Nyam. A third synonym, *Carum petroselinum* Benth. is seldom used.

The species is usually divided into two varieties separated by leaf shape and commonly named Curled Parsley and Italian Plain Leaf parsley.

The essential oil products produced from parsley fall into three categories; leaf oil, herb oil and seed oil. Clearly, leaf oil is produced by distillation of leaves while seed oil is obtained through distillation of mature seeds. Herb oil is produced by distillation of the whole flowering plant while it has immature umbels.

Each type of oil has its own particular characteristics. In addition, different cultivars also produce oils with different characters. It is not possible to define “good quality oil” as the characteristics required vary immensely between end-product users. The chemical components important in imparting each parsley oil with its characteristic organoleptic qualities are menthatriene, elemicin, TMAB (tetramethoxyallylbenzene),

Leaf types are used to classify parsley cultivars. The curled leaf form is on the left, the plain or flat leaf form is on the right.
myristicin and apiol. Each oil will have specific concentrations and combinations of these compounds.

**Markets and marketing issues**

The world market for parsley oil is fragmented into a series of niche markets, with each end-user demanding oil of a particular organoleptic character. Penetration of established niche markets is difficult for new suppliers because the markets are small and limited. Current end-users are usually unwilling to take on new suppliers unless forced to do so by external forces such as political instability or irregular supply. Generally each parsley oil niche market is well supplied by current growers and oversupply is a serious risk to future production. New producers may need to seek new niche markets.

Currently Tasmania produces approximately 3.5t of oil from the 70ha of parsley grown in the state. This is exported to Europe, USA and Japan. Tasmanian production supplies about 50% of the world trade in the herb oil of that particular niche market.

Parsley oil is also produced in USA and European countries, including amongst others Germany, France, Holland and Hungary.

**Production requirements**

Parsley prefers a cool, temperate climate and has an optimum, average daily temperature of 20°C. It is well suited to production in south-eastern Australia.

Soil for parsley production needs to be free-draining in order to avoid root disease, particularly through the winter months. Sandy loam is an ideal soil type. The pH may vary from 5 to 8.5 but parsley is more productive on the more alkaline soils.

Irrigation is essential, first during crop establishment and later during flowering. Flood irrigation is not recommended as it can lead to root disease.

A precision seeder should be used to sow the crop, since regular plant spacing will produce a more even crop at harvest time. A forage harvester will be required at harvest time. Post-harvest the crop is steam-distilled to obtain the oil, therefore access to a distillery is necessary.

**Key statistics**

- World market is fragmented into a series of niche markets
- Australian herb oil production is 3.5t/annum
- Seed oil market is less than 5t/annum

**Key messages**

- Establishment costs are high
- Risk of oversupply of niche markets
- Careful control of oil separation imperative

Irrigation is essential, first during crop establishment and later during flowering. Flood irrigation is not recommended as it can lead to root disease.

A precision seeder should be used to sow the crop, since regular plant spacing will produce a more even crop at harvest time. A forage harvester will be required at harvest time. Post-harvest the crop is steam-distilled to obtain the oil, therefore access to a distillery is necessary.

**Varieties/cultivars**

As detailed in the introduction, parsley oil cultivars are usually divided into two groups based upon leaf shape. They are Curled Parsley and Plain Leaf parsley. The nomenclature for these varieties varies but typically the former, with the curled or crinkly leaf morphology is known as *P. crispum* var crispum. The latter, with the plain or flat leaf type is called *P. crispum* var *neapolitanum*. Plain leaf parsley is also referred to as Flat leaf parsley or Italian parsley.

Another classification of parsley is based on the chemical composition of the oil rather than the morphology of the leaves. The races are separated on the relative concentrations of three of the main oil components i.e. myristicin, apiol and 2,3,4,5-tetramethoxyallylbenzene (TMAB). Each race carries the name of the compound (myristicin, apiol or TMAB) that is highest in concentration. Two mixed races have been also identified.

Parsley of the curled type e.g. “Triple Curl” tends to belong to the myristicin race, while Plain Leaf varieties e.g. “Dark Green” belong to the apiol race. The plain leaf variety “Napoli” belongs to a mixed race, since it produces oil with similar concentrations of both myristicin and apiol.

The superior cultivar for a particular niche market can only be selected once the requirements of a particular end-user are known. In Tasmania, Triple Curl parsley is currently
Parsley oil

Pest and disease control

*Sclerotinia* is perhaps the most economically important disease in parsley. It is a ubiquitous, soil-borne disease requiring management with an effective fungicide program. Growers need to contact the Australian Pesticides and Veterinary Medicines Authority (APVMA) for advice and if necessary, a Minor Use Permit, prior to using any chemicals which are not registered within their area.

*Septoria* leaf spot can be a problem in parsley, more so in Plain Leaf varieties than the curled types. This is a seed borne disease so a clean seed source is desirable. It is also spread through water splash. It can be controlled with copper. Again, a permit is required.

The major pest in parsley is the aphid.

Harvest/handling/storage/post harvest treatments/processing requirements

The optimum time for harvesting parsley is determined by the desired oil composition. The balance of components in the oil changes throughout the growing season, as the crop passes through each maturity stage. For example, leaf oil has higher menthatriene concentrations than floral oil and the immature flowers have lower concentrations of apiole than the mature seed. The best method for determining optimum harvest time is to take pre-harvest samples on a regular basis and to analyse the oil yield and composition of these.

Since oil yield is higher in floral rather than vegetative material, oil yield increases as the season progresses. Optimum harvest time is often a compromise between maximum oil yield and premium oil composition. A further consideration in the production of seed oil is that although dry seed has the highest oil content, dry mature seed is very resistant to steam distillation. Steam does not penetrate the seed coat well, making extraction of the oil slow, inefficient and often uneconomical.

Generally harvesting is undertaken using a modified forage harvester. After cutting, the crop is allowed to wilt in the field for one to two days prior to distillation. This reduces the moisture content, giving better steam penetration through the charge during distillation.

Typical fuels burnt to power steam generation are wood, diesel oil or coal. Usually, low-pressure steam is used for the distillation of parsley.

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The duration of distillation affects not only oil yield but also oil quality. Mentha triene has a higher vapour pressure than the other components measured and appears at higher concentrations at the beginning of the distillation. Menthatriene concentration falls with increasing duration of distillation while apiole concentration rises. More of the volatile compounds will appear at higher concentrations in the first fractions of oil collected in the separator. These include compounds such as mentha triene. Elemicin and TMAB will increase in concentration as distillation continues, followed by myristicin and finally apiole. Adjusting the duration of distillation may help produce oil of the desired composition for a particular niche market. Economic aspects, especially the cost of additional fuel, need to be considered when determining the duration of distillation.

Parsley oil forms both a heavy and light fraction in the separator. Separators must be designed so that the oil can be drawn off from both the top and the bottom.

It is possible to make some modification to oil composition by collecting oil fractions from the separator during the distillation instead of collecting the entire yield at the end.

A significant problem to be addressed is the loss of oil in the wastewater discharged from the separator. Parsley oil has a specific gravity very close to that of water, meaning that separation by density is not always complete. Careful control of condenser and separator temperatures is necessary to gain good separation. It is important to minimise turbulence within the separator and maximise the time available for separation of the oil and water distillate. This can be achieved by the use of two separators in series. The first separator should be quite warm to allow separation of the light fraction oil. The draw-off point for this separator should be as low as possible. The second separator should be relatively cool to allow separation of the heavy fraction i.e. to maximise the difference in specific gravity. The use of a high draw-off point on the second separator will maximise recovery of heavy oil.

The first separator should be maintained at a relatively warm temperature (~50°C) in order to maximise separation of the light oil fraction. The temperature of the second separator should be as low as possible, without falling below 30°C in order to maximise separation of the heavy oil. The minimum temperature must be held above the melting point of apiole (29.5°C) or the apiole will solidify.

Starting with the separators empty is of benefit in reducing loss of oil, by allowing more of the distillate to be held for longer and increasing the time available for separation.

The marc (spent plant material) from the distillation can be a valuable mulch material once it is cooled.

Essential oil storage must take into account that the oils are volatile and flammable. The composition of parsley oil is also unstable. Menthatriene is degraded by a photooxidative process. Storage should be in full containers, in a cool dark place.

### Financial information

Prices for parsley oil are highly elastic and heavily dependent upon the volumes of oil being traded.

Oversupply is a significant risk to any particular niche market.

Prices are in the order of $100/kg oil for herb oil and $200/kg for seed oil. Of course, these prices are dependent on the producer being able to supply oil of the composition desired by the particular end-user.

Market sizes are small, even in comparison with other essential oil products. The parsley seed oil market is less than 5t per annum. The current Tasmanian herb oil market is around 3.5t per annum.

The gross margin supplied in Table 1 is tentative and should be taken as a rough guide only. Both price and yield will fluctuate dramatically, although the costs of production tend to be quite stable.

#### Table 1. Tentative gross margin for Parsley (per hectare)

<table>
<thead>
<tr>
<th>Oil yield (kg/ha)</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price ($/kg)</td>
<td>85</td>
</tr>
<tr>
<td>Gross income</td>
<td>3,400</td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td></td>
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Key references


http://www.hort.purdue.edu/ newcrop/med-aro/factsheets/parsley.html (12/3/04, 11am)

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Dr Linda Falzari is a researcher with the Essential Oils Group at the University of Tasmania. She has spent the last ten years studying the cultivation of essential oil crops and the production of essential oils and extracts.
Introduction

West Australian Sandalwood oil is obtained from the heartwood of *Santalum spicatum* which is an indigenous species of sandalwood with a natural distribution that covers a large proportion of the western half of the Australian continent.

*Santalum spicatum* is a small tree with olive green foliage, that assumes a rounded habit. Sandalwood is often described as “scrubby” and produces numerous branches from a relatively short trunk.

The production of sandalwood oil and its associated use pre-dates written history. However, the commercial utilisation of the species endemic to the western half of the Australian continent did not commence until 1845. Prior to this date Indian sandalwood *Santalum album* was the predominant sandalwood species used in Asia, the Middle East and North Africa.

West Australian sandalwood produces a range of products including timber and powders but the oil it produces provides a number of unique opportunities. There is a growth in markets willing to use West Australian sandalwood oil due to the limited and decreasing availability of Indian sandalwood oil. West Australian sandalwood oil has application in the perfume, incense and complementary medicines markets providing the opportunity...
for producers to target a number of market segments.

West Australian sandalwood has been identified (RIRDC Publication No. 00/173) as having potential as a bactericide.

The primary challenge for West Australian sandalwood oil is the education of markets that have traditionally used Indian sandalwood oil. West Australian sandalwood oil cannot be used as a direct substitute for Indian sandalwood oil and has its own unique characteristics.

The strength of Australian production is the credibility of Australia farmers on the global stage accompanied by the stable political and economic climate that allows resource security over the timescales required to achieve a profitable harvest.

Many of the world’s leading perfume houses will only invest in developing a new perfume if they are certain the supply of key ingredient can be maintained for the foreseeable future. Australian growers can offer certainty of supply with guaranteed quality.

Demand for West Australian sandalwood is increasing. Domestic demand for raw material has increased significantly over the past five years from less than ten tonnes per annum in 1998 to approximately 700 t in 2003.

Total production of West Australian sandalwood oil is approximately 12 t/annum.

Commercial oil production is almost entirely located in WA and relies on the natural harvest of 2000 t/annum, which is strictly controlled by the Forest Products Commission of WA (FPC). However a number of small research trials and feasibility studies are under way in the Eastern States.

At least 1000 ha of private plantations have been established in Western Australia and less than 200 hectares in SA and NSW combined. The rate of private plantation establishment is increasing and is estimated to be in the order of 500 ha/annum. Currently there are no known overseas growers of S. spicatum.

Potential growers must have a long-term outlook and a thorough understanding of tree growing fundamentals.

**Markets and marketing issues**

Quality assurance is critical to potential buyers of wood or oil. Growers should determine whether they choose to be a supplier of wood to an oil processor or whether they wish to become an oil producer.

In either case, production techniques must be environmentally sustainable and minimise the use of chemicals in the plantation.

Producing sandalwood oil for sale to an oil buyer is only an option if quality control can be maintained. As sandalwood oil is used as a raw material in a range of products it is critical that sources of contamination of oil at all stages of processing are eliminated. This may prove difficult for small-scale operations.

Foreign oil producers normally obtain their sandalwood in a powder form from importers or powder men. Large foreign oil producers, most notably in India, powder sandalwood purchased direct from government auctions or importers to their own standards.

Domestic oil producers purchase sandalwood powder from the FPC.

Oil processors will not tend to buy direct from a sandalwood grower.

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**Key messages**

- Industry is in its infancy
- Long term crop
- Capital costs for oil production high due to specialised equipment and techniques required for extraction
- Markets require product to be free of all chemical contamination

**Key statistics**

- Current estimated Australian sandalwood oil production 12t/annum
- Current estimated Indian sandalwood oil production 150t/annum
- Indian Government sandalwood production has declined 20% in 12 years
- Indian Government price for sandalwood has increased over 80% in 12 years
Australian sandalwood oil sells for between $350 and $600/kg depending on the grade of the oil.

The global trend for sandalwood is that demand is unable to be satisfied from traditional sources due to overexploitation in many countries and strict environmental controls in Australia. This has opened a window for plantation grown sandalwood.

**Production requirements**

Sandalwood requires drained sites in areas with a mean annual rainfall of 400 – 600 mm. The preferred soil type is sandy-loams over clay. The soil depth should be at least 1.5 m. Soils comprising white or grey sands, heavy clay soils and sites prone to waterlogging or salinity are to be avoided.

There are no existing cultivars or varieties that have been developed. However a tree breeding program has been established and work is being undertaken by the FPC to examine the heritability of sandalwood oil yield and quality. Trials are also underway in Queensland, the Northern Territory and WA to investigate the potential of other *Santalum* species.

It is important to note that the quality of sandalwood produced from plantations will not match naturally grown sandalwood. This is due to the faster growth rates achieved in plantations which in turn leads to a lower proportion of heartwood in plantation grown sandalwood when compared to an equivalent diameter sandalwood log from a naturally grown stand.

*Note: Santalum spicatum seed can be purchased from the FPC and native seed merchants.*

**Establishment**

As sandalwood is a parasite it is necessary to establish host plants that will survive for the expected rotation period of the plantation. Research indicates that nitrogen-fixing legumes are suitable hosts. The preferred host for most plantations has been Jam (*Acacia acuminata*). Recent research is indicating that *Acacia saligna* may also be a good host but only in the initial stages of the plantation rotation as it is not particularly long lived.

In the establishment year the planting area should be ripped on lines 4m apart with a single tyne ripper to a depth of 0.5 m between March and May. Weed control should be undertaken using a control method appropriate to the site using either chemical, mechanical or organic means as preferred. In July or following a minimum of 50mm rainfall, plant Jam seedlings along rip lines at 2m spacings. This will provide 1,250 Jams/ha.

Follow up seeding of sandalwood can occur in the following year or two years after initial host establishment. Timing is dependant on the survival rate and vigour of the host plants.

To seed the area, plant one sandalwood seed 0.5 to 1 m from each Jam seedling. Plant the seeds 2–3 cm below the surface in the rip line. A critical factor in successful establishment relies on each sowing spot being free of weeds before the sandalwood seedlings emerge. Due to the extreme variation in the target weeds species that may be encountered...
and the significant variation in climate and land systems on which sandalwood can be established, it is not possible to provide specific information on weed control methods.

During the following year sandalwood seedlings that have successfully established should be thinned to 400 stems/ha to obtain a ratio of 1:2 sandalwood to hosts or a ratio of 1:3 on harder sites with lower rainfall.

Sandalwood may need to be pruned to ensure growth is concentrated in one main stem. During the mid term of the rotation an application of fertiliser may be required to maintain the health and vigour of the hosts. A good local nursery will be able to provide advice on the most suitable fertiliser for native species in the area.

Sandalwood plantation establishment utilises standard equipment used in tree establishment. Growers considering on-site oil extraction would need to invest considerable funds in setting up an extraction facility. The minimum cost of setting up a suitable scale plant is estimated to be in excess of $100,000. However extraction technology is improving rapidly and processing equipment is likely to fall in price by the time plantations are ready for harvest.

The time taken for sandalwood to reach harvest is dependant on the site and rainfall. As a general rule sandalwood will take a minimum of twenty years to produce a suitable size log that has enough heartwood of suitable quality for oil production.

Ongoing maintenance of the plantation is minimal apart from initial weed control in years one to three. Sandalwood does not have any major pests or diseases and the main threats are fire and unintended grazing by stock.

It is important to maintain a sandalwood to host ratio of at least 1:2 throughout the rotation period of the plantation. If host trees appear under stress or have died then infilling with new host seedlings should be undertaken to maintain the correct ratio.

**Harvesting and processing requirements**

Sandalwood trees are harvested by complete removal from the ground. This is due to the large amount of heart wood contained in the butt and roots of the tree. This is normally achieved by “pulling” the tree from the ground using a small loader or large tractor.

The stem is then cut into short lengths of 0.5 to 1 m. The pieces are debarked using mechanical tumblers or high pressure water cleaners. At this point the sandalwood can be packed and transported to a buyer or broken down further for oil production.

Prior to oil processing the sandalwood is broken down into a powder or pre-grind. This is similar to coarse sawdust. The powder is then placed in an extraction vessel and oil extraction is undertaken by either steam or solvent extraction methods. Steam distillation requires steam to be passed through a “charge” in an extraction vessel over an extended period of time, up to 100 hours. The condensate containing water and oil is collected and the oil separated and bottled. Solvent extraction is a more technical process and requires specialised equipment to operate at a commercial scale.
simplified terms a solvent is mixed with the sandalwood “charge” and heated. The solvent containing the oils is then re heated and recaptured leaving behind only the sandalwood oil.

Financial information

The initial establishment cost of a sandalwood plantation is slightly higher than normal tree crop establishment on a comparable site. Additional costs are incurred due to the need to direct seed the sandalwood seed after the establishment of the host species.

Trials to date indicate that four to five tonnes of sandalwood can be produced per hectare over a twenty year period. At a current domestic market value of $5,000/t the gross return per hectare is approximately $22,500. The yield of oil from one tonne of Western Australian sandalwood averages 2%, by weight (20 kg). At a price of $500/kg the gross return from oil production is estimated to be $10,000/t or $45,000/ha.

Oil processing costs are highly variable and dependant on the method of processing and the scale of the plant. It is vital that prospective growers recognise that the plantation sandalwood industry is in its infancy in Australia and the above prices represent the current supply/demand scenario. It is expected that as supply increases there will be a corresponding fall in prices paid. Future prices, in today's terms are estimated to be in the vicinity of $4,000/t for wood and $350/kg for oil. This would provide gross returns of $18,000 for wood or $31,500 for oil per hectare, in today's dollar terms.

Key references

Brand and Jones. (1997) Growing Sandalwood (Santalum spicatum) on Farmland in Western Australia. Forest Products Commission WA.


Table 1. Establishment and harvesting costs per hectare

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Acknowledgement is given to John Murtagh, the author of this chapter in the first edition of this publication.

Introduction

Tea tree can hardly be classed as a new rural industry as it has been distilled for the production of medicinal tea tree oil for 80 years. It is only in the last 20 years that *Melaleuca alternifolia* has been cultivated intensively as a commercial agricultural crop. Producers were able to use existing eucalyptus oil technology as a model, adapting where necessary to cater for the peculiarities of this steam-distilled oil producing crop.

While sourcing oil from natural stands of this Australian native plant, tea tree remained a cottage industry. When sourced from plantations, production increased rapidly, peaking in the late nineties before falling back to more sustainable levels. Most of these plantations are located on Australia’s sub-tropical and tropical eastern coastal hinterland.

Once established, tea tree is a hardy perennial crop which survives well. Plantings established 20 years ago are still giving good yields. Apart from the normal horticultural crop skills required for such farming practices, mechanical expertise in the harvesting and distillation areas will also reduce costs. Poor management leads to highly variable returns. New opportunities exist for the establishment of superior plantations based on the improved genetic material now available.

Local practical knowledge in tea tree oil production gives Australia a technological and marketing advantage over the rest of the world which must not be lost as has happened with the eucalyptus.
oil industry. Australia currently accounts for approximately 80% of world supply with the remainder chiefly sourced from China (approx. 15%) and Zimbabwe (approx. 3%).

Australian tea tree oil is marketed in health-care products. Research in recent years has confirmed this in vitro activity which is now being supported by in vivo clinical trials. The opportunities provided by these positive results now present a challenge to the industry to aggressively market the product and reverse the current trend of declining production and lower prices.

Markets and marketing issues

Producers usually supply oil to the essential oil industry for purchase by formulators who supply the marketplace with value-added products. More than 80% of Australian oil is exported mainly as bulk oil with a small proportion in value-added products. Because of substantial anti-fungal, anti-bacterial, anti-viral and anti-inflammatory activity the oil is sold over-the-counter as neat oil in small bottles, 10-15% tea tree oil solutions or in formulated products for healthcare, cosmetic, pharmaceutical, veterinary or aromatherapy use.

Key messages

- Industry uses an Australian native plant
- Supply/demand seeking better balance
- Improved genetic material now available

Potential use in agricultural, hospital (the oil is effective against Golden Staphylococcus (Staphylococcus aureus), veterinary and industrial applications present opportunities to further expand the market.

The increased production resulting from plantation establishment has not been maintained in recent years due to overproduction. The increase from below 10t/annum to more than 600t/annum by the turn of the century has now steadied to around 300t/annum. Prices have varied accordingly from base values of $10/kg to about $60 during the early nineties to less than $20 ten years later (Fig. 1).

The industry stabilisation predicted in the previous edition of this chapter has been reached with respect to volume of production (approximately 300t/annum compared with an estimate of 360t/annum) and halved with respect to price (approximately $17/kg compared with an estimate of $34/kg).

In addition to Australian production, increasing volumes are coming from off-shore. In 2003, estimated production from Zimbabwe and China are 12 and 70-80 tonne respectively although some of the latter oil has been of substandard quality.

Production requirements

The main production area is the north coast of NSW chosen because Melaleuca alternifolia is native to the region and consequently was the home of the bush industry. Significant plantations have also been made further up the east coast especially in far north Queensland where tea tree has been grown as a substitute crop for tobacco in the Mareeba-Dimbulah district. More recently plantations have been established in western NSW, south-western WA and the Ord River area of northern Australia.

With plant variety and processing procedures optimised, the variable which farm management must maximise is leaf yield. Trees grow best with ample supplies of heat and moisture as provided by the tropical and sub-tropical climates of eastern Australia. Plants approach dormancy when soil temperature is below 17 °C and are susceptible to frost damage.
Severe frost can cause extensive defoliation and kill some trees.

Plantations, except those in low rainfall areas, are only irrigated during the establishment phase. Plants have a poor regulation of water use and growth declines markedly as the soil begins to dry out. As trees are tolerant of wet conditions and need good water supplies, plantations are commonly situated in high rainfall districts (>1000mm/year) or where there are plentiful supplies of irrigation water. Growth is best on medium textured soils and plantations are often sited on alluvial flats.

**Varieties**

Tea tree oil is sourced from *Melaleuca* species rich in terpinen-4-ol, the bio-active ingredient. Although *M. linariifolia* and *M. dissitiflora* can give acceptable oils, most of the industry is based on the terpinen-4-ol rich chemical variety of *M. alternifolia*.

Whereas seed collected from bush plants has been used in the past for plantation establishment, improved seed, seed orchards and hence clonal material are now available. This has come about because of a long-term tea tree breeding project conducted by NSW Agriculture and the CSIRO and funded by the Rural Industries Research and Development Corporation (RIRDC) and the Australian Tea Tree Industries Association (ATTIA).

Some workers have selected superior trees and have used clonal methods to propagate large numbers of plants. This approach provides a quicker route to capture genetic gain at a higher cost per plant. The narrow genetic base for such an approach is of higher risk without the meticulous selection and testing of parent trees.

For seed collection, mother trees are usually selected on the basis of oil yield and composition. Progeny vary however because of very strong outcrossing during pollination. Also growth vigour is unknown unless a separate and time-consuming step of conducting yield trials is included before seed is sold. Consequently government and industry saw the need to fund a major plant breeding project which was based at the Wollongbar Agricultural Institute.

Beginning in 1993, improved types were selected for oil concentration and composition, growth and coppicing ability. The project released best provenance natural stand seed in 1997. Following the establishment of the first generation seedling and clonal seed orchards following yield, progeny and coppicing trials, improved seed became available in 1999. Yield trials on orchard seed have shown improvement of up to 91% over unimproved seed. The best material from these orchards, along with controlled crosses and clones has been incorporated into a second generation seedling seed orchard which is expected to yield seed giving even greater gains.
Cultural practices

Tea tree is grown as a perennial row crop and many of the husbandry practices are similar to those used for other row crops. One of the advantages of tea tree is that harvest time is not critical. At establishment, however, planning and procedures are of the utmost importance. Being a perennial crop, good establishment provides benefits over many years. For example, laser levelling is often used to optimise paddock drainage and facilitate flood irrigation. The design and depth of drains in areas with acid sulphate soils, as are common on the east coast, are also important. Good drainage also means access during all but the wettest periods. Timing is critical for weed and insect control and poor drainage can restrict these operations at critical times.

Direct sowing is not an option due to the minute size of the seed and poor survival rates. Seedlings are raised in nurseries and planted out at 10-16 weeks. Planting densities and configurations need careful planning. Densities of up to 35,000 trees/ha achieve full ground cover quickly after harvest and compete better with weeds by shading. Row spacing and configuration need to be planned with respect to the size of the tractors, mowers, cultivators, sprayers and harvesters likely to be used.

The first two weeks after transplanting are critical as seedlings have a poor competitive ability and the survival and vigour of adult plants is dependant on good husbandry during this phase. Weed control and adequate water are the most important factors during this time. Although irrigation becomes less critical from then on, weed control remains an important issue even in established plantations.

Nutritional requirements of tea tree are not well understood. Each harvest removes a large quantity of biomass and some return of nutrients is essential for long term productivity. Nevertheless, a number of trials have given small or no response to conventional fertilisers possibly because tea trees tap into soil nutrients below the rooting depth of previous crops. If so, the lack of fertiliser response should be viewed as a short-term condition. There are some indications that tea tree requires a slow steady supply of nutrients as can be obtained from organically bound nutrients. In a trial conducted in north Queensland, the addition of N, P, K fertilisers at four different rates enhanced the productivity of 6 year old trees that had been harvested 7 times. Although oil concentration was not affected (an anticipated result as oil concentration is known to be largely genetically controlled), biomass yields were increased by up to 50%. The estimated cost of fertiliser application however would not give any significant cash returns at present oil prices.

In NSW, the crop is ready for harvest after 18-24 months and then every 12 months thereafter. Although oil concentrations are highest in late summer, this is negated because regrowth is best after a spring harvest and hence month of harvest does not seem to affect oil yield. In north Queensland, harvest time can be reduced to 8-9 months because of the absence of the winter dormancy period. In practice however, yearly harvests are preferred because of tree deaths that occur during a post-harvest wet period.

A plantation then requires farm machinery suitable for row cropping along with specialised harvesting and steam-distillation equipment. Some producers pool their resources in a co-operative and use a single distillation unit. In some districts, harvesting and distillation is done under contract.

The oil yield from a plantation is dependant on both oil yield from the leaf and leaf yield from the plant. Target oil yields from unimproved seed should be in the 170-220 kg/ha range with occasional reported yields exceeding 300 or even 400 kg/ha. Yields from the new selections should make these higher yields
commonplace with even higher yields expected.

**Pest and disease control**

Insect problems with tea tree result in reduced growth rather than the death of the plants. Most damage is done to young growth and the plant generally responds by re-shooting from dormant buds. The most important insect pests are pyrgo beetle (*Paropsisterna tigrina*), psyllids (*Trioza* spp.) which forms pits on the leaf and mites (*Eriophyoid* spp.).

The impact of these pests can be reduced by the presence of beneficial insects. Hence integrated pest management strategies need to be adopted to prevent broad-acre spraying that also removes the beneficial insects. A list of pesticides currently registered for use with tea tree is available from the Australian Pesticides and Veterinary Medicines Authority.

There are no known serious diseases of tea tree.

The growth of plantation weeds can be prolific, especially in the high rainfall coastal regions.

Research has shown that tea tree is sensitive to weed competition both at the seedling and post-harvest regrowth stages due to competition for light, moisture and nutrients. Weeds can reduce leaf yields by 30–50% during regrowth periods if left unchecked and some interfere with harvesting. Control strategies include managing them for 12 months prior to establishing a plantation. Pre-emergent herbicides applied to the bare ground at planting time are strongly recommended for control for up to 12 weeks. Managing the crop to optimise tree growth will also minimise weed problems. Recommended methods for controlling weeds include inter-row cultivation, mowing, mulching, perennial ground covers, grazing, flame cultivation and herbicides.

**Harvest and post harvest**

A heavy duty forage harvester is used to cut the stems close to ground level, chop the stem material and feed it into a transportation bin. The bin can also be designed as the distillation vessel by incorporating perforated steam inlet pipes into the base and a sealable lid with an outlet for a condenser that can be attached when the bin is transported back to the distillation facility. Steam injected from a separate steam boiler then vaporises the oil which is then condensed and separated from the condensed water by flotation.

The farm-gate product must meet the buyer’s quality control criteria which are normally based on at least one of an increasing number of national or international standards. The International Standards Organisation (ISO), the European Pharmacopoeia (EP) and World Health Organisation (WHO) have produced
international monographs and Australia, France and Germany have published national standards.

As long as producers plant the right cultivars and distil the leaf material using conventional stills, the quality of the resultant oil is guaranteed as oil quality is highly heritable. Terpinen-4-ol, the active ingredient, must be present at between 30 and 48% and cineole at 0-15% so as to avoid confusion with the cineole variety oil which does not have equivalent bioactivity. Market forces favour oils with tighter limits and suggest that oils with more than 38% terpinen-4-ol and less than 5% cineole are desirable for the trade.

The oil has a long shelf-life if stored appropriately to suit market considerations. Clean, inert containers, sealed to exclude water vapour, flushed with nitrogen to retard oxidation, are desired. Stainless steel is commonly used, not only for storage containers but for all distillation vessels and tubes that contact the oil.

Oil quality is determined by Gas Chromatography for each batch to determine the chemical composition of the oil for any potential buyer. There are numerous registered laboratories able to provide the appropriate analysis and issue a quality control certificate. More sophisticated tests are available (eg full ISO standard, peroxide value, chiral column analysis) but not generally required at the first point of sale.

Financial Information

Tea tree oil has been classed as a high return crop. Establishment costs are so variable that it is not possible to give an estimate.

Whilst, plantations are expensive to establish, the plant’s perennial habit and the value of the oil when the price was high, gave high profits.

Now with prices about one third of what they were ten years ago, “returns for capital invested” tables need to be extrapolated to allow for the lower price.

One such revision is shown in Table 1. At times when prices are low, such a table confirms the value of a breeding project which has the ability to double oil yields.

Table 1. The effect of oil yield and price on return (%) on capital

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(extrapolated from Murtagh, 1991)
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Fruits and berries

- Durian
- Lychee and longan
- Minor tropical fruits
- Rambutan
Introduction

Durian (Durio zibethinus Murr.), is considered the “King of Tropical Fruits” by most Asian and smitten Western consumers. The fruit is highly esteemed and widely grown throughout the wet tropics of SE Asia. The fruit is considered a delicacy and aphrodisiac by many dedicated consumers but is also renowned by some Europeans for its complex flavour and odour interactions which have been described as akin to eating custard in the lavatory. The durian tree is a member of the Bombacaceae family which includes economically important members such as; balsa wood, kapok and pachira. Forest trees in the same family include Australia’s northern Baobab (Adansonia gregorii).

The centres of production in decreasing order are Thailand, Malaysia, Indonesia, Vietnam and Philippines. Durian was introduced into Australia in the early sixties and clonal material was first introduced in 1975 (Watson 1988). Over thirty clones of D. zibethinus and six Durio species have been introduced into Australia (Lim, 1997, Zappala et al. 2002). In Australia an industry has established along the wet tropical coast of north Queensland from Cape Tribulation (16°S) to Tully (18°S). There are 30 growers with 8,000 trees. A smaller, but geographically concentrated industry, has developed in the rural environments around Darwin (12°S). There are 6 growers with approximately 5,000

Acknowledgement is given to T.K. Lim, the author of this chapter in the first edition of this publication.
trees. Current Australian fruit production varies from 20 to 50 t/annum with a maximum value of $0.5M.

The Australian industry strengths include:

- a world class gene pool introduced by government agencies and dedicated growers
- out of season production with neighbouring Asian production areas
- a dedicated domestic consumption base for Australian grown fresh fruit
- growing areas are currently free of the durian fruit borer, a major pest in Asian orchards.

Constraints to industry development include:

- a stall in investment by current and potential growers due to the recent (2001) approval by Biosecurity Australia to allow imports of fresh fruit from Thailand. NB. The approval has not been acted on by Thailand at the time of writing.

- rapidly increasing imports of whole frozen fruit (1000 tonnes in 2002)
- mature established orchards based on inferior cultivars
- mature tree die back due to environmental stress combined with soil pathogens such as Pythium and Phytophthora.

The production of durian in Australia is a challenge and should only be contemplated by experienced horticulturalists.

**Markets and marketing issues**

World production is estimated at 2.0 million t annually and Thailand the major producer is a major exporter of both fresh and frozen fruit to Asian metropolises such as Singapore and Hongkong and whole frozen fruit to USA, Australia and Europe (Subhadrabandhu and Kesta, 2001). Malaysia and the Philippines, although major producers of durian, are reported to import fresh fruit from Thailand (Table 1).

<table>
<thead>
<tr>
<th>Table 1. World production, domestic consumption and export data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic consumption (t)</td>
</tr>
<tr>
<td>--------------------------</td>
</tr>
<tr>
<td>Thailand</td>
</tr>
<tr>
<td>Malaysia</td>
</tr>
<tr>
<td>Indonesia</td>
</tr>
<tr>
<td>Philippines</td>
</tr>
<tr>
<td>Brunei Darussalam</td>
</tr>
<tr>
<td>Australia</td>
</tr>
<tr>
<td>TOTAL</td>
</tr>
</tbody>
</table>

Source: (Subhadrabandhu, S. and Kesta, S. (2001); www.foodmarketexchange.com)

<table>
<thead>
<tr>
<th>Table 2. Australian durian availability and source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Durian</td>
</tr>
</tbody>
</table>

Current Australian production, from 20 to 50 t/annum with a maximum value of $0.5M, is miniscule. Australian tree number statistics (13,000 trees) and conservative production (50 fruit/tree at 2.5 kg/fruit) and price estimates ($6.50/kg) suggest that by 2010 the industry could produce 2,000 t valued at $12M from 130 ha.

The main Australian consumer demand is from ethnic Asians who are located in Sydney, Melbourne and Brisbane. In the growing regions fruit is commonly available, during the season (Table 2), for sale in local fresh fruit and vegetable markets in Cairns and Darwin. Many fruit are pre-ordered by friends and acquaintances of the growers. Growers report an increasing demand for fresh fruit from European converts. Current fruit prices vary from $8 to $12/kg depending on cultivar and availability. Semi processed fruit,
Durian aril packed in punnets, has sold for $20/kg. Watson (1988) suggested that the domestic market could absorb production from 100 ha of durian.

Approximately 1,000 t of whole frozen fruit is imported from Thailand each year. The frozen fruit is distributed through retail shops specialising in Asian foods. Retail prices vary from $3.00-6.00/kg. The recent (2001) approval by Biosecurity Australia to allow imports of fresh fruit from Thailand (not acted on by Thailand at the time of writing) may dramatically change the market in Australia. Thailand is able to produce fresh fruit from March until September, due to climatic variation from southern to northern growing areas (Subhadrabandhu and Kesta, 2001).

The season can be further extended by the use of growth regulators such as Paclobutrazol. Fresh fruit could be landed in Australia from February to October, hence eliminating any seasonal advantage Australian producers may have had. On the other hand a regular supply of fresh durian on Australian markets may help increase demand for fresh product and grow the market. Australian producers may still have a relatively competition free market window from November to March which takes into account the bulk of production.

**Production requirements**

The durian is a tree native to the wet tropics of Peninsular Malaysia, Sumatra and Borneo (Brown, 1997) and is now grown extensively through out SE Asia (Macmillian, 1991, Subhadrabandhu and Ketsa, 2001). Nanthachai (1994) reports that durian in their native environment experience an average temperature range from 24-30°C and high rainfall from 1,600 – 4,000 mm/year. Subhadrabandhu and Ketsa (2001) suggest that the most favourable regions for commercial durian cultivation as being within 12° north and south of the equator, at altitudes of up to 700 m which experience a temperature range from 22°C to 32°C and an annual rainfall of 2,000 to 5,000 mm preferably distributed over six to eight months of the year. High humidity for most of the year is also essential. The production areas in Australia, Darwin and the wet tropical coast of far north Queensland do not have a climate that matches the ideal (Table 3). Darwin has a long dry season where irrigation is essential for at least 8 months of the year while the wet coast of far north Queensland experiences a cool winter well below that experienced in durians native growing area.

<p>| Table 3. Climate comparisons between SE Asian and Australian growing areas |
|-------------------------------------------------|----------------|-----------------|------------------|------------------|------------------|------------------|</p>
<table>
<thead>
<tr>
<th>Harvest area</th>
<th>Rainfall (mm/annum)</th>
<th>Average Evaporation (mm/day)</th>
<th>Months experiencing water deficit (evaporation exceeds rainfall)</th>
<th>Mean annual maximum temperature (°C) and monthly extremes.</th>
<th>Mean annual minimum temperature (°C) and monthly extremes.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chanthaburi, Thailand (12.36oN)</td>
<td>3015</td>
<td>4.3</td>
<td>6</td>
<td>31.5 Apr – 33.4 Aug – 30.4</td>
<td>22.6 Aug – 24.0 Jan – 19.6</td>
</tr>
<tr>
<td>Jakarta, Indonesia (6.11oS)</td>
<td>1823</td>
<td>2.8</td>
<td>4</td>
<td>31.9 Oct - 32.9 Jan - 30.1</td>
<td>23.5 May – 20.0 Jul - 22.9</td>
</tr>
<tr>
<td>Darwin, Australia (12.25oS)</td>
<td>1664</td>
<td>7.4</td>
<td>8</td>
<td>31.9 Oct – 33.1 Jul – 30.4</td>
<td>23.2 Nov – 25.3 Jul – 19.3</td>
</tr>
<tr>
<td>South Johnstone, Australia (17.36oS)</td>
<td>3308</td>
<td>4.3</td>
<td>4</td>
<td>28.1 Jan – 31.2 Jul – 23.8</td>
<td>19.0 Feb – 22.5 Jul - 14.4</td>
</tr>
</tbody>
</table>

Durians can be grown on a range of soils with the correct nutrient and water management. Optimum growth and fruiting occurs on rich, deep, well drained sand to clay loams which are rich in organic matter. Excellent drainage is a most essential criteria as durian roots are susceptible to root rot. Clay soils with poor drainage should be avoided, unless extensive drainage and mounding works are incorporated in the orchard plan.

Vietnamese farmers are successfully growing durian on water inundated delta soils through the use of extensive mounding. In Australia durian is successfully grown over a range of soil types Ferrosols (Krasnozems and Euchrozems) and Brown Kandosols (Yellow earths). Soil
pH (water) is generally acidic and can be as low as pH 4 in ex sugar-cane growing regions.

**Varieties**

Durian seeds were first imported from Malaysia, Indonesia and Thailand in the early 70’s (Watson 1988). As growers gained a taste for and commercial interest in Durian, budwood and grafted trees were imported. Approximately 40 clones of *Durio zibethinus* and seven other *Durio* species have been introduced into Australia (Lim 1997).

Varieties that are showing promise and being grown in commercial orchards include Monthong (Thailand), Luang (Thailand), D24 (Malaysia), D2 (Malaysia), Hew 2 and 7 (Malaysia), Hepe and Permasuri (Indonesia). A number of local seedling selections have been made and include Limberlost, Jacki and Chong. A recently completed evaluation of Durian germplasm, carried out in north Queensland, suggests that several other *D. zibethinus* clones (Hepe, D 175, DPI Monthong, Hawaiian Monthong, D190 and Kradum Thong) and *D. macrantha* should also be considered for commercial production in north Queensland (Zappala et al. 2002).

In Australia durian clones are chiefly produced by budding or cleft graft techniques. Clonal production remains a relatively specialised task and further information is available from the following publications (Zappala et al. 2002; Lim et al., 1992, Subhadrabandhu and Ketsa 2001).

**Cultural practices/agronomy**

Site preparation will vary depending on growing location. Windbreak trees are considered essential particularly in areas prone to prevailing winds. Species used include Jak fruit, which can be used to contribute to orchard income in the early years (Hassall and Associates, 2000). Orchard spacing can range from 6 to 10 m within the row and 8 to 12 m between rows, depending on variety selected, growing environment and land availability. Durian trees can grow to 20 m tall with a diameter of 8–10 m within 15 to 20 years. Deep ripping along and across the intended tree lines is essential in some soils. Mounding should be carried out where water logging may be an issue and should be considered an essential input in the high rainfall growing areas of north Queensland.

The use of clean nursery stock from a recognised nursery which produces advanced planting material (trees six to twelve months old) is recommended. Lim (1997) recommends that orchards consist of mixed clonal stands to reduce the incidence of self-incompatibility. Where possible varieties should be planted within the same row to allow control of irrigation and hence flowering. Newly planted trees should be protected with shade cloth surrounds or alternatives such as dried palm fronds. Young trees in the NT and Queensland may benefit from the use of plastic covers during the cooler winter months. Trees should be mulched with non-compacting straw (eg. sugar-cane or spear grass), which remains well aerated under wet conditions. Application of regular small amounts of a well-composted chicken or alternative manure may be advantageous.

Fertiliser management research and information is limited and durian is managed similarly to many other tropical fruits with growers adopting strategies to suit their orchards. Based on the
fertiliser regime used at the Centre for Wet Tropics Agriculture, South Johnstone, a 10 year old tree would receive a total of 5.0 kg of 13:2.2:13:3:18.7 (N:P:K:S) and 4.0 kg of Dolomite, which is equivalent to 650 g Nitrogen, 110 g Phosphorous, 665 g Potassium, 935 g Sulphur, 800 g Calcium and 320 g Magnesium.

A foliar fertiliser spray to run-off, consisting of iron sulphate and zinc sulphate, each at a concentration of 1 g/litre four times per year (January, April, August and November) is also added. Appropriately less fertiliser should be applied evenly through out the year for young vegetative trees. Once trees reach reproductive maturity (5 – 7 years) the bulk of NPK should be applied from fruit set to just after harvest (Lim, 1997). Tentative leaf nutrient guidelines were developed for NT growers by Lim (1997) and work is currently underway in north Queensland.

Irrigation is essential particularly during plant establishment and during the long dry season as experienced in the NT. Irrigation rates of up to 2,000 L/tree/week for trees 8 m in diameter from September to November have been recommended in the NT. Subhadrabandhu and Ketsa (2001) suggest that frequent watering in small amounts is more beneficial than applying large amounts of water infrequently.

The use of soil moisture monitoring devices eg tensiometers and moisture probes, is recommended. These devices assist in determining irrigation rates and scheduling.

First fruit can be expected five to seven years following planting of clonal material, with regular production occurring from 10 years and onwards. Withdrawal of irrigation for 10 to 14 days is reported to assist flowering. Heavy rain post-flowering is associated with flower drop and poor pollination and subsequent fruit set.

### Pests and diseases

A range of insect and mite pests are found in Durian orchards in northern Australia (Zappala et al., 2002). The banana spotting bug (*Amblypelta lutescens*) or fruit spotting bug is considered to be the most serious, causing fruit drop and damage due to its feeding habit (sucking) from early fruit set through to fully developed fruit. Flesh eating beetles, in particular *Rhyparida* sp. can cause serious damage to young trees during periods of active leaf flushing. Green ants (*Oecophylla smaragdina*) are known to nurture colonies of mealy bugs (*Planococcus citri*), which can cause damage to developing flowers, young and developing fruit.

In the NT the larvae of longicorn beetles (*Acalolepta mixus* and

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**Table 4:** Comparison of durian leaf nutrient levels for the Northern Territory, Queensland and Malaysia

<table>
<thead>
<tr>
<th>Durian leaf analysis</th>
<th>N %</th>
<th>P %</th>
<th>K %</th>
<th>S %</th>
<th>Ca %</th>
<th>Mg %</th>
<th>Na %</th>
<th>Cl %</th>
<th>Mn mg/kg</th>
<th>Fe mg/kg</th>
<th>Cu mg/kg</th>
<th>Zn mg/kg</th>
<th>B mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durian (Innisfail region) Av.</td>
<td>1.95</td>
<td>0.24</td>
<td>1.53</td>
<td>0.24</td>
<td>1.59</td>
<td>0.70</td>
<td>0.04</td>
<td>0.02</td>
<td>69.52</td>
<td>57.35</td>
<td>8.06</td>
<td>11.95</td>
<td>58.96</td>
</tr>
<tr>
<td>23 samples Mar 00 Mar 01 stdev</td>
<td>0.23</td>
<td>0.05</td>
<td>0.40</td>
<td>0.05</td>
<td>0.37</td>
<td>0.09</td>
<td>0.01</td>
<td>0.01</td>
<td>30.18</td>
<td>18.45</td>
<td>1.71</td>
<td>2.57</td>
<td>18.65</td>
</tr>
<tr>
<td>Malaysian recommended range (leaf age 4 - 6 months) min</td>
<td>1.80</td>
<td>0.12</td>
<td>1.60</td>
<td>0.16</td>
<td>0.90</td>
<td>0.25</td>
<td>na</td>
<td>na</td>
<td>25.00</td>
<td>50.00</td>
<td>6.00</td>
<td>15.00</td>
<td>15.00</td>
</tr>
<tr>
<td></td>
<td>max</td>
<td>2.30</td>
<td>0.25</td>
<td>2.20</td>
<td>0.25</td>
<td>1.80</td>
<td>0.50</td>
<td>na</td>
<td>na</td>
<td>50.00</td>
<td>150.00</td>
<td>10.00</td>
<td>40.00</td>
</tr>
<tr>
<td>NT Standards (TK Lim, 1997) min</td>
<td>1.58</td>
<td>0.18</td>
<td>1.48</td>
<td>0.17</td>
<td>1.11</td>
<td>0.25</td>
<td>0.01</td>
<td>0.05</td>
<td>6.25</td>
<td>15.02</td>
<td>5.82</td>
<td>11.92</td>
<td>33.29</td>
</tr>
<tr>
<td></td>
<td>max</td>
<td>1.98</td>
<td>0.22</td>
<td>1.96</td>
<td>0.22</td>
<td>1.88</td>
<td>0.50</td>
<td>0.09</td>
<td>0.07</td>
<td>27.65</td>
<td>30.86</td>
<td>12.47</td>
<td>14.64</td>
</tr>
</tbody>
</table>
Platyomopsis pedicornis) has been noted to cause severe damage to young trees and mature trees following pruning. Durian, like many other minor fruit crops, has a distinct lack of registered pest control chemicals. Minor use permits, which expire regularly, are a feature of the industry.

Durian die-back, is the major threat to the viability of the industry. This generally occurs on mature fruit-producing trees. Symptoms include, initial leaf yellowing and leaf loss from the top of the canopy, with further loss of leaf occurring through the canopy at varying rates. New shoots may appear following initial severe defoliation, but further development and growth is unusual. Tree death generally occurs in four to twelve months from the initial onset of symptoms.

The soil borne pathogen Phytophthora palmivora was the major pathogen implicated as it was regularly isolated from rotten feeder roots, collar rots and rotting fruit. It is the known cause of root death, stem canker and fruit rots and is reported to be a major cause of tree loss in commercial orchards in SE Asia (Lim 1990).

Work in north Queensland as part of an ACIAR funded project has shown that the fungal pathogen Pythium vexans is also implicated in tree decline in north Queensland. Regular use of the chemical potassium phosphonate (Fosject®), only effective against P. palmivora, is part of the integrated program to control durian decline.

It is recommended that young trees be sprayed regularly with the phosphonate fungicide while older trees may benefit from trunk injection with potassium phosphonate.

Tree decline and death has continued to occur in north Queensland despite the input of phosphonate either via foliar spray or injection. Other diseases of less economic importance include leaf blight (Colletotrichum gloeosporioides), tip die back (Pusarium sp.) and fruit rot (Lasiodiplodia theobromae, Erwinia spp.).

Fertiliser and irrigation management and its possible interactions with, tree productivity and cultivar/rootstock susceptibility to dieback deserves further investigation. As an interim measure growers are recommended to begin a leaf and soil nutrient monitoring program and to fertilise in small amounts regularly rather than a few infrequent large doses which may affect the delicate balance in soil micro flora.

Irrigation management can also have a major impact on root rot development. Moisture stress can increase the susceptibility of roots to infection, and over-watering can increase the severity of the disease. Mulching of trees, during the drier months, is highly recommended.

Harvesting and postharvest handling

In Australia growers generally pick ripe fruit after they have dropped or when the peduncle (fruit stalk) begins to swell and split indicating that fruit drop is imminent. Picking fruit at this stage results in a full flavoured and odoriferous fruit, preferred by consumers who developed their taste for durian in Malaysia and Indonesia. Mature, dropped fruit tend to have a short shelf life and the pericarp (skin) will split open commencing at the fruit tip within 2 to 3 days. The shelf life of intact fruit can be lengthened by cold storage at 5 – 10°C. Dropped fruit often suffer damage on falling that further reduces the shelf life.

Durian is a climacteric fruit like mango and papaya, that is, it will continue to ripen if picked at a hard mature stage. Harvesting of fruit prior to the ripening process commencing results in fruit with an extended shelf life, however, fruit maturity plays an important role in the development of favour when ripe. Durian postharvest research is the most advanced in Thailand where new and
developing export markets require ever more innovative practices to ensure sound good quality fruits reach distant markets. Subhadrabandhu and Ketsa (2001) report that in Thailand a range of techniques are utilised to determine harvest maturity. These include:

- calendar days from full bloom; Variety and climate dependent
- fruit colour; as the fruit approach maturity the colour of the base of the spines from dark to light green or brown
- sound; mature fruit give off a hollow sound when the spines are tapped
- spines; become more flexible and can be more easily pushed inwards
- odour; the fruit emits a characteristic odour as it begins to ripen.

Thai postharvest techniques for export fruit include cold and modified atmosphere storage and waxing to prevent water loss. In Australia mature, sound, odour free fruit are packed in cardboard cartons and dispatched to southern markets, via airfreight, where ripening continues. Where developing fruit odour may be a problem a sealed polystyrene carton is used. In addition CSIRO has recently developed an odour proof packaging for this product. This requires a double packing technique, utilising a plastic wrap around the inner carton, which is then repacked into an outer carton.

The aril (flesh) of durian fruit can be susceptible to wet or hardcore at certain times of the year. Industry observations indicate wet or hard core condition of the aril is caused by excessive rainfall or other climatic variations. Both of these serious flesh conditions can result in the aril becoming inedible. To minimise the rejection of fruit in southern markets, some growers have minimally processed fruit by extracting the aril and packaging it in cling wrapped Styrofoam trays. This technique requires a sound cool chain to ensure that the aril reach southern markets in a sound condition.

**Financial information**

Financial analysis of a durian orchard, based on information provided by a north Queensland grower, performed by Hassall & Associates, indicates that durian production in north Queensland has a 25% internal rate of return (Hassall and Associates, 2000). Establishment costs for a 10 ha orchard are approximately $330,000 with recurrent input costs of $232,000/annum.

The investment break even period is 11 years. These figures were based on the assumption that Thai fresh durians would not be allowed into Australia. Biosecurity Australia has sanctioned the imports of fresh fruit, but to date none have occurred.

Tree dieback, should it occur, would impact heavily on the economic performance of a durian orchard. In a number of cases major tree losses have occurred in producing orchards once they reach 12 to 15 years of age.

**Acknowledgement**

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**References**


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Key message
- Durian prefers a true tropical climate
- Tree dieback, particularly in mature trees, can occur rapidly, especially in wet years
- Durian is for experienced horticulturists only
- Thai fresh fruit can be imported into Australia

Key statistics
- Estimated total durian production in Australia in the 2002/03 season was 35 t with a value of $350,000
- During this season, 10 t was produced in the Northern Territory and 25 t in Queensland

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Introduction

The lychee (*Litchi chinensis* Sonn.) and longan (*Dimocarpus longan* Lour.) are two of the most important commercial species of the Sapindaceae family, which also includes rambutan (*Nephelium lappaceum* L.). Lychee and longan are grown for their value as fresh fruit and are both believed to be native to North Vietnam and southern China where these species can still be found in remnant forests.

It is assumed that Chinese immigrants introduced lychee and longan seed into Australia during the gold rush in north Queensland in the late 1800’s. Lychee marcotts (cv. Tai So and Wai Chee) were introduced from China in 1930 by the Wah Day family who had settled in Cairns, north Queensland. Commercialisation of lychee and longan began in the 1970s and production has continued to expand despite many challenges.

China, Vietnam, India, Taiwan and Thailand are the major lychee producers with production areas in 2002 reported to be 600,000, 62,000, 56,000, 11,900 and 20,000 ha respectively. Longans are predominantly grown in China, Thailand, Vietnam and Taiwan with production areas in 2002 reported to be 440,000, 82,000, 64,000 and 12,000 ha respectively. Other minor production areas for both crops include, Malaysia, Indonesia, Australia, USA. While South Africa, Madagascar, Israel,
Central America, Mauritius and Reunion Island produce lychee. Australia is a relatively small producer of lychee with 4,000-6,000 t produced by 250 commercial growers. Current longan plantings are reported to be in the vicinity of 45,000 trees and the annual production of 300-500 t is valued at $2.0M.

Lychee is difficult to grow and yield consistently with irregular flowering and premature fruit drop being major problems. Longan is not as difficult to crop, however small fruit size and limited domestic and export markets are major hurdles to industry expansion. Both crops require considerable horticultural management skills.

**Markets and marketing issues**

Lychee and longan are principally traded as fresh fruit on the domestic market. Australia produces 4,000-6,000 t of lychee. Growing regions are spread 2,100 km along the east coast and with variation in cultivars allows the season to be spread from November/December until February/March. The bulk of production is consumed on the domestic market (Sydney and Melbourne). Approximately 20-35% of the lychee crop is exported with major markets being China (Hong Kong), Singapore and Europe. Current longan production varies from 300-500 t annually and is valued at $2.0M.

Production is centred on the Atherton Tablelands in north Queensland but occurs in small areas along the east coast of Queensland into northern NSW. Since the introduction of a flowering stimulant (potassium chlorate) in longan, Australian longan producers have lost export markets based on counter-seasonal production advantages.

The recent proposal by Biosecurity Australia to allow imports of lychee and longan from China and Thailand will significantly alter the current market volumes and prices. The Australian longan industry will face direct competition from year round production in Thailand and to a lesser extent in China. The Australian lychee industry will still maintain its counter seasonal advantage and off-season imports may assist the development of the domestic market.

Access for Australian lychees into China during the lucrative Chinese New Year festive season may improve.
Production requirements

The native environment of lychee and longan is sub-tropical with a period of relatively cool weather (12-20°C) required for flower initiation. The climatic requirements for flowering and subsequent fruit set vary with cultivars.

There are a number of cultivars that have the ability to flower more regularly in warmer environments. However, areas that have a cool winter followed by relatively humid and warm spring/summer periods are preferred.

Hot dry weather during fruit development can be associated with fruit drop, browning, splitting and poor fruit colour development.

Approximately 50% of Australia’s lychee production occurs north of the Tropic of Capricorn (Mackay, Ingham, Cardwell, Mossman and the Atherton Tablelands). The remaining production occurs in central Queensland (Rockhampton, Bundaberg, Childers), southern Queensland (Gympie, Nambour and Beerwah) and northern NSW as far south as Coffs Harbour. Longan production occurs primarily on the Atherton Tablelands with small areas of production along the east coast of Queensland to northern NSW.

Flat to undulating areas are preferred due to the high level of mechanisation required for orchard management and the requirement for netting during the fruiting season to control winged vertebrate pests.

Observations indicate that lychee and longan thrive on a wide variety of soil types as long as drainage is good enough to prevent water-logging and supplementary irrigation is available during prolonged periods of dry weather. Lychee and longans trees thrive best on deep clay loam soils and prefer a slightly acid (pH 5.0 to 6.5) soil. Soil types that support lush growth may be counterproductive to regular fruit production, particularly in environments where a check in growth caused by either dry or cool conditions does not occur.

Irrigation is required for commercial fruit production. Water requirements for mature orchards vary from 0.6 ML/ha to 5.0 ML/ha depending on growing location and average annual rainfall. Water quality, although not an issue in most growing areas, should be low in dissolved salts (< 600 microsiemens/centimetre).

Varieties/cultivars

There are over 40 cultivars of lychee and 20 of longan in Australia. Both industries have a collection of preferred commercial cultivars. For lychee the cultivars Bosworth 3 (syn. Kwai Mai Pink) and Tai So are the predominant cultivars throughout the production area with Tai So becoming less important in southern growing regions.

In northern Australia the early cultivar Souy Tung and early small seeded cultivar Fay Zee Siu are preferred for new plantings while in southern growing areas the small seeded Salathiel and late cultivar Wai Chee are being planted to extend the growing season. Recent imports of new cultivars from China and the potential release of material from a CSIRO breeding project may impact on the commercial cultivar mix.

The major longan cultivars are Kohala, Chompoo and Biew Kiew. The Florida selection Kohala is planted due to its earliness, however as the latter two cultivars become available the markets prefer them. The use of chemicals for out of season flower induction may lead to a change in cultivar mix.

Both lychee and longan are propagated vegetatively by marcotting (air layering). Plants are readily available from commercial nurseries and are also commonly produced on-farm.
Cultural practices

Protected areas, free of prevailing winds with no topographic limitations and well-drained soils are preferred for lychee and longan orchards. As the crop is long lived (25 years + commercial life) and netting will be required, it is important that careful planning of orchard layout is undertaken. Lychee growers should consult the Queensland Departments of Primary Industries Lychee Agrilink (Menzel et al., 2002). The manual comprehensively covers land preparation, planting and tree management issues.

Lychee and longan were traditionally planted at low densities (70 to 100 trees/ha) with inter-row and intra-row spacing varying from 10 m to 12 m. To accommodate netting and pruning practices both crops are increasingly being planted at higher densities.

In north and central Queensland new longan and lychee plantings at 6 m between rows and 2.5 m within rows are being explored (666 trees/ha). Standard densities are in the range of 150 to 200 trees/ha. Tree row direction is best running north to south, particularly from central Queensland south, however, terrain and other issues needed to be taken into account. Following planting of young potted trees; mulch, irrigation and individual tree wind/shade covers should be applied. A few growers have successfully planted marcotts directly from the tree to the paddock, however, if climatic conditions are harsh, high losses can be expected.

Young trees in the first two to three years following planting benefit from regular small applications of compound fertilisers high in nitrogen. Fertiliser applications immediately post planting should be avoided, particularly for lychee, until roots begin to explore beyond the pot. Application of fertilizer needs to correspond with differing needs at various stages of the growth cycle.

Diczbalis (2002) reported that for a longan crop yielding 25 t/ha the macronutrient inputs per hectare required to replace total nutrient loss are 118 kg N, 109 K, 45 kg Ca, 26 kg P, 11 kg Mg, 7.2 kg S. Similarly a 10 t/ha lychee crop would require the following macronutrient nutrient replacement, 22 kg N, 6 kg P, 23 kg K, 3 kg Ca and 4 kg Mg. Micro nutrients such as zinc, iron and boron may need to be applied regularly. Fertiliser management can be enhanced by the use of soil and leaf analysis (early panicle emergence) and nutrient replacement based on nutrient removal plus losses due to leaching, runoff or volatilisation.

Irrigation is required for all commercial orchards and under-tree systems are generally used. Drip irrigation is increasingly being used particularly in association with high-density orchards. In dry growing areas young trees will have to be watered regularly to ensure growth is not restricted and particular care is required from flowering to harvest to ensure that irrigation inputs are sufficient to allow maximum fruit numbers and size to develop.

Tree pruning is a vital management practice and starts within the first twelve months after planting to establish the preferred tree shape. Young lychee and longan trees need to be pruned to develop a strong tree structure that will minimise damage caused by wind and maximise the fruit bearing area. The pruning strategy used will depend on the growth habit of the variety. Removal of week branches, tip pruning (particularly in long-limbed cultivars) and skirting are all required to establish the canopy.

Bearing trees require both structural and strategic pruning. Structural pruning is required to further develop the canopy structure and to set the desired tree height, internal branch...
thinning and skirting form part of this activity. In lychee strategic pruning is based on the use of mechanical pruning machines to prune the outer surface of the tree, at a specific time, based on growing location (latitude) and cultivar so that the synchronous development of new vegetative flush will promote new terminal bud movement in mid winter when the likely hood of average temperatures below 20°C is at its highest, thus maximising flowering.

Lychees and longans are terminal flowering trees, that is; the floral panicle develops on relatively young wood. A number of growers in Australia are currently using mechanical pruners, following harvest, to reduce tree size and shape trees to allow machinery access. The effect of mechanical pruning on tree productivity depends on the time of pruning and the amount of wood removed. In situations where relatively heavy pruning has taken place, flowering may be delayed to the following season. Internal pruning is required to remove water shoots; pest and disease infected shoots and dead branches, along with crossing branches.

**Pest and disease control**

Winged vertebrate pests (birds and fruit bats) are the main threat to fruiting lychee and longan trees in all growing regions. Growers must have the ability (financially and physically) to net trees as fruit approach maturity. Netting systems vary from simple throw-over arrangements to permanent enclosures, depending on growing region and management preferences. Excellent developments in throw-over systems have occurred in the last few years.

Lychee postharvest facilities need to meet QA standards

The Australian lychee industry has been well serviced by entomology and pathology expertise. Invertebrate pests of the greatest economic importance include Erinose mite (*Aceria litchi*), Macadamia nut-borer (*Crytophlebia ombrodelta*), fruit spotting bug (*Amblypelta lutescens* and *A. nitida*), flower caterpillars (*Platypeplus aprobola* and *Isotenes miseran*) and fruit piercing moths (*Eudocima salamina* and *Othreis fullonia*). Leaf swarming beetles (*Rhyparidae* spp. and *Monolepta* sp.), scale (*Cocidae*) and assorted ants and mealybugs can also be problematic. Current control strategies are based on routine spraying or when growers become aware of an insect outbreak. Regular use of monitoring as part of an IPM strategy is still relatively rare, however, an increasing number of growers are utilising the services of commercial “bug checking” services to improve strategic spraying.

In Australia lychee diseases are generally not considered to be a major issue. Sudden tree dieback continues to occur and the causes are not well understood. However, the relatively minor nature of the problem suggests that little effort will be applied to understanding the problem in the near future. A disease that is rapidly becoming a major problem is “Pepper Spot” caused by *Colletotrichum gloesporioides*. The name describes the symptoms, which occur as small, slightly raised dark spots on lychee leaves and petioles and most importantly on fruit. The disease was first noticed and recorded in 1993 on lychee orchards in south east Queensland but is now commonly observed in coastal lychee orchards from far north Queensland to Byron Bay in north coastal New South Wales (Drew and Drew, 2001). Pepper Spot symptoms on fruit render the fruit unsaleable and severe losses have been reported in some growing districts and seasons.

Longan trees and fruit experience a similar pest and disease range as lychee but are not susceptible to Erinose mites and to “Pepper Spot”. For both crops the pest and disease complex changes with growing region.
**Harvesting and post harvest handling**

Lychee and longan must be harvested when ripe, as they do not continue to ripen after harvesting. Lychees are best harvested when fruit colour is appropriate to the cultivar and the protuberances on the skin are flattened. Most importantly the fruit must taste ready to eat with the correct balance of sugar to acid. Fruit colour changes with cultivar and fruit of the cv. Fay Zee Siu are often still partially green when at the best eating stage. Longans are judged mature when they have reached sufficient size to be classed as first grade fruit (28 mm diameter +) and flavour. Care must be taken as the fruit can quickly become bland if picked over-mature.

Lychees are picked individually or by the panicle depending on flower synchrony and market prices. Picking should be restricted to the early hours of the morning to ensure fruit are fully turgid (hydrated). Picking during the heat of the day results in soft fruit that rapidly lose their attractive colour. Harvested fruit, rapidly lose water and start to dry out and brown.

Management systems should be in place to ensure that picked fruit are kept moist and rapidly transferred back to the shed. Handling systems differ depending on management preference. In north Queensland most growers “hydro-cool”, that is soak fruit in cold water (5 to 12°C) prior to destalking, grading and packing. In South East Queensland there is a mixture of practices with a preference for the use of “forced air” systems post packing to cool fruit. Either way, fruit should be free of surface moisture prior to packing to avoid post-harvest rots.

The standard lychee carton is 9 L in volume and holds 5.0 kg of fruit, which are packed, into two 2.5 kg bags. Bags used are either a crispy bag (finely perforated) or a low-density polyethylene bag depending on marketing group and market preference. Following packing fruit should be stored at 5°C at high relative humidity.

Many small scale growers are members of one of the marketing groups which have specific grade standards and many of them are under the umbrella of the United Lychee Marketing Association (ULMA).

Longans similarly need to be picked in the early morning prior to the heat of the day. Longans are panicle picked and after being transported to the shed the panicles are sorted and trimmed by hand to remove undersized or defective fruit. Longans are sold on the panicle. After grading small bunches of fruit on the panicle branchlets remain, but generally all wood above 5 mm diameter is removed. Longans are either packed into 9 L cartons holding 5.0 kg wrapped in paper or into open webbed plastic crates holding 8.0 kg. Longan growers can choose to treat fruit with sulfur dioxide prior to dispatch to market although many smaller growers do not undertake this operation preferring to send high quality fruit which is quickly consumed once it reaches the markets. Longans are best stored at 8-10°C (Drinnan, 2003). Sulfur dioxide treated fruit may be stored at 4-5°C without chill damage.

**Financial information**

Financial information is detailed in the Lychee Agrilink kit (Menzel 2002), however the financial returns are very sensitive to yield and price expectations hence all prospective growers should consider the information carefully, preferably with the assistance of a financial/business professional. The economic analysis indicates that lychees and longan enterprises are marginally economic and should not be considered as a lifestyle choice.

Aside from the cost of land which varies greatly depending on location new investors will need at least $500,000 to set up a viable 7 ha lychee farm. This takes

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*Longan crop on the tree*
into account the purchase of the farming basics such as a tractor, sprayer, slasher, shed, irrigation system, tree establishment. It also should allow growers to purchase netting and a cold room once the trees reach bearing age. It is assumed that a similar sized longan enterprise would cost a similar amount to establish.

Lychee yields vary considerably from 10 to 100 kg/tree. Season, cultivar and location can all influence yield. Average yields are expected to vary from 5 kg/tree at five years increasing to 50 kg/tree for a 10 year old tree. For lychee a yield greater than 10 t/ha is considered excellent but not unachievable. Longan yields also vary but their average yield (15 – 20 t/ha) is generally higher than that of lychee with extremes of 35 t/ha being measured on the Atherton Tablelands, Sarina and Yeppoon.

Prices vary considerably, Tables 1 and 2 show the large difference in price which can occur during the season. Early and late crops tend to achieve higher prices while the price of mid season crops of less preferred cultivars can be marginal at best. Gross margins have been calculated for lychee on the Atherton Tablelands. A yield of 55 kg/tree for a planting density of 140 trees/ha (7.7 t/ha) the estimated gross margin (income minus variable costs) is approximately $21,600/ha. These figures take into account the normal distribution of fruit sold as first, second and farm gate sales.

The gross margin is very sensitive to price. These issues can be further explored using a computer based model designed to look at the economics of netting orchards (Johnson et al. 2002).

Key messages

- Lychee and longan are suited to moist and humid areas from the Atherton Tablelands to northern NSW
- Recent laws allowing the import of lychee and longan from China and Thailand may impact on profitability. Longans may be disadvantaged and lychees may profit
- Both crops have a concentrated harvest season over the summer months
- A strong commitment to quality and group marketing is required by grower

Key statistics

- Commercial Australian growers produce 4,000–6,000 t of lychee
- Current longan plantings are reported to be in the vicinity of 45,000 trees
- The annual longan production of 300–500 t is valued at $2.0M

About the authors

Yan Diczbalis has worked in the tropics his entire professional career, the last 14 years of which he has worked with the tropical exotic fruit industry. He is currently based at the Centre for Wet Tropics Agriculture, South Johnstone, Queensland. His interests include the commercial development of exotic tropical crops based on an understanding of crop production patterns in relation to their growing environment. He currently works on a range of crops including: lychee, longan, rambutan, durian, mangosteen, pitaya and cocoa.

Terry Campbell is a Principal Horticulturist based at Bundaberg Research Station. He has worked in tropical tree fruits for 15 years in both production and post harvest systems. He is currently involved in the DPI&F, industry and HAL funded project Unlocking Lychee Research Project, benchmarking post harvest system handling systems and investigating the suitability of fruit coatings to extend retail red/shelf life.
References


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Minor tropical fruits

Yan Diczbalis and Gerry McMahon

Introduction

There is a large range of exotic tropical fruits available in Australia, many of them only of interest to the rare fruit collector, but many more which have a potential commercial niche market. A number of the main exotics, including lychee, rambutan, mangosteen and durian, are on their way to being well recognised due to their exotic and palatable reputations.

A number of the lesser-known exotics with market potential (Table 1) often struggle for market recognition in the mainstream domestic markets of Australia and are only well known by ethnic buyers resident in the major capitals or the locals in the growing areas with a sense of adventure. These fruits generally have a strong market presence in their countries of origin or localities where they are considered as endemic.

The aim of this review is to list the many exotics which are currently grown and marketed in tropical Australia and to concentrate on a number of the better performers; e.g. Pitaya (dragon fruit), Pomelo, Jack fruit, Hog Plum and Carambola.

Pitaya, pithaya or dragon fruit are all common names used for a number of Hylocerus spp. now regularly seen on the market floor and increasingly in our supermarkets. These cactus fruits have beautifully coloured exteriors and either red or white flesh peppered with small black
seeds. The fruit make beautiful centrepieces to fruit bowls. Pitaya is native to Central America, and is grown commercially in Israel, Thailand, Vietnam and Australia. In Vietnam it is known as Dragon Fruit or Thanh Long, where it has become a large commercial crop. Pitaya was introduced into Queensland in 1970’s and is now grown in Western Australia, Northern Territory, Queensland and New South Wales.

Pomelo, Pummelo, Shaddock (Citrus grandis), a citrus best suited to the hot humid tropics, is the largest of the citrus fruits with specimens recorded up to 6 kg in weight. Pomelos are round or pear shaped, depending on cultivar and tend to have relatively thick rind. Skin colour is generally light green, yellow or light pink. The flesh varies in colour from pale yellow to pink. The juice sacks are large and lightly crunchy containing a mildly sweet acidic juice. The fruit is a favourite among Chinese people, particularly during festivals such as Chinese New Year and the Moon Festival. The pomelo is popular throughout SE Asia and is often sold from specialist road-side stalls in pomelo growing areas.

Jackfruit or Jakfruit (Artocarpus heterophyllus), a relative of breadfruit and mulberry, is chiefly grown for its ripe fruit that is eaten fresh or used in desserts and sweet drinks. Green fruit is also commonly used in vegetable curries and the seed of ripe fruit can be eaten after being boiled or roasted. Fully mature Jackfruit range in size from 5 to 30 kg. The flesh covering the seeds is the edible fruit portion and the bulk of the fruit is made up of stringy segments that are the remains of the inflorescence. Jackfruit is indigenous to South Western India, and has been introduced

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<th>Common Name</th>
<th>Botanical name</th>
<th>Family</th>
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<tbody>
<tr>
<td>abiu</td>
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<td>Diospyros digyna</td>
<td>Ebenaceae</td>
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<td>Artocarpus altlis</td>
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<td>Chrysophyllum caimito</td>
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<td>Pouteria campechiana</td>
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<td>carambola</td>
<td>Averrhoa carambola</td>
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<td>Areca catechu</td>
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<td>Xanthosoma spp.</td>
<td>Araceae</td>
</tr>
<tr>
<td>taro(Samoan)</td>
<td>Colocasia esculenta</td>
<td>Araceae</td>
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<tr>
<td>winged bean</td>
<td>Psophocarpus tetragonolobus</td>
<td>Leguminosae</td>
</tr>
<tr>
<td>yam</td>
<td>Dioscorea alata</td>
<td>Diosceraceae</td>
</tr>
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</table>
into Malaysia, South East Asia, and East Africa. Now it can be found in most tropical lowland regions of the world. In Australia it is found in tropical Queensland and in the Top End of the Northern Territory.

Hog Plum, Fiji Apple, Ambarella, Vi Apple or Otaheite Apple (*Spondias cythera*) is a member of the mango and cashew family. The fruit, dark green in colour, is plum shaped sweet-sour to taste and is eaten at all stages of ripeness. The fruits have a distinct spiny seed that hardens as the fruits mature thus requiring care when the flesh is sucked from the seed. Although the fruit is native to the Pacific it is now commonly grown and eaten throughout SE Asia and Central America. In Australia it is grown commercially in Queensland and the Northern Territory.

Carambola, Star fruit or five corner fruit (*Averrhoa carambola*) is ubiquitous to SE Asia and is commonly used to make a refreshing juice. Transverse sections of the fruit are star shaped and make an excellent addition to an antipasto. The fruit are rich in both vitamins C and A and are reputed to be an excellent cure for a hangover. Believed to have originated from Malaysia or Indonesia, and began moving around the world more than 150 years ago. Now it is found in most lowland tropical and subtropical areas. It came to Australia at the end of the nineteenth century.

Many of the tropical exotics can be difficult to produce and require specialist knowledge that comes from years of experience, others are easier to produce but sustained market growth to meet expected increases in production is the main challenge.

### Markets and marketing issues

Vinning and Moody (1997) in their report on the market prospects of tropical fruits, vegetables and nuts give an overview of the domestic and export potential for a range of crops. This information by its nature becomes quickly redundant and today with the proliferation of tropical fruit marketing sites on the internet there is the potential to rapidly gather a picture of world markets and export potential for any particular product.

The domestic markets for many of the exotic tropical fruits are currently dependent on buyers of ethnic origin. Prices rapidly fall during peak seasonal production periods because production exceeds demand. Not all fruits will break through the ‘recognition’ barrier due to organoleptic reasons (e.g. Marang and Santol) and the fact that a number of them have difficulty in making it to market due to rapid ripening and postharvest breakdown (e.g. Abiu and Rollinia).

Pitaya, Pomelo, Jackfruit, Hog Plum and Carambola have all been good market performers but this does not imply that their status will continue. Other new or currently known fruits may overtake them. Important characteristics of the five selected fruits are that they are all relatively trouble free to propagate, grow and have a relatively sound postharvest life.

### Table 2. Production figures for 2002 – 03 season

<table>
<thead>
<tr>
<th>Crop</th>
<th>Quantity NT# (tonnes)</th>
<th>Total Value# NT ($)</th>
<th>Quantity Qld* (tonnes)</th>
<th>Total Value* Qld ($)</th>
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</thead>
<tbody>
<tr>
<td>Pitaya</td>
<td>41</td>
<td>492,500</td>
<td>40</td>
<td>320,000</td>
</tr>
<tr>
<td>Pomelo</td>
<td>1.42</td>
<td>3,500</td>
<td>300</td>
<td>900,000</td>
</tr>
<tr>
<td>Jackfruit</td>
<td>338</td>
<td>1,290,840</td>
<td>150</td>
<td>450,000</td>
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<tr>
<td>Hog Plum</td>
<td>52</td>
<td>191,088</td>
<td>na</td>
<td>na</td>
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<tr>
<td>Carambola</td>
<td>16</td>
<td>80,550</td>
<td>60</td>
<td>240,000</td>
</tr>
</tbody>
</table>

*Source: Economics Research Branch, Department of Business Industry and Resource Development.

* Source: Rural Industry Business Service, DPI and grower associations.

### Table 3. Average wholesale prices ($/kg) in 2002/2003 at the Sydney markets

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitaya</td>
<td>6.00</td>
<td>3.84</td>
<td>3.90</td>
<td>7.00</td>
<td>-</td>
<td>-</td>
<td>10.00</td>
<td>-</td>
<td>-</td>
<td>7.14</td>
<td>7.00</td>
<td></td>
</tr>
<tr>
<td>Pomelo</td>
<td>4.49</td>
<td>-</td>
<td>2.69</td>
<td>2.60</td>
<td>2.46</td>
<td>2.13</td>
<td>2.92</td>
<td>3.26</td>
<td>3.44</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Jackfruit</td>
<td>3.14</td>
<td>2.85</td>
<td>2.60</td>
<td>2.73</td>
<td>2.74</td>
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<td>3.63</td>
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<td>3.54</td>
<td>3.49</td>
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<tr>
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<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
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<td></td>
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<tr>
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<td>3.75</td>
<td>3.75</td>
<td>3.83</td>
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<td>6.00</td>
<td>-</td>
<td>7.58</td>
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</tbody>
</table>

na: not available
Production requirements

Most of the fruits, vegetables and nuts listed in Table 1 have a distinct preference for a tropical climate. That is they prefer warm temperatures, frost-free year-round and have a relatively high water requirement. Despite their common preference for a warm climate they come from a diverse range of environments.

Experience suggests that all the above fruit will perform well in the wet/dry tropics of northern Australia with variable performance in the wet tropical belt from Cairns to Tully. Some of their more specific requirements are;

Pitaya prefer a dry tropical climate with an average temperature of 21-29ºC, but can cope with a range from 0 to 40ºC. They perform well in full sun but can be damaged by high levels of radiation resulting in sunburn. Rainfall of 600 – 1300 mm is required.

Pomelo prefers a hot, humid tropical environment and can thrive in wetter tropical areas. The fruit develops better flavours in tropical environments. They are commonly grown in peninsular Malaysia, Thailand and Taiwan on raised mounds in lowland areas that are flooded for most of the year. In Australia pomelos are grown in northern Australia around Darwin and in northern Queensland. They grow well on a range of soils but prefer sandy loam to loam soils with a minimum of 1.0 m of soil depth and a pH of 5.5 – 6.5.

Jackfruit like a warm humid climate with an average rainfall of 1500 mm/year. They have a poor tolerance to cold, drought and flooding and prefer deep, well-drained soil in lowland areas.

Hog Plum grow well in a humid tropical or subtropical regions, and can grow at altitudes up to 700 m. They do well across a range of soil types.

Carambola prefer a tropical or warm subtropical lowland areas with an average temperature range of 21 – 32ºC. They cannot withstand frost and are adaptable to poorer sandy soils, if organic manures and water are provided. Sunny conditions, year-round, are preferred for large-scale production.

Varieties/cultivars

Pitaya is a generic name for a number of edible cactus fruits. The white flesh (*Hylocereus undatus*) and red fleshed (*Hylocerus polyrhizus*) are the most popular on the market floor. A smaller fruiting yellow pitaya (*Selenicereus megalanthus*) has yellow skin and white flesh is also seen on the markets. In Darwin, commercial selections of *H. undatus* have been introduced from Vietnam. There are a number of local selections from the ornamental “moonlight cactus” that have proven to be very poor producers.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Native environment</th>
<th>Commonly grown in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carambola</td>
<td>Malukas</td>
<td>SE Asia, Hawaii, Florida</td>
</tr>
<tr>
<td>Hog Plum</td>
<td>Eastern Pacific</td>
<td>SE Asia, West Indies</td>
</tr>
<tr>
<td>Jackfruit</td>
<td>South India</td>
<td>India, SE Asia</td>
</tr>
<tr>
<td>Pomelo</td>
<td>SE Asia</td>
<td>SE Asia, China, Tahiti, Florida</td>
</tr>
<tr>
<td>Pitaya</td>
<td>Mexico and Central America</td>
<td>SE Asia, Israel</td>
</tr>
</tbody>
</table>
There is a range of pomelo cultivars in Australia, mostly based on the introduction of seeds from overseas. Pomelo seeds are rarely true to type hence the selections from these seedling introductions are not considered to be representative of the parent material. Popular cultivars in Queensland include Bosworth Pink, Termat, and K17. A range of new cultivars is being evaluated. New cultivars are not readily available due to the five-year quarantine time required for introductions. However, a number of registered cultivars are available through accredited tropical fruit nurseries.

Jackfruit is a major crop in Malaysia and Thailand and both countries support active breeding and selection programs. Australia has a limited range of cultivars with the majority of material based on seedling selections introduced during the 1960’s and 1970’s. Fruit are either soft or firm fleshed (crispy) and the aerial colour is yellow to pinky-orange. The crisp pink/orange fleshed cultivars generally obtain the highest market prices.

**Hog Plum**

Cultural practices

Protected areas, free of prevailing winds with no topographic limitations and well-drained soils are preferred for most orchard crops.

Pitaya is best grown from healthy green cuttings, as seedlings are very slow growing and are unreliable producers. Cuttings of 30-50 cm are cured in a dry place for a couple of weeks, and then potted into a free-draining mix. They require minimal shade and a weak foliar fertiliser spray can be applied. When they have developed a shoot they can be planted out into a well-drained mound of sand and organic material.

A wooden or concrete post is used for support, with a wooden frame at the top to train the branches over. Poles should be at least 2 m high and 3 m apart in the row and 4 m apart between rows depending on machinery available.

A single stem is grown up the post then allowed to branch and hang down over the frame. When the branches hang they will flower, which is about 12-15 months after planting the cutting.

A balanced NPK fertiliser every three months is suggested, with an annual application of lime and organic material. Urea sprays, at 3-5%, can be used to encourage vegetative growth, with micro elements added if required. *H. undatus* is a long-day plant, requiring longer days to induce flowering. In northern Australia the fruiting season extends from October to April. Buds emerge from the hanging stems and then form into branches or flowers. The scented, white, night-blooming flowers attract bats and moths. Bees and other insects visit the flowers before dusk as the petals open, and after dawn as the flowers begin to close.

Pomelo in northern Australia is commonly propagated by budding or cleft grafting. A range of standard citrus stocks are used but the interactions between scion and stock are not well understood.

Troyer-citrange stock has proved to be useful at the Center for Wet Tropics Agriculture, South Johnstone. Planting density varies with each orchard and range from 200 to 300 trees/ha. North-south planting patterns are preferred with anecdotal evidence that east-west patterns are less productive.

Pruning, fertilising and water management are based on management techniques used for grapefruit and are all integral to obtaining maximum yields. In north Queensland cropping can extend from April to early September depending on season.

Jackfruit are often utilised as windbreak trees due to their fast growth and tree shape characteristics hence they are
not often grown specifically as
an orchard crop. Tree spacing of
6-12 m are suitable depending
on growing location. Seedling
trees take 5-6 years to produce
fruit. Seedling or grafted trees
should be propagated in tall pots
to allow the development of the
tap root. Air layering, inarching,
epistyl grafting and bud grafting
are methods of propagation that
have varying degrees of success,
depending on time of year and tree
selection. A regular application
of a mixed fertiliser is beneficial
during all growth stages.

Hog Plum, is easily propagated by
seed, large hardwood cuttings, air
layering or grafting. Seedlings may
fruit when 4 years old, and young
trees should be given some light
shade. Mature trees are somewhat
brittle and can be damaged
by strong winds. No other
information has been gathered
on plant spacings or fertiliser
requirements but general orchard
practices apply.

Prior to planting Carambola,
consideration should be given to
providing netting to eliminate
attack by birds and fruit piercing
moth. Under netting, trees have
to be planted at higher densities
and periodic pruning, hedging
and topping have to be carried
out to keep trees to a manageable
height. Planting distances are 4-6
m within the row by 6 m inter-
row, giving densities of 280-420
trees/hectare. Higher densities
can be used such as a T-trellis
system with plants at a close
spacing of 1-2 m within rows.

Current recommendations are to
shape trees when young to 4-6
sturdy, wide angled branches with
a vertical leader. Low hanging,
cross-cross branches are removed
periodically to open up the canopy
and facilitate sunlight penetration
and pollination activities. Trees
planted at higher densities, for
instance under netting or in a
trellis system, need to be hedged
and topped at least once a year.

Carambola trees stay active all year
in the tropics and need a regular
supply of water and NPK + trace
elements and calcium fertilisers. A
mixed N, P, K fertilisers should be
applied regularly either manually
or through the irrigation system
i.e. fertigation. Trace elements of
iron, zinc, boron and copper can
be applied as foliar sprays six times
a year. Regular applications of
manure and organic material can
also be beneficial.

Pomelo

Pest and disease control

Winged vertebrate pests (birds and
fruit bats) are the main threat to a
number of tropical fruits. Netting
is required for Carambola and may
be required for Pitaya as birds have
caused serious damage to both
these crops.

Meat ants, ginger ants, caterpillars
and mites have been recorded
as causing damage to Pitaya. A
watery rot on the stems has also
been recorded if conditions are too
wet or the plant has suffered injury
e.g. sunburn. This can be a major
problem in some growing areas.

Pomelo are susceptible to a range
of pests and diseases similar to
that experienced by other widely
grown citrus. Leaf eating beetles
(Monoleta sp. and Rhyparida spp.)
can severely defoliate young trees.
Ants, mealy bugs and associated
sooty mould that cover fruit can
also be a problem. Although
the mould can often be washed
off with the use of high pressure
washers its best to avoid the
problem by judicious ant control.

Fruit spotting bugs (Amblypelta
lutescens) can sting fruit at all
stages of development.

Insect pests of Carambola
include fruit fly, fruit piercing
moth (Othreis spp. and Euderma
salaminia), fruit eating caterpillars,
green vegetable bugs, flatids
and red-banded thrips. Leaf
eating beetles (Monoleta sp.
and Rhyparida spp.) can severely
defoliate young trees.

Some of the major pests and
diseases of Jackfruit include shoot
borers, bark borers, mealy bugs and
scale insects. Blossom and fruit
rots, pink disease and bacterial
dieback can also be a problem.
Most of these do not cause
economic damage to any great
extent, and regular monitoring and
appropriate control measures will reduce most problems although fruit rots caused by Rhizopus stolonifer can be a significant postharvest problem.

No particular pests or diseases have been recorded on Hog Plum in Darwin although leaf eating beetles (Monolepta sp. and Rhyparidae spp.) can severely defoliate young trees.

**Harvesting and post harvest handling**

All the fruit covered in this review are relatively trouble free when it comes to harvesting and post harvest handling. Specialist systems are required to cater to the peculiarities of each crop.

Pitaya season extends from September to March. Fruit maturity occurs approximately 28 to 30 days after flowering when 85% of the fruit has attained a pink colour. The fruit are cut off at the short stem, placed carefully in crates so as not to damage the soft scales surrounding the fruit. Fruit are washed, dried and packed into single layer trays (cardboard or polystyrene). Fruit are generally sold on count and the pack weight may vary from 3.5 to 5.0 kg. Pitaya should be stored at 5°C and 90% relative humidity, and can be stored for up to 40 days.

Carambolas have to be harvested when mature. Fruit should be harvested when there is some tinge of yellow, i.e., covering less than 25% of the fruit surface or in the case of some varieties, when the fruit is pale whitish green.

Carambola require careful handling so that the edges of the wings are not bruised and damaged. To avoid fruit bruising and to extend postharvest shelf life, fruit should be carefully harvested with hand or picking pole with an attached bag and carefully cleaned, washed, graded and packed. Pack size depends on market requirements but are usually 4.0 to 6.0 kg in weight. Fruit wrapped in paraffin paper or netted socks are placed in a carton lined with foam.

Carambola can be stored up to 5 weeks with or without packaging and retain acceptable flavour. Mature green fruits can be stored at 10°C up to 5 weeks and still ripen in storage to the ripe yellow colour with acceptable flavour; and fruit destined for processing can be stored at 5°C up to 10 weeks without appreciable loss in flavour.

Jackfruit are picked as immature green fruit for curries or as mature fruit which will ripen during transit. The fruit is mature when there is a change in colour, from pale green to brownish-yellow. The spines also flatten out and there is a characteristic odour. The stalk must be cut with a sharp knife and the fruit carefully lowered to the ground. The fruit are usually washed prior to packing. The large size and weight of the fruit make it expensive to transport fruit the long distance from northern growing areas to the main domestic markets on the east coast. Fruit are normally packed in large cardboard cartons to a weight of 20 kg. Fruit rots can be a problem in some months with the problem worsening as the fruit ripen. Jackfruit can be kept wrapped in polyethylene bags and stored at 12°C for 20 days. Temperatures lower than this will cause chilling injury.

Pomelos are ready to harvest approximately six months after flowering. Fruit do not drop when mature and skin colour change is a good indicator of maturity, however, coloured fruit can safely hang on the tree for a further three months. Picked fruit are pressure washed to remove dust and sooty mould and then dried prior to packing in cartons containing 20 kg. Some growers market their fruit in bulk crates holding several hundred kg. The thick rind reduces the requirement for packing material between fruit. Pomelo fruit store relatively well at room temperature. The Chinese custom of eating the fruit after it has spent 15 days on the temple altar is reported to enhance fruit flavour. The fruit will store for a longer period under refrigeration (7-9°C, 85-95% RH), but fruit appearance may deteriorate as the rind begins to shrivel.

Current research into pitaya fruit maturity indicates that the optimal harvest time for local markets is 28-30 days after flowering. The fruit are cut off at the fruit stalk, placed carefully in crates so as not to damage the soft scales surrounding the fruit. Fruit are washed, dried and packed into single layer trays (cardboard or polystyrene). Fruit are generally sold on count and the pack weight may vary from 3.5 to 5.0 kg. Pitaya should be stored at 5°C and 90% relative humidity, and can be stored for up to 40 days.
Hog plum are picked washed and packed in 36 L cartons. Hog Plum is available most of the year in Darwin, and should be stored at 10-15°C with a relative humidity of 90-95%.

Financial information

Financial analysis of these five crops is lacking due to the small size of the industries. Most of these crops are grown as part of a suite of crops by growers and hence are not the sole source of farm income. The main investment costs (shed, tractors, mowers, irrigation system) are similar to other mainstream tree crops. The need for netting and support infrastructure, as required by carambola and pitaya, should also be taken into account.

The largest risk associated with investment in these crops is the limited domestic market. Prices are currently favourable, however, this could rapidly change if large volumes of fruit were to reach the market. Intending growers should carefully assess the market volumes and prices prior to investing.

Acknowledgement

Thanks to Jeff Daniells and Roger Goebel, Queensland Department of Primary Industries and Fisheries, for their useful comments on the manuscript and to Judy Noller, Trade and Business Officer, Department of Primary Industry and Fisheries for market price information.

References


Key message

- There is a large range of tropical exotics with a potential market
- The market for exotic fruit is often limited and linked to buyers of ethnic origin
- Check the markets and determine who wants your product before you invest
- Demand will increase with time
- Imaginative approaches to market growth are required e.g.
  - e.g. increased promotion via life-style television programs
  - Internet and direct home marketing
- Advocate required in market place to promote and foster sales.
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Introduction

The rambutan (*Nephelium lappacium* L.) is grown for its value as a fresh fruit. The rambutan is a close relative of lychee and longan and the three fruits are known in SE Asia as the “three venerable gentlemen”. The attractive red or yellow fruits are an essential addition to any fruit basket. The fruits range from 25 to 60 g in weight and are oval to round in shape. Generally 5 to 20 fruits occur on a panicle. The outer skin (pericarp) is 2-4 mm thick and covered in long soft spines (spinterns).

Whitehead (1959) indicates that the species is indigenous to the Malay Peninsula and widely cultivated in the area whereas Van Welzen and Verheij (1991) report that the exact origin of rambutan is untraceable because of a long history of domestication. Rambutan is now well-distributed and produced throughout Southeast Asia. The crop is grown in a number of locations outside of its natural distribution, including Central America, Sri Lanka, India, New Guinea, tropical Africa, Hawaii and northern Australia.

Thailand, Indonesia and Malaysia are the major producers with production areas in 2002.
reported to be 88,000, 80,000 and 20,000 ha respectively. China, which until recently was not considered to be a producer or consumer of rambutan has become a major producer of rambutan in the last 10 years. There are 2,000 ha planted in Baoting county on Hainan Island. The major production area is on the south side of the island protected from the cold northern winds by a mountain range. Researchers estimate that the planted area will expand to 6,600 ha by 2005. Smaller but active growing areas are in Hawaii (100 ha) and Tropical America (Guatemala, Honduras, Costa Rica and El Salvador). The total area of rambutan in Central America is 300ha with approximately 200 ha grown in Guatemala.

Rambutans from Hawaii currently undergo electronic irradiation for disinfection prior to export to mainland USA. Tropical American countries have submitted protocols for export fruit to the USA for consideration. Tropical American production is aimed primarily at local consumption. However, these growing areas may meet the challenge of supplying the US and Japanese markets.

Australia produces between 500 to 1,000 t of rambutan per annum from approximately 32,000 trees on 150 ha (Table 1). The variation in production is a result of seasonal variation and management. The bulk of plantings (24,000 trees) are located from Cooktown to Tully. A smaller industry (8,000 trees) is based in Darwin, NT. The industry supplies fruit mainly to buyers of Asian descent in the State capital cities with an increasing demand from Australians of European decent, particularly those who have travelled extensively or lived in SE Asia where the fruit is an everyday favourite commonly available from street fruit vendors. The Australian industry has started to focus on overseas markets and a small but growing market is being developed in Japan.

A rambutan orchard requires considerable horticultural management skills and should not be taken on lightly unless a secure income from alternative sources is available.

### Markets and marketing issues

The rambutan is principally traded as fresh fruit on domestic and export markets. The major Asian producers of rambutan also process fruit and a common product available in the Asian food section of Australian supermarkets is canned rambutan stuffed with pineapple. The Australian market chain is made up of growers, marketing groups, agents, Asian wholesalers, boutique fruit retailers and supermarkets.

### Table 1: Australian rambutan production for the 2002/03 season

<table>
<thead>
<tr>
<th>State</th>
<th>Production (t/annum)</th>
<th>Value ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern Territory</td>
<td>80</td>
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<tr>
<td>domestic</td>
<td>68</td>
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<tr>
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<td>120,000</td>
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<tr>
<td>Queensland</td>
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<tr>
<td>domestic</td>
<td>550</td>
<td>3,000,000</td>
</tr>
<tr>
<td>export</td>
<td>50</td>
<td>600,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>680</td>
<td>4,319,000</td>
</tr>
</tbody>
</table>

### Table 2. Rambutan production intensity and regions of availability and associated average wholesale prices ($/kg) at the Sydney market

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
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<tbody>
<tr>
<td>Rambutan</td>
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<td>Qld</td>
<td>Qld</td>
<td>Qld</td>
<td>Qld</td>
<td>Qld</td>
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</tr>
</tbody>
</table>

High volume Low volume
(Noller, 2001). Buyers are clearly demarcated, the bulk of sales are to ethnic Vietnamese and Chinese who are reported to be the main consumers while consumption by the Caucasian mass market via supermarket chains is still relatively small due to low consumer awareness and high prices at the retail end.

Production varies from year to year, due to the biennial nature of the crop with a gradual upward trend due to new plantings coming into production (Table 2). At the same time smaller older orchards are being abandoned due to the high management requirements of the crop. Most orchards are less than 500 trees in size. In north Queensland there are several orchards with tree numbers in the 2,000 to 4,000 range. Average tree yields range from 30 to 60 kg, with yields up to 200 kg/tree being recorded on older trees at wide spacings. Australian production varies from 500 to 1,000 t/annum with approximately 50 to 150 t being exported. Exports to domestic markets and Japan are channelled via several marketing groups and their coordinators.

**Production requirements**

The native environment of the rambutan is characterised by high, evenly distributed rainfall (2,000 mm or greater), high humidity, low evaporation rates and average minimum temperature above 20°C. In South East Asia rambutan flowering is correlated with the end of the dry season. A dry period of at least a month is thought to be essential to initiate rambutan flowering. Rambutan is considered not to have a cold requirement for flowering and is suited to tropical areas with a temperature range of 22°C to 30°C.

In Australia, flowering in the dry tropics (Darwin, 12.5°S) usually follows the onset of cool nights (18-12°C) in July to August (Diczbalis et al. 1996). However in the wet tropics of north Queensland flowering is reported to occur throughout the year, regardless of climate (Watson 1988) but usually occurs from September to October following a short dry season. There are limited areas in Australia that have the climatic attributes required for rambutan production.

Observations indicate that rambutan thrive on a wide variety of soil types as long as drainage is good enough to prevent waterlogging and supplementary irrigation is available during prolonged periods of dry weather. Rambutan trees thrive best on deep clay loam soils and prefer a slightly acid (pH 5.0 to 6.5) soil. Soil types that support lush growth may be counterproductive to regular fruit production, particularly in environments where a check in growth caused by either dry or cool conditions does not occur.

**Varieties/cultivars**

Salma (1993) identified and developed a key to 31 cultivars of rambutan grown in Malaysia out of a collection list, which exceeds 65. Each country has selected material suited to their growing climate and local palette.

Breeding and crop improvement are limited. Sarip et al. (1996) report on the outcomes of a large-scale evaluation of F1 hybrids based on two maternal parents (R99 and R134) and fourteen popular Malaysian cultivars. Six years after the establishment of 7,000 open pollinated seedlings, 50% of the population had flowered and about 40% of them were males. Seven percent of the population flowered two weeks earlier than both maternal parents (R99 and R134) and less than 1% produced high quality fruits with the combined attributes of good appearance, high recovery and cling free.

The Australian industry has had the opportunity to select material from over 50 imported clones. Most of the selected clones are marketed as “Classic Red” which includes six varieties (Binjai, Jitlee, R134, R156 (red), R162, R167). These varieties are similar in colour and shape and the flesh
is easily removed from the seed. A further two varieties R9 and Rongrien are marketed separately due to shape and colour differences.

Varieties are propagated vegetatively, primarily by budding that can only be successfully carried out by a few specialist propagators. The Asian industry is primarily based on budded trees due to the low long-term survival rate of marcotted trees. In the last five years the Australian industry has increasingly turned to the use of marcotted trees due to the shortage and expense of budded trees.

### Cultural practices

Protected areas, free of prevailing winds with no topographic limitations and well-drained soils are preferred for rambutan orchards. Deep ripping and mounding may be pre-plant options that require consideration. Rambutans were traditionally planted at low densities (70 to 100 t/ha) with inter-row and intra-row spacing varying from 10m to 12 m. Rambutans are increasingly being planted at higher densities. In the Northern Territory 10 m between rows by 5 m within rows is a popular spacing (200 trees/ha). While in north Queensland new plantings at 6 m between rows and 3 m within rows are being explored (555 trees/ha). Following planting of young budded trees six to twelve months of age, mulch, irrigation and individual tree wind/shade covers should be applied. A few growers have successfully planted marcotts directly from the tree to the paddock, however, if climatic conditions are harsh, high losses can be expected.

Young trees in the first two to three years following planting benefit from regular small applications of compound fertilisers high in nitrogen. Rambutans are relatively shallow rooted trees and small regular irrigations are most beneficial. Rambutans are sensitive to water stress, particularly in the hot dry environment experienced in growing areas around Darwin or Cooktown. Detailed irrigation recommendations are available Diczbalis (1997).

The crop requires adequate moisture, from rainfall or irrigation, during fruit set and growth. Irrigation is required for rambutan grown for high value domestic and export markets as water stress during flower and fruit development leads to reduction in yield and fruit size. Irrigation is also essential during the vegetative flushing stage after harvest but should be limited during floral initiation. Pre-flowering water stress that does not induce leaf wilting, can induce earlier flowering and improved harvest synchrony. High rainfall during blooming can lead to poor fruit set. Rambutan have a shallow root system with 80% of the roots in the top 15 cm which does not extend beyond the tree canopy sometimes necessitating irrigating up to three times a week. In trees grown on sandy soils in hot dry growing environments severe leaf loss can occur within 4 to 10 days of withholding irrigation.

The amount of irrigation should at a minimum, replace that lost by evaporation particularly from flowering to harvest.

Early pruning is required to establish the tree shape. A single trunk with three to four branches commencing at 0.5 to 1.0 m above ground level is recommended. Further branching at approximately 0.6 m intervals is ideal.

Trees should commence flowering and fruit set in their third year. Growers are encouraged to nurture this first crop, which can assist in tree size control.

Application of fertiliser needs to correspond with differing needs at various stages of the growth cycle. Diczbalis (2002) reported that a crop yielding 6,750 kg/ha in north Queensland would remove 13.6 kg N, 2.1 kg P, 12.1 kg K, 3.7 kg Ca, 1.9 kg Mg and 1.3 kg S. The study reported tentative leaf nutrient standards (north Queensland) at early panicle emergence should be; 2.01% N, 0.21% P, 0.66% K, 1.2% Ca, 0.32 % Mg, 0.21% S, 485 mg/kg Mn, 102 mg/kg Fe, 54 mg/kg Cu, 26 mg/kg Zn, 51 mg/kg B. The report suggests

### Key messages

- Rambutans are an attractive and tasty fruit with potential to grow domestic and export markets
- Rambutans require intensive care (fertiliser, irrigation and pruning) if yields are to be maximised
- Control of moisture loss and temperature control are vital for successful postharvest management

### Key statistics

- Australia has an estimated 32,000 rambutan trees on 150 ha
- Estimated total Australian production 2002-2003 season is 680 t/annum with a value of $4,319,000
- The Northern Territory produces 80 t/annum of which 68 t is for the domestic market and 12 t is exported
- Queensland produces 600 t/annum of which 550t is for the domestic market and 50 t is exported
that fertiliser management in rambutan can be enhanced by the use of soil and leaf analysis (early panicle emergence) and nutrient replacement based on nutrient removal plus losses due to leaching, runoff or volatilisation. Compound fertilisers must be free of chlorine based sources of potassium otherwise leaf burn and fruit drop can occur.

When pruning mature trees growers must be mindful that rambutans are terminal flowering trees, that is; the floral panicle develops on relatively young wood. A number of growers in Australia are currently using mechanical pruners, following harvest, to reduce tree size and shape trees to allow machinery access. The effect of mechanical pruning on tree productivity depends on the time of pruning and the amount of wood removed. In situations where relatively heavy pruning has taken place, flowering may be delayed to the following season. Internal pruning is required to remove water shoots; pest and disease infected shoots and dead branches, along with crossing branches.

**Pest and disease control**

Winged vertebrate pests (birds and fruit bats) are the main threat to fruiting rambutan trees in both the Northern Territory and north Queensland growing regions. The rainbow lorikeet (*Trichoglossus haematodus*) is the major bird threat in both growing regions, while fruit bat species varies with region except for the Black Flying Fox (*Pteropus alecto*), which is common to both. The bulk of growers have the ability to net trees as fruit approach maturity. Netting systems vary from simple throw-over arrangements to permanent enclosures, depending on growing region and management preferences. Excellent developments in throw-over systems have occurred in the last few years.

Astridge (2004) has identified over 35 pests of rambutan. The major categories include:

- leaf swarming beetles - Rhyparida spp. and red shouldered leaf beetles *Monolepta* sp which damage new flush
- moths and caterpillars – yellow peach moth (*Conogethes punctieralis*), rambutan fruit borer (*Triathaba rufivena*), fruit piercing moth (*Eudocina* sp.), flower eating caterpillars (number of species), primarily attack fruit and flowers whereas loopers (*Oxyodes tricolor*, *Achaea janata*) and leaf rollers (*Adoxophyes* sp., *Lobesia* sp. and *Toricidae* family) damage leaves.

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**About the author**

Yan Diczbalis has worked in the tropics his entire professional career, the last 14 years of which he has worked with the tropical exotic fruit industry. He is currently based at the Centre for Wet Tropics Agriculture, South Johnstone, Queensland. His interests include the commercial development of exotic tropical crops based on an understanding of crop production patterns in relation to their growing environment. He currently works on a range of crops including; lychee, longan, rambutan, durian, mangosteen, pitaya and cocoa.
• red banded thrip (*Selenothrips rubrocinctus*) and mites (*Tatranychus* sp and *Brevipalpus* sp.) damage fruit and foliage
• plant hoppers (*Colgaroides acuminata*), mealy bugs and scale all cause damage to flowers and fruit. The latter two are often managed by ants, which feed on the secreted honeydue they secrete. Fruit and banana spotting bugs (*Amblypelta* spp.) sting fruit from early to late maturity.

A restricted list of control measures is available to control the above and growers should check with their state government chemical coordinator or InfoPest as to the legality of application of pesticides. There are also a number of beneficial insects that growers should learn to recognise and foster. The most important of these are lacewings, parasitic wasps, predatory bug, spiders and *Cryptolemus* larva which although are often confused with mealy bugs are important predators of the former.

Diseases are generally less of an issue than winged vertebrate and insect pests. Fruit rots, such as *Colletotrichum gloeosporioides*, *Pestaloteopsis* sp, *Phomopsis* sp can occur particularly following damaged caused by insects or fruit rub. Under sustained wet conditions algal leaf spot caused by *Cephaleuros virescens*, can develop on older leaves. Stem canker, categorised by the development of a dark brown flaky crust on the main trunk and branches of older trees is reportedly caused by *Dolabra nepheliae*. Pruning which allows increased air and light penetration along with the judicial use of copper fungicide (free of chlorine) can assist with the management of all of the above.

### Harvesting and post harvest handling

Rambutans are a non-climacteric fruit, and must be harvested when ripe, as they do not continue to ripen after harvesting. The fruit are best harvested when the body of the fruit is fully coloured and the spinterns still retain some green colour. This is usually associated with a total soluble solids (brix) level of 19 to 22°. A number of the marketing associations have their own maturity standards which members are obliged to follow. A picking poster which documents fruit maturity, fruit quality and packing standards is available from the Northern Territory Department of Business, Industry and Resource Development.

Individual fruit or whole panicles of fruit are picked depending on flower synchrony and market prices. Picking should be restricted to the early hours of the morning to ensure fruit are fully turgid (hydrated).

Harvesting during the heat of the day results in soft fruit that rapidly lose their attractive colour. Harvested fruit, rapidly loose water from the many stomata that surround the spinterns. Fruit post-harvest shelf life is markedly improved under high humidity cool conditions. Management systems should be in place to ensure that picked fruit are kept moist and rapidly transferred back to the shed where they can be wet down with cool water prior to grading and sorting. A common system is seen in Figure 1.

Grading and handling systems vary with size of the enterprise and management preferences. Size grading is important to assist with packaging, particularly when punnet systems are used. The minimum acceptable fruit size is 34 g, but most growers are packing fruit in the 40 to 50 g range. Size grading systems vary from simple diverging belt to mechanical and electronic weight systems. All packaging is designed to minimise moisture loss from the fruit. The domestic market accepts single layer trays, six punnet packs and fruit on the panicle at Chinese New Year. The 250 g punnets are primarily designed for the export markets.

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**Figure 1. Picking, grading and packing protocol**

1. **Harvest**
   - Harvest in the cool of morning

2. **Pack fruit into required package**
   - Single layer tray (2.5 kg)
   - 6 x 800 g punnets (5.0 kg)
   - 10 x 250 g punnets (2.5 kg)
   - Fruit on panicle with leaf (5.0 kg)

3. **Final quality grading**
   - Fruit as per marketing group specifications

4. **Transfer**
   - Transfer rapidly to shed. Douse with cool water
   - Destalk ensuring a stub of stem remains on the fruit

5. **Store and transport**
   - Store and transport at 10-12°C

---

**Rambutan**

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**Packing spec**

- Single layer tray (2.5 kg)
- 6 x 800 g punnets (5.0 kg)
- 10 x 250 g punnets (2.5 kg)
- Fruit on panicle with leaf (5.0 kg)
- Chinese New Year

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**Picking Poster**

- Picking during the heat of the day results in soft fruit that rapidly lose their attractive colour.
- Harvested fruit, rapidly loose water from the many stomata that surround the spinterns. Fruit post-harvest shelf life is markedly improved under high humidity cool conditions. Management systems should be in place to ensure that picked fruit are kept moist and rapidly transferred back to the shed where they can be wet down with cool water prior to grading and sorting. A common system is seen in Figure 1.

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Financial information

Most rambutan growers have an alternative income source either on or off farm. Ngo (1996) shows that the profitability of a 5 ha rambutan orchard in the NT can be high at yields of 10 t/ha and a domestic prices of $5/kg. Profitability is further affected by yield fluctuations or cost of production. Netted orchards perform well due to the higher yields and the expected payback period for a fully netted orchard is 7 to 9 years. The cost of netting is a major capital cost and netting enclosures range in price from $7,600 to 17,500/ha for row and permanent systems respectively. Land and other capital costs such as buildings and machinery vary depending on location and quality, however, establishment costs for a 8 to 10 ha farm are unlikely to be less than $250,000. Similar studies have not been carried out for north Queensland growing areas, but less profitable returns are expected given the higher volume of production and the lower returns experienced as a result.

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Grains and legumes

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Azuki and kintoki beans

Anthony Hamilton

Acknowledgement is given to Peter Desborough and Robert Redden, the authors of this chapter in the first edition of this publication.

Introduction

Azuki (*Vigna angularis* (Willd.) Ohwi and Ohashi) is a summer pulse crop grown in southern/central Queensland, the North Coast of New South Wales (NSW) and irrigated regions in southern/central NSW. The grain resembles mung beans but has a maroon seedcoat and is slightly larger (100-160 mg). Although it is the sixth most commercially important crop in southeast Asia and is the most important pulse after soybeans, it is a minor crop in Australia. The key market for Australian azuki beans is Japan, where the beans are used to make a sweetened paste (ahn) that is made into a range of products such as traditional confectionery (wagashi), cakes and buns. Although usually referred to as adzuki bean in Australia, it is more correctly referred to as azuki, which means small red bean in Japanese.

Taisho kintoki is a large (500-600 mg), red-seeded kidney bean (*Phaseolus vulgaris* L.) grown in Japan. It has been included in various culinary bean trials in Australia since 1995 by Dr Robert Redden (formally Qld DPI) but not yet grown on a commercial scale. Small quantities of seed were imported into Australia to assess its potential, and NSW Dry Bean Growers Association (NSWDBGA), in conjunction with NSW Agriculture, is increasing basic seed stocks as some Japanese companies have expressed interest in purchasing kintokis from Australia.

As with azuki, kintoki is also used in confectionery, but differs from azuki in that it is usually consumed as whole seeds after infusion with sugar. Experience in Australia and North America have shown that harvesting can be a major problem with Kintoki.

Seed moisture at harvest needs to be 20-25% to prevent seed splitting. Tebo beans (*Phaseolus vulgaris* L.) are another culinary bean, similar to kintokis but possessing a white seed coat. Much of the agronomy and marketing for Tebo beans is similar to Kintoki beans.
Markets and marketing issues

Most azuki grain is traded through dealers, who may issue contracts. Harvested grain has to be carefully graded to produce a uniform and attractive sample. Most grain is exported to Japan, where Erimo is the preferred variety. A premium price is paid for large (120-160 mg), bright, light red azuki, seed free of hard seeds. It is difficult to compete with cheap imports from China for lesser quality seed. Small, niche markets exist for larger seeded ‘Dainagon’ type azuki, and there is some interest in purchasing white seeded azuki and Japanese ‘heritage’ cultivars such as Takara from Australian producers.

The azuki market is highly regulated in Japan, with quotas and tariffs on imported grain. The size of the quota varies each year depending on Japanese production levels. Japanese imports for quota grain come mostly from China for grain of lower quality. Production in Australia is influenced by price projections, which in turn are largely determined by the size of the import quota issued twice yearly by the Japanese government to importing companies. The size of the USA/Canada crop also influences prices. Approximately 1,500 t to 2,000 t tonnes are produced annually in Australia. Prices for good quality graded grain generally range from $750 to $1,500/t. There are currently no import quotas on azuki paste and a lower tariff than on raw beans. Some Japanese companies are processing azuki in Australia and Thailand then exporting it to Japan. As production from these companies increases, it is anticipated that at least 3,000 t of azuki may be produced in Australia.

Grain traders who buy azuki also source kintoki in Japan, and may purchase kintoki in future from Australian growers. It is anticipated that this market would be small (about 500 t), grown opportunistically in response to shortages in Japan. Figure 1 indicates the price variation in Azuki, Tebo and Kintoki beans since 1982.

Production requirements

Azuki and kintoki are summer crops and are considered more demanding than some other pulse crops, such as mung bean or soybean. Successful azuki crops have been produced in many areas in NSW and Queensland with yields of 2.5-3.0 t/ha possible under ideal conditions, with most growers being able to harvest 1.5-2.0 t/ha. Kintokis have achieved similar, to slightly higher, yields than azukis for comparable sowing times in trials.

In irrigation areas, where the majority of azuki crops are grown, it is important to select well-drained soils and be prepared for frequent light irrigation to alleviate moisture stress, as they are both shallow rooted crops, easily reverting to indeterminacy when stressed.

Seed quality is higher where pods can ripen under milder temperatures. This can be achieved by matching the sowing time to the location (altitude and latitude) in order for the crop to be ripening under cooler conditions with daily mean temperatures typically less than 20°C. Excessive summer heat can result in poor

Key Messages

- High value pulse crop but Japanese markets can be volatile
- Limited but lucrative local and primarily export markets
- Scope for value adding in Australia
- Requires good farmer skill levels

Key statistics

- Annual azuki production 1500 –2000 t
- Price range $750-1,500/t
- Yield range 1.5-3.0t/ha
quality small and dark coloured seed.

The main azuki bean growing areas in Japan are located on the northern island of Hokkaido (lat > 42°). The key azuki growing areas in north America are in Michigan and Ontario (lat ~ 42°). Both of these areas have mild summers which result in excellent quality beans. Azuki beans are grown in Australia at latitudes of 36–20° which experience hot summer conditions. They therefore need to be sown much later than in the Northern Hemisphere so as that the beans mature during cooler autumn temperatures.

**Varieties**

Azuki cultivation commenced in Australia in the 1970s with ‘Dalgety’. It was then superseded in 1980 by ‘Bloodwood’, a variety bred by the pioneer of the Australian azuki industry, Peter Desborough of NSW Agriculture. ‘Erimo’ is currently the most widely grown variety in Japan and was released in Australia in 1997 where it is now almost exclusively grown. Dainagon was also released in 1997.

There are promising new lines in Japan. However, they cannot be grown in Australia until plant variety patents expire. The Japanese Ministry of Agriculture randomly tests imported azuki for these varieties. Chinese varieties were also evaluated in Australia, but as yet have not been commercially released. NSW Agriculture has also evaluated Japanese varieties including so-called ‘heritage’ azuki cultivars Takara and Kotobuki.

Taisho is the major kintoki variety grown in Japan and is the only commercially available kintoki variety in Australia. Tancho kintoki has larger seeds but is protected by plant variety rights and is not yet available to Australian growers.

**Agronomy**

Publications containing detailed information on growing azuki are listed in ‘Key References’. NSW Agriculture publishes seasonal updates. There is limited published information about growing kintoki in Australia. However, information about both azuki and navy bean agronomy would be applicable.

Azukis are usually grown on narrow row spacings (15–30 cm) and high plant densities (500,000 to 700,000 plants/ha) and can be sown with a conventional combine or airseeder. This seems to promote taller plants, with pods above cutterbar height. Although wider row spacings and lower plant densities, with inter-row cultivation can produce good results (and are the most common systems used in Japan and North America), most trials have shown increased yield responses to higher densities. Kintokis, having much larger seeds, should be preferably sown with a precision seeder to achieve the desired plant population (300,000 to 500,000 plants/ha).

The optimum sowing time is usually a compromise between sowing early enough to have the crop mature before winter and late enough to achieve high quality seed. Both azukis and kintokis flower in response to thermal time (heat unit accumulation) and the growing period, from sowing to harvesting, ranges from 80 days in northern warmer climates to 140 days in cooler southern areas. Kintokis mature about 7–10 days earlier than azukis at comparable sowing times. Suggested sowing dates are as follows:

- Bathurst – early December
- Wagga – early January
- Forbes – mid January
- Southern Qld / NSW North coast – late January/early February

Azuki need to be correctly inoculated with Rhizobium, whereas nitrogen fertiliser is needed for kintokis, which cannot fix sufficient nitrogen for their requirements.
Azuki and kintoki crops are best grown on light freely drained soils. They are unsuited for cultivation on heavy self-mulching clays.

Irrigation management is critical to the success in inland irrigation districts as azuki and kintoki have poor tolerance to waterlogging.

**Pest and disease control**

Azuki and kintoki are slow growing in the first few weeks and need excellent weed control. Registration of suitable herbicides and insecticides has been difficult due to the limited scale of these crops. However, there is now a range of registered herbicides that control most grasses and broadleaf weeds in azuki crops. Growers should consult their agronomist for advice about suitable herbicides and insecticides.

Azuki and kintoki are most vulnerable to insect attack, especially from leaf and pod-eating caterpillars such as Heliothis (Helicoverpa spp.), Lucerne Seed Web Moth and Bean Pod-borer, and pod-sucking species such as Green Vegetable Bug as well as thrips, aphids, bean fly and mites. Crops must be scouted regularly and growers should budget on at least two insecticide applications. Insecticide resistance is an ongoing issue. Integrated pest management (IPM) including rotating chemical groups is useful for delaying resistance.

Sclerotinia can be a major problem, especially with azukis grown on centre pivot irrigation. Isolated instances of Powdery Mildew and a condition known as ‘Gummy Pod’ which results in sticky exudates from ripening pods, have been periodically reported in some azuki crops. Gummy pod is thought to be a symptom of hot conditions during flowering and can be over come by sowing at the correct sowing date. Powdery mildew is a more significant problem with kintokis than azukis, as is root rot due to Fusarium solani.

**Harvesting and grading**

Under the right conditions, azuki crops will mature over a relatively short period. However, indeterminacy can be a problem and most azuki crops are desiccated with glyphosate prior to harvest. Seed crops should be desiccated with diquat to ensure there is no reduction in seed viability. Crops can then either be windrowed or, more usually, direct headed. A conventional harvester can be used but rotary headers do a better job with less cracked seed. Harvesting kintokis can be a major problem in environments with low humidity, as the seed splits easily making it unsuitable for whole seed uses. One option is to grow kintokis under spray irrigation and apply a light (~5mm) irrigation just prior to harvest to soften the seed. This seed could be harvested above 30% moisture content and subsequently dried.

Japanese buyers look for a uniform sample with large (120-160 mg) azuki seed displaying a pale, bright colour and large (500-600 mg) kintoki seed displaying a dark but bright maroon seed coat. Some buyers measure colour with a colorimeter quantifying brightness ($L^*$), redness ($a^*$) and yellowness ($b^*$) values. Seed must be graded to ensure uniformity and freedom from contaminants. Kintoki seeds may need to be sorted with a colour sorter to remove any mottled coloured seeds.

A recognised quality assurance system will assist in marketing the crop. Cool storage should be contemplated for any long-term storage (>6months) as azuki will darken and deteriorate with age.

**Financial information**

The attractiveness of azuki and kintoki crops depends, in part, on the range of alternative crops and, in part, on the Japanese crop prospects and quota allocations. Azuki prices have been quite volatile in the past ranging from $600 to $2000/t. Kintoki prices are similar to azukis but, in some years, can be counter-cyclical to azuki prices (Figure 1).

Benchmarking azuki crops by NSW Agriculture in conjunction

![Figure 1. Tokyo dry bean wholesale prices](image-url)
Azuki and kintoki beans

with Co-ordinated Marketing Systems (CMS), Lachlan Rural Consultancy and the NSWDBGA shows a large range of gross margins (Figure 2). These are primarily determined by the yield of the crop, and to a lesser extent by the price received for the grain. Input costs, while high, are not the major determinant of gross margin. They are costly crops to grow so need to be well managed to produce high yields (Table 1).

Azuki and kintoki crops are short season crops suitable to double-cropping with wheat. The combined gross margin of a well-grown azuki crop followed by an irrigated wheat crop can be about $2,000/ha.

Table 1. Typical gross margin analyses for azuki and kintoki crops

<table>
<thead>
<tr>
<th>Activity</th>
<th>Azuki $/ha</th>
<th>Kintoki $/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor costs</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Seed &amp; fertiliser</td>
<td>220</td>
<td>920</td>
</tr>
<tr>
<td>Sprays</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Irrigation</td>
<td>160</td>
<td>160</td>
</tr>
<tr>
<td>Harvest &amp; freight</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Grade &amp; bag</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>Other costs</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Total cost</td>
<td>970</td>
<td>1740</td>
</tr>
<tr>
<td>Yield (t/ha)</td>
<td>2.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Price ($/t)</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>Total Income</td>
<td>2400</td>
<td>3000</td>
</tr>
<tr>
<td>Gross Margin</td>
<td>1430</td>
<td>1260</td>
</tr>
</tbody>
</table>

Figure 2. The effect of yield and price paid for azuki on gross margin. (Data are from 1999/2000 crops “benchmarked” by NSW Agriculture.)

About the author

Anthony Hamilton is a farmer based at Forbes NSW. He completed his PhD in 2002 studying aspects of the agronomy and seed quality of azuki and kintoki beans and was awarded an Australian Nuffield Farming Scholarship in 2003 to further study these crops. He operates a mixed farming and grazing property with his parents-in-law, producing beef cattle, lucerne, jojobas, cereal and oilseed crops, and azuki crops.
Azuki and kintoki beans

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Guar,

Cyamopsis tetragonoloba (L.) Taub. or ‘clusterbean’ is a tropical summer grain legume that has potential for the farming systems of Queensland, northern New South Wales and the Northern Territory. Its seed contains 20-30% galactomannan gum; this vegetable gum is widely used in food processing and in the building, petroleum, mining, paper, textile and pharmaceutical industries.

India and Pakistan have been traditional producers of guar grain but the increasing world demand for the gum product and its derivatives has seen processors seek alternative sources of supply. As a deep-rooted crop, guar exhibits good tolerance of the high temperatures and dry conditions found in grain growing regions of northern Australia.

The galactomannan gum fraction of the seed is removed with the endosperm or ‘splits’. Guar seed is rich in protein (around 35%) and should be heat-treated before feeding to non-ruminants. As a summer legume, guar may be useful in crop rotations to increase soil nitrogen for subsequent crops. Actively growing plants and guar stubble are both considered good fodder.

Markets and marketing issues

In 2001 the world market for guar gum was estimated at 160 000 tonnes (equivalent to 650,000 tonnes of seed). Australia itself imported 3000 tonnes of processed gum (12,000 tonnes of seed) to meet domestic demand.

A Guar Industry Development Association has been set up by a number of growers and industry stakeholders in southern Queensland over the past two years. This group is focused on marketing and agronomy to foster the development of a viable Australian guar industry.
It is essential that a buyer be arranged prior to growing guar in a commercial situation. In the past five years a European based multinational company has purchased guar grain from Australia in an attempt to diversify their source of supply. This company is now looking to source guar ‘splits’ (gum plus the seed coat) rather than whole grain from Australia.

In the 2002/03 season, the price for good quality grain was $330/t. Evaluation of a new milling process is underway in Queensland that will allow the export of guar ‘splits’ rather than whole grain. For information on marketing and grain processing see the Key Contacts section.

Production requirements

Guar is best adapted to dry tropical or sub-tropical regions with summer dominant rainfall. In India and Texas the main production areas for guar receive less than 800mm rainfall. Guar can also be grown as a supplementary irrigated crop, however over-watering can result in excessive production of vegetative growth and reduction in harvest index. The crop grows best under hot conditions, with maximum summer temperatures of 35-40°C. The crop is highly susceptible to frost.

Deep, well-drained sandy loam or sand soils with moderate alkalinity (pH 7.5-8.0) are considered optimal for guar. Well-drained alluvial clay and clay loams are also suitable. Care should be taken when growing guar on heavy, clay soils where the crop may be exposed to wet conditions; soil crusting can reduce seedling emergence and waterlogging increases the likelihood of root diseases.

Cultivars

At present only one variety of guar is available commercially, ‘CP177’. This is an erect, minimal branching, long season variety. Current seed stocks appear to be contaminated with off-types so some variation in plant type will be observed.

Over 400 lines of guar held at the Australian Tropical Crops and Forages Genetic Resource Centre in Biloela have been evaluated for their suitability to commercial production. The collection reflects the diverse nature of the crop and contains forage, grain and vegetable varieties of guar. Multi-location field trials are underway to identify a suitable grain cultivar for commercial production.

Additional varietal improvement is being undertaken by Australian Gum Products and by some independent growers.

Agronomy

Paddock selection is vital for successful production of guar. As well as considering soil type it is important to select an area that is free from summer growing weeds. In the early stages the crop is susceptible to weed competition and there are no herbicides registered for use in guar in Australia in 2004.

October to late December is the preferred planting time for guar in Queensland and New South Wales. For the Northern Territory optimum planting time is between mid-December and early January. Soil temperatures should be 20°C to produce reliable germination. The current commercial variety of guar is photoperiod sensitive and planting after mid-January will result in smaller plants, premature flowering and reduced yield potential.

Guar has a high requirement for phosphorous. Deficient soils or those with low levels of vesicular-arbuscular mycorrhiza (VAM) will require moderate to high levels of P fertiliser at sowing. As a legume guar requires inoculation with Rhizobium bacteria in order to fix atmospheric nitrogen. The correct strain of inoculant for guar is CB3035, which should be applied to the seed at planting.

Established plant populations of 100,000 to 200,000 plants/ha are satisfactory for dryland crops. The seed size of guar is approximately

Key messages

• Ensure you have a buyer before planting
• Paddock selection is vital
• Pay good attention to nutrition and seed inoculation'
• Yields of up to 1t/ha dryland and 3t/ha irrigated'

Key statistics

• World market for guar gum was estimated at 160,000 tonnes (equivalent to 650,000 tonnes of seed) in 2001
• Australia imported 3,000 tonnes of processed gum (12,000 tonnes of seed) to meet domestic demand (2001 figures).
30,000 seeds/kg, which equates to a planting rate of 7-10 kg/ha. Good results have been achieved with row spacings from 30-100cm. In the absence of registered herbicides wider row spacings allow inter-row cultivation for weed control.

**Pest and disease control**

Leaf sucking insects such as thrips (*Thrips* spp.) and leafhoppers (*Austroasca* spp.) can attack young plants. Telltale signs are white spots or stippling on the leaf surface. Green vegetable bug (*Nezara viridula*) and brown bean bug (*Riptortus serripes*) feed on developing pods and can cause seed damage or pod abortion. In particular Central Queensland crops or those grown under irrigation are at greater risk from these pests.

In Australia, the main diseases of guar are ashy stem blight, (*Macrophomina phaseoli*) and root rot (*Fusarium* sp.) both of which are associated with crops grown on poorly drained soils. In addition leaf spot (*Alternaria cucumerina*) thrives under humid conditions and is characterised by brown target-like lesions on the leaves. In acute cases, lesions may cover the whole leaf surface and lead to leaf drop. *Alternaria* has caused economic damage in some Queensland guar crops.

No insecticides or fungicides are registered for use in guar in Australia in 2004.

**Harvesting**

The current commercial variety of guar is indeterminate and will continue growing until soil moisture or low temperatures become limiting. Particular care should be taken when harvesting crops that contain a mixture of mature and immature seed pods. Wet or humid conditions during grain development as well as harvesting at high grain moisture contents can both result in weathering of the grain. This grey or black discoloration reduces the commercial value of the crop. Guar holds its seed relatively well and shattering losses are generally low.

The crop can be harvested with conventional headers using a low drum speed to minimise seed damage. Some guar pods may be held at or near ground level. These are difficult to harvest, especially on uneven ground and can result in loss of yield. Volunteer guar in subsequent crops can be controlled by the use of rotations.

Yields of around 1t/ha dryland and 3t/ha irrigated are achievable from well-managed crops.

**Further work required**

Marketing studies and varietal assessments funded by RIRDC are under way. In addition to marketing studies, further development work is required by growers and the industry to make guar a viable and competitive crop.
that will fit into current rotations. Some of the studies that are needed are:

- Testing herbicides and insecticides for registration
- Agronomic studies on nutrition, sowing date, row spacing and plant population

**Key references**


Various authors (2001) Proceedings of Guar Workshop Roma. Queensland Department of Primary Industries and Fisheries


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**Key contacts**

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**About the authors**

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Richard Routley has over 20 years experience in various advisory, teaching, extension and research positions in the broadacre cropping industries in southern Qld. He is currently Senior Development Agronomist based at the QDPI&F AFFS Research Station at Roma in South West Qld.

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Lima beans (Phaseolus lunatus) are in the same plant genus as common, or navy beans (Phaseolus vulgaris), to which they are distantly related. Currently up to 700 t/year of raw beans are imported, while some are imported in processed products from offshore canneries (although navy bean production has exceeded 9,000 t/yr, it is currently about 3,000 t/yr). No lima beans are commercially produced in Australia despite several years of research demonstrating the feasibility of such production.

For dry grain production under rainfed conditions in Queensland, lima beans are 20–40% superior in yield to navy beans, and are more drought-tolerant. Because of the extensive low branching of the bean bushes and indeterminate pod maturity on flower bearing stalks (racemes), cutting and windrowing harvest techniques are recommended. Equipment for this is available in traditional navy and peanut areas such as the Burnett (Qld).

The major competitors for exports of ‘green baby’ and other lima market classes are USA and Myanmar. Australian production, besides meeting local demands, could target Japan for high quality exports. Potential producers require skills in intensive crop management superior to those needed for navy beans. Skilful harvesting is needed to preserve seed coat integrity, to be free from chipped grain and maintain the right seed colour to meet market specifications, or risk being disposed of in the low value market for stock feed.
Markets

Australian lima grain imports are 400 t/year of the large green-white and about 300 t/year of the small white and small ‘green baby’ lima beans. The large lima beans are retailed direct to food consumers in small 200g-1kg dry bean packages through supermarkets, and may be self served from large sacks in specialty food stores. However the canning industry mainly uses the ‘green baby’ lima beans canned in brine either alone or in 3-4 bean mixes for use in salads. Lima beans are imported from Delaware and California, USA, where they are the by-product of harvesting immature ‘wet’ green beans, the latter need to be immediately canned. Given the small scale of demand in Australia, such a specialised industry for ‘wet’ lima bean canning would not be feasible here, however Australian production of dry grain could replace the current imports for both the canning and packaged grain markets.

Principal market outlets in Australia are the major supermarket chains for dry bean packages, while canneries include Simplot at Bathurst, Western Port at Tyabb Victoria, and Windsor Farms at Cowra. Health and specialty food shops are also retail outlets for raw beans. Potential export markets included Japan and East Asia.

The market chain to canneries is from producers via intermediate grading plants capable of meeting delivery specifications, such as Bean Growers Australia, Kingaroy. Most raw grain is distributed to retailers from importers who specialise in repacking bulk shipments, as do, for example, Ward McKenzie, and Trans Global Food Traders.

Prices for beans landed in Australia are based on world parity with associated fluctuations in a 10-20% range. Current prices of raw bean seed landed in Australia are $1,600 - 1,700/t for large, and $1,400 - 1,500/t for small, lima beans.

Production requirements

Lima beans are a summer crop of 90-110 days duration, best suited to a 20-35°C range. The cropping zones of southern Queensland and northern NSW are suitable for rainfed crops in the 600-1000 mm rainfall zone with a predominantly summer peak. Although more tolerant of water stress than navy beans, lima beans are more sensitive to daily minimum temperatures below 15°C and have a narrower climatic crop window than navy beans. In southern Queensland best yields are obtained with early summer sowing, whereas a late (February) summer sowing lowers yield, delays maturity and reduces seed size to a much greater extent than for navy beans.

With irrigation, the crop could be summer grown from central NSW to central Queensland and winter grown in both north Queensland and the Ord River irrigation region. The crop needs 300-400 mm of irrigation

Lima beans are best suited to light, well-drained soils with deep profiles. Yields can be very constrained on some heavy black mulching clays.

Agronomy

Lima beans can be drilled either into conventionally tilled seed beds or directly into minimum tillage stubble, using either row crop or conventional seed drills. ‘Trifluralin®’ herbicide can be applied pre-emergence, while post-emergence weed control can be achieved with ‘Basogram®’ and ‘Stomp®’, in the lower range of recommended navy bean rates for all herbicides – none of which are yet registered for lima beans. Alternatively inter-row cultivation

Key messages

- No lima beans are commercially produced in Australia despite several years of research demonstrating the feasibility of such production
- Under rainfed conditions in Queensland, lima beans are 20-40% superior in yield to navy beans, and are more drought-tolerant
- Australian production, besides meeting local demands, could target Japan for high quality exports
- Potential producers require skills in intensive crop management superior to those needed for navy beans
- Skilful harvesting is needed

Key statistics

- Currently up to 700 t/year of raw beans are imported
- Current prices of raw bean seed landed in Australia are $1,600 - 1,700/t for large, and $1,400 - 1,500/t for small, lima beans
For optimal yields, the potential crop nutrient requirement must be supplied as fertiliser; under rainfed conditions, 40 kg/ha of nitrogen for a 1 t/ha harvest; and up to 80 kg/ha for 2 t/ha irrigated crop. Under Australian conditions the nitrogen fixation capacity is unreliable.

The growth rate of lima beans is very temperature sensitive with maturity delayed as minimum temperatures fall below 15°C. Due to indeterminacy in growth habit, the plant’s leaves often remain green and functional while pods mature, especially if moisture and temperature are favourable.

The interval from planting to first ripe pod is in the range 75-80 days, with 1-2 weeks more for 50% ripe pods. In southern Queensland, optimal sowing time is November-December, with some reduction in yield potential with either earlier or later planting. In other regions sowing could be timed to place the crop in the warmer summer months in more temperate latitudes, or early winter in tropical latitudes.

Abortion of flowers and pods is a risk with regular maximum temperatures above 40°C, and USA experience indicates that a high relative humidity is an advantage to crop growth and pod maturity.

Varieties

The emerging varieties suited to production in south Queensland and with acceptable canning quality include the ‘Green Baby’ series, ‘Improved Kingston’ and ‘Mendoza Bush’.

About the author

Dr Robert (Bob) Redden is curator of the Australian Temperate Field Crops Collection, with responsibility for worldwide collections of the genetic resources of pea, lentil, chickpea, faba bean, vetch and the Brassica oilseeds (eg. canola). Previously he bred navy beans, culinary phaseolus beans, adzuki and lima beans based at DPI Hermitage Research Station Queensland, with activities of introduction of genetic resources, germplasm evaluation for both agronomic and food processing traits, and adaptive research to fit Australian farming systems.
**Harvest**

Although lima beans have seed pods with thick hard shells, they tend to split open along the inner suture, exposing seed to the weather and, at full maturity, tend to dehisce. Due to uneven ripening of pods over a 2-3 week period and non-ripening of up to 20% because of indeterminate flowering and partially developed pods, timing of harvest is problematic. The desired green coloration of seed is best expressed at point of maturity - seeds tend to be bleached white at full maturation.

The best compromise appears to be harvest when pods are 30-50% mature, although immediate grading to remove green leafy trash is required to avoid growth of moulds on damp seed. Harvest trials using desiccants and different harvest timing points have indicated that growers can achieve optimal retention of marketable grain colour with either windrowing or desiccation at 50% pod maturity, but maximisation of grain yield at 90% pod maturity. Yields may be reduced by up to 20% if the crop is harvested before 50% maturity, however, prices drop to feed grain level if the grain does not meet market specifications.

For marketing for human consumption, deliveries to grading facilities should have less than 5% trash/foreign matter. This should fall to zero after grading, which will also remove split and undersized seed. It may be important to arrange for grading immediately after harvest. Direct harvest rather than windrowing may reduce the level of dust on the seed, which for the red soils of the Burnett region in Queensland is difficult to remove for market acceptance.

**Financial information**

Although lima beans are suited to a wider geographic area, commercial trials have only been conducted in the Burnett region of Southern Queensland, where gross margins under rainfed conditions are likely to be at least 20% better than for navy beans. Input costs for the two crops will be similar but yields and prices will be higher for lima beans.

At 0.74 t/ha, gross margins for navy beans are $207/ha. Lima beans are likely to yield at least 20% better on average and to be up to 100% better in price with a gross margin of up to $900/ha, although losses during grading to meet commercial specifications are likely to exceed those for navy beans. Harvest risks are also high with lima beans, with stringent market specifications and a ‘cliff face’ drop to feed grain prices if unacceptable.

Establishment costs may be minimal for current peanut and navy bean growers who can use existing equipment for cutting and windrowing at harvest. However, for other growers, either specialised harvesting equipment will need to be purchased, or locally suitable harvest methods will need to be developed.

**Key references**


University of Queensland Gatton College), p 8


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Sesame, *Sesamum indicum* L., is an ancient oil crop supplying seeds for confectionery purposes, edible oil, paste (tahini), cake and flour. It is typically a crop of small farmers in the developing countries. In 2001, all but 1,000 ha of the about 8 million ha of sesame grown were in developing countries (Table 1).

Sesame has important agricultural attributes:

- it is adapted to tropical and temperate conditions;
- it grows well on stored soil moisture with minimal irrigation or rainfall, and
- it can produce good yields under high temperatures while its seed is of high value, $A1,000/mt (export quality).

Sesame world production areas have remained generally stable over the years, however in some countries the crop is being marginalised. Competition from more remunerative crops and a shortage of labour has pushed sesame to the less fertile land and to areas of higher risk. Left unchecked, world sesame production may decrease in the foreseeable future. This provides an opportunity for Australia to produce larger quantities of high quality sesame seed to replace ‘lost’ world production.

The areas and production of sesame in Australia from 1999/01 – 2002/03 is shown in Table 2.

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**About the author**

Malcolm Bennett (B. Agric Sc), Sesame Agronomist for 16 years with NT Department of Business, Industry and Resource Development.
Before sesame can realise its potential, extensive research is needed to adapt sesame to mechanical agricultural systems. Furthermore, as Australia is becoming more involved with Asian regional activities, where much of the world’s sesame is grown, Australia’s own agricultural self-interest could be combined with its international extension and aid programs by taking the lead in a regional sesame research and development project.

### Markets

In 2000, world exports of sesame seed were 657,000 t, with Japan being the largest importer taking 23% of the world imports.

European Community, Korea and USA are the other major importers of sesame seed.

It is forecasted that the imports of sesame seed will grow at between 4% and 6% per annum until the year 2012.

### Oil industry

Australia imported 1,116 t of sesame oil and sesame products in 2002 (worth $A4.2 million). Currently, there is one sesame oil processor in Australia producing small quantities of sesame oil from locally produced seed.

### Confectionery and biscuit industry

The raw seeds currently used in Australia for confectionery and biscuit production are sourced from both local and overseas suppliers.

### Table 1. Sesame areas, production and yields in 2001 by region

<table>
<thead>
<tr>
<th>Region or Country</th>
<th>Harvested area (1,000 ha)</th>
<th>Production (1,000 mt)</th>
<th>Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>7,784</td>
<td>3,150</td>
<td>405</td>
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<tr>
<td>Developed countries&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>&lt;1</td>
<td>600</td>
</tr>
<tr>
<td><strong>Regions</strong></td>
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<tr>
<td>America</td>
<td>238</td>
<td>148</td>
<td>647</td>
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<td>Asia</td>
<td>4,753</td>
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<td>Africa</td>
<td>2,793</td>
<td>739</td>
<td>264</td>
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<table>
<thead>
<tr>
<th>Major producers</th>
<th>Harvested area (1,000 ha)</th>
<th>Production (1,000 mt)</th>
<th>Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico</td>
<td>72</td>
<td>41</td>
<td>567</td>
</tr>
<tr>
<td>India</td>
<td>2,180</td>
<td>730</td>
<td>335</td>
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<tr>
<td>Myanmar</td>
<td>1,311</td>
<td>426</td>
<td>325</td>
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<tr>
<td>China</td>
<td>702</td>
<td>1,127</td>
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<tr>
<td>Nigeria</td>
<td>151</td>
<td>69</td>
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</tr>
<tr>
<td>Sudan</td>
<td>1,900</td>
<td>300</td>
<td>158</td>
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<tr>
<td>Uganda</td>
<td>203</td>
<td>102</td>
<td>502</td>
</tr>
</tbody>
</table>

<sup>a</sup> Source: FAO Production Yearbook, Vol. 55, 2001

<sup>b</sup> Countries using mechanised harvesting practices

<sup>c</sup> Author’s estimate

### Table 2. Areas and production of sesame in Australia

<table>
<thead>
<tr>
<th>Year</th>
<th>Northern Territory</th>
<th>Southern Queensland</th>
<th>New South Wales</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (ha)</td>
<td>Production (t)</td>
<td>Area (ha)</td>
</tr>
<tr>
<td>1999-00</td>
<td>350</td>
<td>189</td>
<td>*</td>
</tr>
<tr>
<td>2000-01</td>
<td>620</td>
<td>200</td>
<td>*</td>
</tr>
<tr>
<td>2001-02</td>
<td>30</td>
<td>10</td>
<td>*</td>
</tr>
<tr>
<td>2002-03</td>
<td>30</td>
<td>11</td>
<td>*</td>
</tr>
</tbody>
</table>

<sup>1</sup> Farming region affected by drought

* Figures not available
**Tahini industry**

Tahini, a traditional Middle Eastern sesame paste is made from hulled sesame seed. Market demand is currently met by local manufacturers and imports from Mexico, the Middle East and some Mediterranean countries.

**Dip and spread manufacturers**

Dip manufacturers add ingredients, such as chickpeas and eggplant, to tahini and call the products Hommus and Baba Gannouj. These manufacturers purchase their tahini from local suppliers and some also use imports.

**Bakery industry**

The bakery industry prefers dehulled seeds that are purchased from local and overseas suppliers.

**Halva industry**

Halva is a popular sweet made by mixing approximately 50% tahini with boiled/whipped sugar and several other ingredients to a manufacturer’s recipe. At present all halva sold in Australia is fully imported from Greece, Turkey and Israel.

**Flour industry**

A project to design and install a commercial scale extraction facility to produce protein flour from sesame seed is under development.

**Marketing issues**

Two aspects, antioxidants and organic sesame, would improve marketing of Australian sesame seed. Sesame seed contains antioxidants, which inhibit the development of rancidity in the oil. In the food industry where synthetic antioxidants are used extensively, there is an increasing demand for more natural products.

With the growing demand for organically grown food there is also a market for sesame products produced under organic conditions.

Australian unhulled sesame seed is sold according to (Australian) Grade Standards. Specifications include Australian Premium grade for export, Australian Number 1 grade for the top end of the domestic market and Australian Standard grade which is designed for sesame import replacement.

**Crop potential**

During the 1970-80s Australian agronomists targeted chick-pea and canola in their search for new commercial crops. Now, almost two decades later, chickpeas and canola are grown extensively with domestic and international sales. Sesame has the potential to follow their development pattern with adequate research and persistence by scientists and farmers.

**Production requirements**

**Soils**

Sesame grows best on well-drained soils of moderate fertility. The optimum pH for growth ranges from 5.4 to 6.7. Good drainage is crucial as sesame is very susceptible to short periods of waterlogging. Sesame is intolerant of very acidic or saline soils.

**Climate**

The response of sesame to both temperature and day length indicates that it is well adapted to wet season production in the tropics or summer production in the warmer temperate areas.

While there is some variation between cultivars, the base temperature for germination is about 16°C. In temperate areas soil temperatures determine the earliest date of sowing. The optimum temperature for growth varies with cultivar from 27 to 35°C.

Periods of high temperature above 40°C during flowering reduce capsule and seed development.

Because sesame is a short day plant with flowering being initiated as day length declines to a critical day length, cultivars are developed for particular latitudes.

The total amount of water required to grow a sesame crop ranges from 600 to 1,000 mm depending on the cultivar and the climatic conditions.

The water requirement can be met from available soil moisture at sowing, rainfall during the growing season and irrigation.

Hail and frost cause severe damage to sesame crops. Strong winds as the crop matures will greatly increase the likelihood of lodging and pre-harvest seed losses.

**Cultivars**

Five sesame cultivars are recommended for use in Australia. They are Yori 77 and Edith for the NT and northern WA and Magwe Brown, Aussie Gold and Beech’s Choice for QLD and northern NSW. The characteristics of these cultivars are given in Table 3. There are no cultivars recommended for growing in central and southern NSW and it is advised that prospective growers seek advice from Namreh Grain Trader Pty Ltd., NSW. Namreh Grain Trader anticipates the release of two new cultivars in the 2005 season.
Agronomy

Crop rotations
There are a number of advantages in including sesame in a crop rotation system. If sown after a leguminous crop, sesame can utilise the residual nitrogen from the legume. If the leguminous crop made good growth then the residual nitrogen should meet about one-third to one-half of the sesame crop needs.

Where sesame is rotated with a cereal, there can be mutual benefits in weed control. Broad leaf weeds can be readily controlled in the cereal crop using selective herbicides, such as atrazine or 2,4 D, greatly reducing the risk of broadleaf weeds in the subsequent sesame crop. Similarly, grass weeds which are difficult to control in the cereal crop can be fairly easily controlled in a conventionally tilled sesame crop using pre-emergent herbicides such as Treflan®, Dual® and Stomp®. Eptam® can be used as a pre-emergent herbicide for the control of some broadleaf weeds.

Paddock selection
Paddocks to be sown should have an even grade and be well drained. As control of broadleaf weeds is a problem in sesame, paddocks should be chosen which have a low content of broadleaf weed seeds.

Date of sowing, seed rate, and sowing depth
The optimum sowing date for sesame in northern NSW is the first half of December, in QLD the second and third weeks of December while in the NT the second and third weeks of January are recommended.

Seed should be sown in rows 30 to 50 cm apart to give 30 to 35 plants/m². Generally a sowing rate of 3.3 kg/ha of seed is required. If sesame is sown on one metre row spacing to fit with equipment configuration or irrigation bed arrangement then the seeding rate should be reduced by half. Sowing in cool conditions in NSW will require higher sowing rates.

As sesame seed is small, sowing depth should be no greater than 2.5 cm and the seed should be sown into moist soil using press wheels on the planting equipment.

Fertilisers
The fertiliser requirements for sesame will depend on the fertility of the soil which will vary with soil type and previous land use. The following is a guide on the type and rate of fertiliser to be applied.

An application rate of 60 kg/ha of nitrogen is likely to be adequate based upon the nitrogen content of the seed being 4%. The nitrogen should all be applied at sowing as there appears to be no advantage in a split application. Most sandy loam soils can be expected to be deficient in P, K, S, Cu, Zn and B. Unless the area has received prior applications of fertiliser an application of at least 100 kg/ha of both single superphosphate plus trace elements and Muriate of Potash is warranted. The clay soils tend to be more fertile and don't require K but do require P, S, Cu, Zn and B.

Irrigation
The number and timing of irrigations will depend on soil type, location and seasonal conditions. Generally the crop requirements for water can be expected to be about half of that for cotton or maize. The preferred method for establishment is an initial watering prior to sowing. The soil needs to be kept moist until the beginning of flowering to help early growth and to maintain herbicide activity. The most critical time for moisture is between first flower and completion of flowering. The final irrigation should be applied when the lower capsules turn yellow.

Weed control
Sesame grows slowly during the early stages of growth and is not strongly competitive with weeds. Poor weed control early in the life of the crop can result in greatly reduced crop yields.

In the NT, zero-tillage techniques are recommended to assist establishment. Zero-tillage involves sowing the crop into mulch which reduces weed growth and has other beneficial

<table>
<thead>
<tr>
<th>Characters</th>
<th>Queensland</th>
<th>Northern Territory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Magwe Brown</td>
<td>Aussie Gold</td>
</tr>
<tr>
<td>Seed yield (t/ha)</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Seed size (g/1 000)</td>
<td>2.6</td>
<td>3.3</td>
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<tr>
<td>Capsules per leaf axil</td>
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<tr>
<td>Days to flower</td>
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effects. These include reducing soil temperatures, reducing soil surface evaporation and protecting the soil from erosion. No post-emergence herbicides for grass control can be used.

In NSW where wide row spacing is used, interrow cultivation and spot spraying with glyphosate is possible. The pre-emergent herbicides trifluralin, metolachlor, and pendimethalin can be used for control of grassy weeds. Sesame is extremely sensitive to low concentrations of the residual herbicides in the sulfonylurea family which are widely used in wheat and barley. These include Glean®, Logran® and various products containing metsulfuron such as Ally®. Growers should observe the plant back periods listed on the label. The control of broadleaf weeds poses a major problem at the present time as no effective post-emergent herbicides have been identified.

#### Pest and disease control

While a wide range of insect pests attack sesame around the world only the sesame leaf webber (Antigastra catalaunalis), Heliotris caterpillars, Helicoverpa punctigera and *H. armigera* and Green Vegetable Bug (*Nezara viridula*) have caused serious problems in Australia. To date, sesame leaf webber has not been observed in NSW. Mirids can also infest sesame crops. The yellow mirid is beneficial and should not be sprayed, while the green mirid may require control.

Heliotris caterpillars are highly mobile and can rapidly damage sesame capsules. Control is made difficult by the high levels of pesticide resistance found in Heliotris. Regular monitoring and the application of integrated pest management strategies are essential to minimise their impact. Similar pest management strategies to those used for cotton are recommended. The threshold level for spraying is one small to medium sized caterpillar per ten plants. To date two applications of insecticide have provided satisfactory control.

Sesame is prone to root and stem diseases associated with waterlogging while damping-off diseases can also occur if humidity is high. While seven diseases affecting sesame have been identified only two *Corynespora cassiicola* (target spot) and *Pseudocercospora sesami* (large cercospora leaf spot), can severely affect grain yields.

Large cercospora leaf spot causes large spots on the foliage which are dull brown in colour, and irregularly shaped. The spots often coalesce, killing portions or entire leaves on susceptible cultivars during humid conditions.

Target spot first appears as dark (often purplish) spots on leaves, stems and pods. As spots enlarge they develop lighter coloured centres.

#### Harvesting, handling and storage

The indeterminate growth habit of sesame with its subsequent uneven ripening of the capsules creates difficulties for mechanical harvesting. However, techniques have now been developed that reduce seed losses during harvesting to less than 10%.

It is important that the crop be completely dry prior to harvesting as sap from green material passing through the header can discolour and taint the seed creating off-flavours in subsequent processed products.

The recommended procedure for harvesting sesame is to spray the crop with a desiccant when at least 70% of the capsules have changed colour from dark green to light green or yellow. In northern Australia an aerial application of Reglone® at 1 l/ha has proved effective.

In New South Wales and southern Queensland the rate of Reglone® should be increased to 2 to 3 l/ha. In southern NSW where
temperatures are much cooler, desiccants have proved unreliable and it is recommended that the crop be harvested and windrowed to dry.

The crop is harvested when 100% of the capsules have turned brown which should be about ten to fifteen days after desiccation. At this stage the grain moisture content will be about 6 to 7% in northern Australia.

In temperate areas the grain moisture content is likely to be higher and require a longer time to dry down before harvesting.

Harvesting is most efficient at a ground speed of 4 to 6 km/hr using a harvester fitted with a Harvestair® air reel and an extended table which gives a knife to auger distance as large as possible.

Sesame seed is easily threshed and relatively delicate so drum speed should be reduced to about half of that required for cereals and the concave clearance made as wide as possible. Seed damage during harvesting affects both the viability of the seed, storage and the quality of the oil.

For safe long-term storage, sesame seed should be clean, have moisture content no more than 6% and be stored at a relative humidity of approximately 50% and at a temperature less than 18°C.

Financial information

The economics of sesame production will vary with location while the attractiveness of the crop to a potential grower will depend on the expected returns from alternative crops that can be grown.

The area sown to sesame is dependent on the area that can be harvested in 3 days by one harvester. Currently 90-100 ha is the recommended ‘unit’ area. A smaller area should be sown if the crop is being sown for the first time.

Table 4: Gross margin budget for sesame production in the Northern Territory, Queensland and New South Wales

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<th>Item</th>
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<th>QLD² Dryland</th>
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1 Indicative price for Australian Number 1 grade sesame seed according to variety
2 Zero tillage land preparation
3 Seed is sold at the farm gate and seed supplied free by contractor.
Key references


Acknowledgements

This paper has been largely prepared from papers presented at the First Australian Sesame Conference held at Darwin and Katherine in 1995, (Australian) Sesame Growers Guide and Grade Standards for Sesame Seed and Sesame Oil. The assistance of Don Beech, Chris Cole and Brett Clift is particularly acknowledged for editing this paper.

Key statistics

- In 2001, world production of sesame seed was 3,150 mt
- Australia imported 6,100 t of sesame seed in 2002 (worth $A9 million), with China, Mexico and India the main suppliers
- Australian production of sesame seed decreased from 620 t in 2000-01 to 170 t in 2001-02
- Australia imported 1,116 t of sesame oil and sesame products in 2002 (worth $A4.2 million)

Key messages

- Suitable to sorghum growing regions
- High value oil seed crop
- Extensive local and overseas markets

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Coriander and fenugreek 229
Culinary herbs 236
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Jojoba 251
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Capers

Jonathon and Samantha Trewartha

Introduction

A global cuisine appears almost inevitable as the world’s diverse foods are increasing available internationally. The caper plant is a drought-tolerant, perennial bush that grows in semiarid areas, requires very little water, has a favourable influence on the environment, stabilizes eroding slopes, provides medicinal and cosmetic compounds and is an essential and unique component of many meals.

The demand and consumption of capers is growing as lifestyles focus increasingly on healthy and sustainable food. Food tastes are expanding and as Mediterranean flavoured foods spread internationally, unique specialized products are increasingly sought out. In 1999 Steve Hubbard, worldwide Marketing Manager for Griffith Laboratories, a global manufacturer of food ingredients, commented on capers as one of several “potential celebrities in the culinary world” (Food Product Design magazine).

Capers have a long history of use by humans; the first evidence of consumption dating back to around 18,000 years ago in Upper Egypt, with evidence that they were eaten in Iran and Iraq in 6000 BC, in ancient Greece, in Rome in the middle ages and, in the last several centuries, in Spain and France.

The caper of commerce is in fact the immature flower bud and left to grow it increases in size and opens into a flower, which then ripens into a caper berry, which can also be pickled for use as a condiment if picked before it ripens and bursts open.
Capers also have a long history of use in medicine and cosmetics.

Hippocrates wrote about the medicinal properties of different caper plant tissues and they are still sought after today for their medicinal value and in particular the health giving properties of the anti-oxidant bioflavinoid rutin which the plant contains in considerable amounts.

Today, global trade in capers involves around 60 countries and average annual production is estimated around 10,000 t.

Capers are hand harvested and growers would need to be able bodied or in a position to employ casual labour over the summer harvesting period. The Australian industry is young and while this presents an opportunity to build a cohesive, co-operative Industry and Marketing body, participants would need to persevere and consider their investment over the medium term.

Markets and marketing issue

Morocco and Turkey lead world production, but in both countries capers are largely harvested in the wild. The major cultivated plantations are in Spain (2,600 ha) where the industry has received considerable government support and research assistance and in Italy (1,000 ha) where caper farming has a long tradition.

Quality is determined by size, the smallest capers being the most prized, uniformity (difficult to ensure similar shape and color with wild harvesting) and flavour influenced by preserving technique.

Production has been increasingly exposed to the competitive influence of Turkey and Morocco and prices have been on a downward trend, however, caper quality and presentation are recognized by traders and higher prices are paid for Italian products. Recently capers from Morocco were rejected in some EU countries when they tested positive for high levels of toxic insecticide residues. Even higher prices are paid for French and Greek products where capers are generally produced in very small amounts for sale to those concerned with securing a high-quality supply.

Australia currently imports all caper products and although the customs data for imports of foods in this category is non specific it is estimated that around 600 t of product is imported with a wholesale value of approximately $AUD 7-9million.

The local market is relatively immature but an opportunity...
exists for a niche market initially targeting discerning consumers concerned with the image, freshness and quality of their food. Restaurants, gourmet supermarkets and grocers, produce markets and wholesale to gourmet food producers all provide niche markets.

The caper offers product variety and value adding can occur by downstream processing into tapanades (‘tapana’ means ‘caper’ in French), pestos, sauces and pastes. The caper leaf is also edible and a niche market may develop for these either fresh or as an ingredient in pestos and pastes.

With an increasing focus globally on sustainable production systems and quality, Australia has an international reputation for “clean and green” food production and is positively positioned to take advantage of a high-end export market.

In addition Asia is increasingly enjoying Mediterranean flavored foods with a sharp increase in olive oil consumption over the last 15 years.

In order to compete with established low cost caper producers in countries with low labor costs the Australian industry would need to find ways to increase economies of scale and decrease the cost of production. Opportunities exist for the fledgling industry to combine resources limiting capital expenditure, ensuring supply and sustainable price points in the marketplace reducing competition between growers, as well as developing a quality system that maintains Australia’s commercial advantage as a quality producer.

Key messages

- Immature market not clearly identified and quantified
- Opportunity for young industry to develop a cohesive approach
- Focus on quality and price
- Investigate niche marketing, value adding and downstream marketing

Production requirements

Capers are native to the Mediterranean and are as a general rule of thumb they can be found in regions where olives and almonds are grown.

The caper bush requires a semi-arid climate. Mean annual temperatures in areas under cultivation are over 14°C and rainfall varies from 200mm/year in Spain to 680 on the island of Salina in Italy. A rainy spring and a long, hot, dry summer are important for production.

The caper bush can withstand temperatures of over 40°C in summer but it is sensitive to frost during its growing period. It is a deciduous plant able to withstand low winter temperatures of up to –10°C in the form of a stump.

Capers have been found in the foothills of the Alps at altitudes of over 1000m but they generally prefer lower altitudes and are closely associated with the ocean growing wild over rocky cliffs and on dry coastal ecosystems and withstanding strong winds. They appear to have no specific topographical preferences although a gentle slope may assist drainage.

Deep and well-drained sandy to sandy-loam soils are preferable although the caper adapts perfectly to chalky soils and some clay as long as the drainage is good.

Soil pH between 7.5 and 8 are optimum though pH values from 6.1 to 8.5 can be tolerated. The caper plant is able to grow well in poor soils as it has the ability to maximize the uptake of nutrients.

Young caper buds maturing to flower (Photo courtesy of David and Kathy Cox)
**Varieties**

Few, if any breeding programs have been undertaken worldwide and given the existence of extensive variations within the cultivated varieties, it is difficult to define the genetic material available.

In Australia, the parent plants of original propagations are of unknown variety but of the five or six different types available several have shown the advantageous characteristics similar to those of commercial plants in Italy. These plants are members of the species *Capparis spinosa*.

There is considerable scope for further research to ensure that varieties are selected for high productivity, flower quality, (flavour and processed appearance), ease of harvesting, short and uniform flowering periods and resistance to water stress and pests.

Attempts have been made to propagate caper plants via tissue culture in a Queensland laboratory. Initial results were encouraging but owing to varied results with planting out and the inability to find a nursery willing to focus on this, the project has been aborted.

Caper seed germination is poor although germination rates can be improved by partially removing seed coats. Seeding direct into the field would give limited success (5%) and is not recommended.

The most important influence of successful germination appears to be seed freshness and germinated seedlings from Australian plants are available.

Caper bushes grown from cutting have an advantage over seed-propagated bushes, as they are genetically identical with their source. This avoids high variability of production and quality.

However, root systems in cuttings are very delicate and the plant may be more susceptible to drought in the first years after planting.

**Agronomy**

Caper plantings are productive for at least 25 to 30 years so site selection is important. Soil, water availability and climate are the main aspects to be considered with the caper growing best on non-stratified, medium textured, loamy soils.

The ground is prepared through moldboard plowing and harrowing or digging backhoe pits for each caper if the ground is rocky.

Plants are usually planted in a square design and spaced from 2 to 6 meters apart to accommodate their sprawling growth.

Fertilisation can take place 20-30 days before planting or applied at planting. The type of fertiliser used and application rates is related to plant age and soil nutrient content. Phosphate and potassium fertilisers are generally applied every two to three years.

First year plants can be mulched...
and in low rainfall areas approximately 200 litres of water is applied to plants over the first year. Over-watering must be avoided, as wet roots will kill the caper plant.

Water is the most limiting production factor and where possible plants should be drip irrigated to encourage productivity.

A yield from 1.5 to 5 kg per plant can be expected in three to five years.

Plants are heavily pruned back while dormant in winter to remove dead wood and watershoots. This is essential for production as flower buds arise on one-year-old branches.

Competition with weeds may be particularly serious while establishing young plants and some herbicide treatment might be required along with mechanical weed removal. Mulch is also effective in limiting weed growth.

Once the caper is established most of the ground is rapidly covered by the caper bush canopy and weed development is largely suppressed.

Harvesting and processing

Harvest
Harvesting is the most costly aspect of caper production since it is done manually. Bud production is continuous throughout the summer and since mechanical harvesting is not currently an option, a harvester will visit the same plant every 8 to 12 days resulting in around 12 harvests per season. To avoid the heat of the day, buds are collected in the morning. Harvest frequency has a direct bearing on the final size and quality of the product and determining the optimum time interval is influenced by the market one is picking i.e. smaller buds require more frequent picking and result in lower kilograms per picking hour.

A harvester can expect to pick up to 1 kg per hour in a mature plantation.

Post harvest technology
Immediately after harvest, capers are sorted and graded to size. In Italy they are graded into 6 different sizes on a scale from >7mm to <13mm. Capers are then packed in brine or under layers of salt in order to remove the intensely bitter flavor and to preserve them.

Approximately 30-50 days later they are repacked in vinegar or salt and packaged in glass bottles for retail sale or in larger plastic containers (5 kg) for sale to restaurants or in bulk for wholesale.

Caper berries are similarly pickled for retail sale.

Pest and disease control

The caper bush is not very sensitive to pest damage and insects do not appear to be a limiting problem. Nonetheless, it is related to the “Brassica” family and attractive to the white cabbage moth. The caper moth also damages caper leaves. Both these insects appear not to harm the flower buds but if left unchecked damage to the leaves would influence the general vigour of the plant.

An advantage to the regular hand harvesting of buds that takes place is that pests are readily observed and can be destroyed manually, thus avoiding the use of insecticides. This process is currently occurring on an existing organic and commercial farm and will continue to occur as long as there is no mechanised way to harvest. Any insecticide treatments would be restricted by the short interval between harvests, as toxic residues at harvest must be avoided.

Snails can damage and kill young plants by stripping them of foliage and young plants must be checked regularly and snails removed.

Since the caper is a very new crop in Australia there is a risk that as yet unidentified pests or disease may prove harmful. Further consideration should be given to the fact that no organic insecticides have been approved for use on the caper plant and biologically integrated pest management approaches should be tested.

Key messages

• Grow in a broad range of soils
• Key is excellent drainage
• Roots of young plants are very delicate
• Once established plants are very hardy
• Plants survive high saline water
# Financial information

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## Financial risks requiring management are:
- premium price
- harvesting costs
- marketing
- reduction in overall cost.

It would be misleading to put a gross margin figure on a ‘typical’ production site, as this is still an emerging crop.
Key contacts

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About the authors

Jonathon Trewartha started experimenting with growing capers in Australia in 1998. He and his parents gradually built the plant stock from an initial 15 plants to a current trial of 1,000 plants. Samantha Trewartha has a background in marketing and writing, and together Jonathon and Samantha are farming capers, processing and selling caper products, and researching and marketing the caper plant as a potential new crop for Australia.

Key statistics

- Export figures can be estimated at 3,500 t/yr for Turkey and 3,000 t/yr for Morocco
- World production is estimated to be around 10,000 t/yr
- Australia currently imports around 600 t/yr

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Coriander and fenugreek
Spice seeds

Max Jongebloued

Introduction

The growing and use of Coriander (Coriandrum sativum L.) as a food is said to date back over 2000 years with a mention in the Bible. Originally named after a bug, which had a similar odour when squashed, it is believed to have originated in the Mediterranean region. As an ingredient in spice mixtures or as a leaf vegetable it is widely used throughout Europe, North Africa, North & South America’s and Asia. In the Pacific and Indian Ocean regions including Australia its spread has followed the migration of peoples from India to these countries.

The principal uses of this plant relate to its seed and leaf, both of which have found wide usage in Australia. The seed of the plant is crushed and used for mixing in curry powders and other spice mixtures. Crushing can also be used to extract the oil which is used in perfumes, condiment flavouring and alcoholic beverage manufacturing (along with juniper berry it gives gin its distinctive aroma).

The leaf with its characteristic strong odour is used a fresh vegetable in a wide range of foods particularly those with rice and of Asian origin. It has also been used as a medicinal herb.

Australia grows two seed types of coriander, these are the so called Moroccan type and the smaller seeded slow bolting type. The Moroccan seed is usually round, 3 – 5mm in diameter whilst the slow bolting types seeds are 1.5 – 3mm in size. Size is very much affected by the growing conditions with seed size differences reducing in dryland production areas. The larger Moroccan type is usually grown in Australia, North Africa, Middle East and India (Indian seed is more oval shaped than round). The slow bolting or later maturing types are grown extensively in central and eastern Europe.

Fenugreek (Trigonella foenum-graecum) originated much earlier than coriander. It was used as
Coriander plants

The harvest may prove hard to sell as the key markets in Indonesia (8-10,000mt/year), Malaysia, Sri Lanka, Fiji and South Africa are being supplied from Bulgarian and adjacent country production at prices well below those indicated as needed by Australian producers. Presently Fiji buys at $US670/t delivered ex Bulgaria versus Australian pricing of $US900/t or more. Even prices from Morocco into China, Japan and Vietnam are cheaper than Australian pricing today.

Markets in Europe were lost to Bulgarian and Russian production in the late 1990's and Canadian production at that time displaced Australian and Morocco sales to the USA.

Large scale production in Australia will only be successful in the future if we can sell to China and regain market share in Indonesia, Sri Lanka, Japan and Malaysia for seed and crushing types as well as retaining markets in South Africa and the Pacific. Europe will continue to be difficult to penetrate.

Limited contracts from Australian companies exist for Moroccan coriander suitable for sowing and...
Fenugreek plants

growers should seek to find them before seeding if at all possible.

Slow bolting coriander is grown for seed for sowing usually under contract to vegetable seed companies selling into China and Asia. To date all production exceeding 70% germination has been sold and cleared in each year of production. Even seed grown without a contract has been sold.

Production in 2003/2004 season is estimated to exceed 500 tonnes. New markets in India and increased demand from China will allow increased production this year but not all at the price levels of $AU1800 to 2000/t delivered Australian port as has been possible over the last 2 years as the strength of our currency is working against Australian sellers. Growers must ensure the stockseed they use to grow these crops is well known to the buyers as they will not buy unless they have had experience with the growth and leafiness of the variety.

Fenugreek production in Australia has always relied on overseas buying because of limited demand by Australian spice companies. Australian consumption is estimated to be in the range of 150–200t/year.

Small lots are used for seeding as green manure crops in cereal and orchard rotations.

Production in Australia up until 1999 was in the range of 400–500mt per year with most going overseas to Europe and USA. However in the past 4 years production in Victoria is believed to exceed 3000mt based on industry estimates, with smaller areas in SA, Queensland, WA and NSW.

It is estimated at publication time over 50% of this production remains unsold. Our growers have not been prepared to accept world price levels.

The largest world producer is India and their pricing of $US400-495/t delivered Europe main ports (Europe is the largest market) has not been attractive to Australian producers.

Markets in New York have always been at risk because of USA quarantine requiring freedom from wheat seeds however current requirements to satisfy USA counter terrorism procedures on foodstuffs has made exporting to this market very costly.

Seller offers of $AU475/t delivered Australian ports are well above buyer bids of $AU400/t.

Because of the large Indian crop, Australia will always find fenugreek a low return crop in the range of $AU250 – 300/t ex farm.

**Production requirements**

Coriander is best suited to areas with a temperate climate however in Australia it has been successfully grown in the sub tropical areas of northern NSW and the Darling Downs of Queensland. Outside of temperate areas, production usually faces a high risk of rain damage at harvest time from tropical downpours.

Plants grow best in deep well drained loamy soils with pH levels of 6.0 to 8.0 which are not prone to waterlogging and receive between 400 – 600mm of rainfall in the growing season. Generally wheat areas can successfully grow the crop. Rainfall below 400mm will usually reduce yields to an uneconomic level compared to cereal crops. Crops can be grown under irrigation, both flood and centre pivot.

Fenugreek is best grown on deep loamy free draining soils in pH range 6.0 – 8.0 which are not prone to waterlogging and receive 500- 650mm of rainfall in the growing season. Being a legume it does not do well on very acid soils or those with a high aluminium concentration. It has been known to tolerate mildly saline soils.

Both coriander and fenugreek should not be sown on soils which easily compact after seeding.

**Varieties/cultivars**

Since 1978 when the first seed lots of the Moroccan type were commercially grown there have been numerous importations of stockseeds from Morocco, India and Egypt. These did not have any variety designation so no name can be directly placed on seed of these lines. Growers sell their seed
after testing for Bacterial Wilt freedom as “Moroccan type”. This lack of variety identification has not been an impediment.

Slow bolting coriander seems to have two variety/cultivar streams. Early contracts for seed production were of the ALS or American Long Standing cultivar supplied from vegetable seed companies from USA and Europe for re-export to Asia and even Brazil. Taiwan buyers sent stockseed of their own selection to Australia for seed increase and it is believed they originated in China which may be the *microcarpum var* sub species. Germplasm of this type seems to be the main stockseed now used with variety/cultivar designation being fixed by the buyer without any recourse to a bred variety like ALS.

Production of central European lines has not featured in Australia. Indian varieties have been tried but not widely adopted as they usually perform as Moroccan types.

Fenugreek is very similar in that seed came from India and the variety stream was lost in the 1980’s. Seedco Australia Cooperative Limited undertook trailling of a wide range of cultivars/lines in 1990 but under Australian conditions found no significant differences in growth, seed production and plant appearance on most lines except in the larger seeded lines. This line was commercialised within Cooperative members. Later research at the Dryland Research Institute at Horsham selected cultivars that gave yield increases and two lines were released through the Lentil Company and were named “Might” and “Power”. These lines can be still grown under production agreements through Ausbulk Ltd in Adelaide. Most growers seem to use any seed with a known purity and germination.

**Agronomy**

Across Australia most coriander sowings occur in the May – June period with some crops in southern Australia being seeded in July depending on rainfall patterns. Crops seeded after the end of June in most regions suffer yield loss. Irrigated crops can be sown as late as August in high rainfall areas. The slow bolting types have a longer growing period and are usually seeded before the Moroccan types unless irrigated or in high rainfall/long growing season areas.

Seeding rates of 8-12kg/ha are in general use and each seed drill row is sown. Experience shows no real yield advantage in lower seeding rates and wider row spacings, dryland or irrigated. Seeds can take up to 4 weeks to emerge.

Fenugreek is also sown at the same time as Coriander with 15-20kg/ha. When seeded as a green manure crop rates as high as 40kg/ha may be required for maximum effect. Legume inoculant treatment is recommended. Wide row spacings are not an advantage unless mounding is required due to soil moisture conditions.

Both coriander and fenugreek prefer weedfree, well-prepared seed beds as they grow slowly after emergence and pre-emergence herbicides like Trifluralin are necessary in most situations.

Linuron can give good broad-spectrum weed control in coriander even applications just before head emergence can be used to suppress competition. Hormone chemicals like 2,4-D have been used as a “last resort”. Herbicides used in carrot seed production can also be considered as coriander is a member of the carrot family. Products such as Prometryne, Diuron and Igran.

**About the author**

Max Jongebloed was instrumental in starting the broadacre seed production of coriander in Australia in 1978 when seed was brought from Thailand and sown in various regions of South Australia. As the General Manager of Seedco Australia Cooperative Limited (formerly South Australian Seedgrowers Cooperative Limited) from 1987 until 2000 he initiated many years of research on coriander, fenugreek and other spices in conjunction with the Waite Agricultural Research Institute (University of Adelaide) and with support funding from RIRDC. Max today continues his very active involvement with these crops, both production and marketing, as an International Seed & Grain broker with Teague Australia.
have also been used on occasions. Fenugreek can tolerate a range of grass control chemicals but being a legume it is susceptible to some hormone herbicides however 2, 4 DB has been used with moderate success.

Phosphorous fertilisers at rates used for wheat in the growing area are usually adequate for coriander and fenugreek. Nitrogen applications are beneficial to coriander at early tillering and just before flower stems emergence. Fenugreek at seeding can obtain a benefit from a nitrogen application.

Slow to emerge and remaining a rosette during winter, Moroccan coriander will send up flower stems approximately 90–110 days after emergence (slow bolting lines 15–30 days later). Stems branch out during flowering and give a large number of white flowered umbels with 10–12 individual flowers in a circular pattern. Plants usually reach heights of 1.25 – 1.5 metres.

Fenugreek plants send up flowering stems in late winter to a height of approximately 1.0m and green seed pods form a very distinctive curved sword shape usually 10 - 12 cm long but can reach 20cm. Plants usually stay upright when mature.

**Pest and disease control**

Coriander crops usually require no spraying for insect pests as it seems the strong odour of the plants acts as a deterrent. Heavy infestations of Red Legged Earth mite at seedling emergence can affect plant survival. Bees and flies are attracted to the flowers and are most important in the pollination and seed set of the crop. Granary type weevils can invade seed after it has been stored for more than 6 months after harvest and it may require fumigation prior to sale.

Fenugreek is susceptible to a wide range of insect pests including Red Legged Earth mite. Lucerne Flea, cutworms, *Heliothis*, Cowpea aphids, thrips and Rutherglen bugs and an active crop monitoring programme must be employed over the life of the crop particulary at seed pod formation.

Today one particular disease of coriander threatens the continued wide scale production of coriander and in particular the Moroccan type. Commonly referred to as “Bacterial Blight” this bacterial disease identified as *Pseudomonas syringae* pv *coriantricola* emerged in the early 1990’s and caused destruction of seed fields. Large areas in South Australia stopped growing this crop because of the losses. The slow bolting lines have shown high tolerance levels to this disease and production has continued to market demand. Research has not yet given us resistant plants nor chemical control methods for this disease in coriander. Tests have been developed to identify certain disease levels in seed and growers should only use seed tested as being negative for this disease.

However seed testing negative can still carry enough infection so that when frost strikes the crop the disease emerges and multiplies and within days can waste crops. Experience has shown that frost is the main trigger for crop infestation so production should not be undertaken in areas with regular frost occurrences. Bacterial Wilt usually occurs at flowering and seed set when seed stems seem to wilt and brown leaving a single main stem that eventually dies. Infection and plant destruction can happen in 3–5 days after severe frosts. Wind, irrigation, rain and vehicle movements through crops seems to aid the spread.

Chemical control has relied on copper and Mancozeb fungicide sprays to slow the spread but are these are not satisfactory. Last season a combination of these sprays with a pre – application of a liquid sterilising agent seemed to arrest the disease in some fields.

The slow bolting /smaller seeded types seem to show the disease but unless there has been a severe frost, spread seems to be slow and does not cause a great yield loss.

Another disease that must be watched is *Alternaria alternata* which affects flowering and seed set but has not killed plants. It causes flowers to abort. Again it appears seed borne. Regular fungicide applications with copper oxychloride or Mancozeb commenced before flowering seem to provide reasonable control of this disease. *Septoria* has been recorded in crops.

Fenugreek seems to be reasonably free of disease but can suffer badly from Powder Mildew (*Erisiphe polyon*). Blight disease (*Cercospora traversiana*), *Rhizoctania solani*, *Fusarium oxysporum* (Wilt) and *Meloidogyne incognita* (root rot) have also been recorded in this crop.

**Harvest, cleaning, packaging**

All varieties of coriander must be harvested when the seeds are light brown to brown and the plant stems are brown and starting to become dry. Open front headers are recommended. Crop losses by seed head shattering can occur if growers wait until stems are completely dry. Windrowing has been used but the windrows must be heavy and left to lie deep in the stalks otherwise wind can move them across the field. Dessication has not been used
with success. Dryland yields of 1–1.5mt/ha are common and 2–3mt/ha when irrigated. Rainfall areas below 400mm usually yield 750–1000kg/ha.

As most coriander seed is used for crushing it should be harvested free of stones, soil and other unmillable contaminants. Once cleaned it should have a minimum purity of 99% to satisfy the majority of buyers. Packaging is usually 25kg nett polypropylene sacks.

Buyers value light brown coloured seed above brown and seed blackened by rain at harvest is of very low value in the market. Within Australia and in certain overseas markets seed must be tested free of Salmonella, E- coli, aflotoxin and coliform bacteria. Some in Australia want freedom from wheat or allergenic compounds. Seed sold for fresh leaf production must meet the purity and germination requirements of the buyer.

Fenugreek is ready for harvest when the long curved pods are brown and just starting to become brittle. Crop lifters will be useful if the crop is tangled and has lodged. Mature pods after rain can shatter and an open front header is best. Pods thresh quite easily and seed should not be overthreshed. Dryland yields range from 1 –1.5mt/ha and have been as high as 3mt/ha. Little is grown under irrigation.

Colour is critical for marketing and seed should have an even light tan colour with no dark or shrivelled seeds. Cleaning into polypropylene sacks either 40kg nett or 25kg nett is usual. Again as for coriander the majority of seed is crushed so must be free of unmillable material and may need to test negative for the pathogens listed.

Seed for sowing must comply with buyer requirements of purity and germination.

**Financial information**

Most growers compare coriander and fenugreek with the returns they obtain from wheat and vetch respectively when budgetting.

They also attribute some non cash benefit in the production year to the nitrogen enhancement of the soil for following crops using fenugreek.

Costs of seeding, fertiliser and harvesting coriander are similar to wheat in all rainfall regions and cost savings are possible in the use of herbicides.

However any savings are quickly used in the significant chemical and post harvest handling of coriander versus wheat.

Fenugreek growing costs are very similar to vetch but again post harvest handling can be a significant impost depending on access to seedcleaners.

The simple estimated comparison below can be applied to a cereal farm unit in a medium rainfall zone of 350–400mm/year.

One factor that is not costed into this calculation is the sometimes long period growers may wait to sell their seed if markets are quiet or if quality is not acceptable to the market.

Seed then remains in growers’ hands long after all costs have been incurred.

<table>
<thead>
<tr>
<th></th>
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<th>Coriander</th>
<th>Vetch*</th>
<th>Fenugreek</th>
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<td><strong>Income</strong></td>
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<td>850.00</td>
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<tr>
<td>- Price</td>
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<td>- Yield / ha</td>
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<tr>
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<td>- Seed</td>
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<td>417.00</td>
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<td><strong>Gross margin</strong></td>
<td>245.00</td>
<td>433.00</td>
<td>100.00</td>
<td>259.00</td>
</tr>
</tbody>
</table>

* Source: 2004 Farm Gross Margins Guide – Rural Solutions
**Key references**


Elder, W., (1999) Coriander seed production. WA Agriculture Agnote AG 0621

Agriculture note AG0826 (June 2000) Coriander Seed. Department of Primary Industries Victoria.


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Jane Parker

Acknowledgement is given to Kim Fletcher and Shirley Fraser, the authors of this chapter in the first edition of this publication.

Introduction

The Australian Culinary Herb and Spice Industry can be described as a maturing industry. Its peak industry body, AHSIA (The Australian Herb & Spice Industry Association Ltd), has been set up to co-ordinate research & development needs, and to provide a strong representative voice for the industry.

Consumption of herbs & spices continues to grow in Australia in line with global trends, fuelled by changes to traditional eating patterns and a return to healthier eating habits in developed countries. Innovative marketing, packaging and processing have also assisted in extending the knowledge and consumption of herbs and spices to a much larger percentage of the population.

The industry has a domestic farm gate value currently estimated at $62 million and a fresh market retail sales section which continues to grow at 20% per annum.

To maintain its growth however the Australian Herb & Spice Industry has to export. Considerable processing & marketing expertise has been developed in Australia, which is of a world class standard. This puts Australia in an excellent position to take advantage of burgeoning overseas markets and several new and innovative processors have entered the market to take advantage of this. The export industry is projected to grow at 100% per annum for the next 5 years giving an export farm gate value of $100 million by 2009. Australian businesses wishing to export must have sound, well managed, quality controlled, cost effective enterprises that are competitive with major processing countries such as Germany, France, the UK and the USA.

The biggest challenge to export, and to increasing domestic productivity, is the lack of sustainable Integrated Pest Management strategies, including minor use permits for herbs and spices, the poor quality and supply of Australian seed and rootstock and, with a small percentage of growers, a limited knowledge and acceptance of the stringent quality requirements of supermarket chains, processors and consumers.

There is considerable opportunity for organically grown product, which is not being met at the moment.

Key messages

• Maturing industry, with defined QA systems
• Importance of supply chain management
• The need to be market driven
• Continuing growth in domestic market
• Increasing export opportunities
• Need for sustainable IPM systems
• Lack of quality seed/rootstock
moment. To meet market demand, just as with conventional growers, organic growers must have Integrated Pest Management strategies in place and meet current quality management program requirements. Program requirements are strict and must be adhered to by all producers, both conventional and organic. Just as incorrect use of chemical controls and subsequent unacceptable maximum residue levels puts conventional growers at risk, the organic industry is at risk of high microbial contamination of produce due to the use of incorrectly treated animal manure products.

Several other low-cost producing countries such as India, Egypt, Turkey and Morocco are major exporters to Australia of dried product. This is an entirely different market segment, with imports around $40 million (excluding chilli/garlic/paprika). However, it is a very price limited market, with few niche opportunities for premium grade, higher priced herbs and spices, and best suited to larger vertically integrated operations. Products flow into Australia via agency agreements that various importers have with producing enterprises in most parts of the world. The importers decide the quality/price ratios that each commodity segment can bear amongst their customer base. They organise importation of those lines either on contract for specific customers, or to hold as stock.

### Marketing and marketing issues

#### Principal markets

**Fresh**

1. *Supermarket chains*: Fresh product being supplied to supermarket chains: a range of climates, producing a range of quality assured products (packaged or bunched), competing in a small market place, which

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### About the author

Jane Parker has a background in dairy farming in Scotland, followed by cotton, lucerne and small crop farming in Queensland. She commenced research and development into herb and spice production in 1992 in order to diversify the local economy and make more sustainable use of available water. She has been involved in the industry since then, particularly in agronomic research and development and supply chain management of broad acre herbs and spices.

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must be supplied all year round. Grower manager deals with supermarket buyers. Terms & conditions are negotiated. Competition is fierce and prices governed by supermarket policies. Individuals/companies dealing with supermarket chains, require thorough understanding of product & category requirements including required support plans, quality requirements, and shipping chain.

2. Processing companies (large & small): Fresh, quality assured product being supplied and transported in bulk, often on a strict 5-7 day week schedule, at specified times of the year. Grower manager deals with company buyer. Contracts generally negotiated and price reflects bulk purchasing. Product often ex-farm gate.

3. State markets: Fresh product, with lower quality requirements than those of 1&2. Grower manager is price taker and subject to fluctuations in prices due to over/under supply. Grower manager responsible for transport to market. Commission paid to marketer. Most of this product makes its way to greengrocers.

4. Local restaurants: A range of products, often delivered to the door, with supply agreements in place. Prices tend to follow state markets + commission + a possible premium for quality.

5. Local markets: On a permanent stall or ad hoc basis. Can be quite successful in an area with popular markets. Price structure varies, but can command premium price.

6. Export fresh (bunched, bagged or loose): This requires excellent understanding of your product and markets, superior supply chain management and sound business backing. Often required as small mixed lots which are repackaged at destination points.

**Dried**

1. Retail chains: Packaged product sold under own brand name or house brand. Competes with major brands eg. Masterfoods, McCormick’s. Generally commands a commodity price only and is a fairly static market.

2. Speciality stores and internet sales: Product sold under own brand name or house brand. Commands a higher price. Uses ‘good name’ to carry out business.

3. Food Service/Industrials: Product sold in bulk and commands a commodity price. Quality of product less important to buyers, and grower competes with imported product.

---

### Estimated major import tonnages

<table>
<thead>
<tr>
<th>Dried herbs &amp; spices</th>
<th>Tonnage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garlic</td>
<td>2000</td>
</tr>
<tr>
<td>Chilli</td>
<td>1500</td>
</tr>
<tr>
<td>Paprika</td>
<td>500</td>
</tr>
<tr>
<td>Oregano</td>
<td>300</td>
</tr>
<tr>
<td>Parsley</td>
<td>200</td>
</tr>
<tr>
<td>Sage</td>
<td>200</td>
</tr>
<tr>
<td>Basil</td>
<td>80</td>
</tr>
<tr>
<td>Cumin</td>
<td>500</td>
</tr>
<tr>
<td>Fennel</td>
<td>50</td>
</tr>
<tr>
<td>Anise</td>
<td>50</td>
</tr>
<tr>
<td>Dill seed</td>
<td>30</td>
</tr>
<tr>
<td>Saffron</td>
<td>10</td>
</tr>
<tr>
<td>Vanilla</td>
<td>10</td>
</tr>
<tr>
<td>Cardamon</td>
<td>10</td>
</tr>
</tbody>
</table>

### Major supermarket sales, 2003,

<table>
<thead>
<tr>
<th>Dried herbs &amp; spices</th>
<th>Retail $’s</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garlic</td>
<td>$107,000,000</td>
<td>43,000,000</td>
</tr>
<tr>
<td>Wet Herbs &amp; Spice</td>
<td>$16,300,000</td>
<td>6,600,000</td>
</tr>
</tbody>
</table>

### Sydney Spot Prices for Dried Herbs & Spices

<table>
<thead>
<tr>
<th>Herbs &amp; Spices</th>
<th>$/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most herbs</td>
<td>$3.00-4.50</td>
</tr>
<tr>
<td>Parsley</td>
<td>$4.00-10.00</td>
</tr>
<tr>
<td>French Tarragon</td>
<td>$20.00-25.00</td>
</tr>
<tr>
<td>Chives - freeze dried</td>
<td>$60.00-80.00</td>
</tr>
<tr>
<td>Cumin</td>
<td>$3.50-4.00</td>
</tr>
<tr>
<td>Anise</td>
<td>seasonal</td>
</tr>
<tr>
<td>Dill seed</td>
<td>seasonal</td>
</tr>
<tr>
<td>Fennel</td>
<td>seasonal</td>
</tr>
<tr>
<td>Saffron</td>
<td>$1700-1800</td>
</tr>
<tr>
<td>Vanilla bean</td>
<td>$500-700</td>
</tr>
</tbody>
</table>
Successful grower/marketers
3 successful grower businesses were interviewed as to their reasons for success. The common threads were:

- Each company, and individuals within the company, had a vision for the future.
- Each company started out to satisfy market demand and incorporate some value adding component into their business.
- Each company had allowed themselves approximately 5 years to establish their business.
- Each company had accessed government funding to assist in their development (The major value of this exercise was not seen to be the dollars collected, but the strategic plan that had to be developed in order to access the money).
- Each company has invested considerable personal amounts in establishing their business.
- Each company has a considerable personal presence in the market place.
- Each company is market driven

Production requirements and cultural practices

The category, herbs and spices, encompasses a large number of species, ranging from temperate to tropical crops and are grown in enterprises all over Australia, eg parsley in Tasmania, rosemary in Victoria, lemon grass in the Northern Territory and green peppercorns in North Queensland with concentrations of growers around all major cities/population areas. Given the range of climatic conditions within Australia, it can only be said that the best yields and economic returns will be achieved if these crops are grown in environmental conditions most suited to their optimum requirements (however a customer’s marketing mix might require a grower to grow a range of species – this could necessitate a single crop being produced in a less than optimum environment, or even being produced at a net loss, to maintain the customer business).

A potential grower should understand the environment in which he wishes to grow his crop and research the best crop for that environment (remembering that all crop choices should be market driven). The grower should understand his soil types, soil nutrient status, water availability, plant water requirements and have an integrated pest management strategy in place before commencing an enterprise. Trial areas should be set up so that a grower learns to understand the crop, and make an informed decision on whether or not he is willing/and or able to grow the crop.

A range of information about cultural practices/requirements of individual crops can be found in the references.

Various cultural practices, both organic and conventional are undertaken, and can be grouped under the following headings:

- Broad acre field cropping, using conventional machinery operations suitable for small or medium cropping enterprises. Enterprises diversify using a mixture of species or single crop with a range of end products. Crops are machine harvested.
- Protected cropping, with all crops grown in controlled environments. Crops may be grown hydroponically or in a medium. Crops are mainly hand harvested.
• Market garden/Mixed cropping, with herbs/spices grown as part of a mixed enterprise, generally lettuce or Asian vegetables. Crops may be machine or hand harvested.

• Opportunity cropping. This is normally part of a mixed cropping enterprise but is grown on an ad hoc basis and usually only applies to the more robust herbs eg parsley. Crops are mainly machine harvested.

• Cottage Industry. These are smaller type enterprises which retain the ‘lifestyle’ tag. Herbs are grown and harvested using hand labour or smaller garden type machinery. Some have diversified into successful tourist enterprises.

Processors, supermarkets and to a lesser extent regional markets, insist that producers have quality assured production systems, with traceability from seed/plant supply to point of delivery, including transport systems. This necessitates strict record keeping of all operational aspects and a yearly audit, either by the customer or an accredited auditor.

Components to be audited will include such checks as seed/plant supply, chemical, fertiliser and water applications, machinery maintenance and wash down/sanitising, chemical storage and application equipment calibration, buildings and vermin control, cold rooms including temperature control/calibrations and sanitising records.

Pest & weeds & diseases

Herbs & Spices are subject to a range of pest, weeds and diseases which tend to be area/production practice and crop specific eg protected cropping experiences few weeds but has to maintain very strict control over temperature and humidity to minimise fungal diseases. Field cropping in hot dry areas is less prone to fungal diseases, but can experience more rusts, than field cropping in more humid environments. Irrigation practices can influence fungal leaf diseases and soil types can influence incidence of fungal root diseases.

To maximise sustainable practices in the control of pests and disease, it is important that Integrated Pest Management (IPM) strategies are implemented. IPM’s are practical strategies which include a broad range of appropriate pest/disease management options, including the strategic application of synthetic and biological insecticides/fungicides, improved pesticide application techniques, insect scouting and crop monitoring procedures and the introduction, protection and fostering of naturally occurring beneficials. The following is true of all crops, but must still be said – healthy crops are less susceptible to insect and disease attack.

The following are common pests/diseases:

Aphis, thrips, jassids, whitefly, other sucking insects, mealy bugs, diamond back moth, heliothis and other lepidopterous pests, altenaria, bacterial blights and root rots, fusarium wilts, phytophthora, rhizoctonia, sclerotina and rusts and mildews.

Weed control is difficult, particularly for producers whose product is destined for export, as few chemical controls are currently available. (See APVMA website). Current management practices include implementing weed control in proposed herb paddock two years before proposed planting dates, row cropping to allow inter-row cultivation, good plant stands to minimise weed invasion and the good old fashioned chip hoe.

Harvest/ handling/storage/post-harvest/processing requirements

A lot of the research and development of companies and individuals has focussed on this aspect of herb and spice production. This has benefited all producers, as there is now a much greater understanding of individual herb harvesting and storage requirements. The biggest
difficulty remaining in this section of the industry is in the shipping, particularly of small lots eg basil has proven to be a major challenge as it has different storage/shipping requirements from the majority of other herbs.

**Harvesting**

For a long time there was a myth perpetuated that it was impossible to machine harvest herbs without considerable product deterioration through bruising etc. In the last 5 years there have been many major break throughs in harvesting techniques and equipment, and the majority of commercial operations are now mechanised. Harvesting temperatures are also critical with more rapid shelf life deterioration if crop is harvested above 25°C.

**Post harvest handling**

The time from the paddock to the cold room is another is another aspect which should always be kept in mind. To maintain optimum quality and shelf life it should never exceed 30 minutes.

Cold rooms are essential and forced air cooling is critical for bulk harvested product. Settings are very specific as the product should not have air drawn over it too quickly or it will cause product burn. Different crops have different temperature requirements, the most sensitive being basil. It is important to cool the stem as well as the leaf or heat will begin to be generated whenever product is removed from forced air environment. (Recommended cooling temperatures are available through AHSIA)

Many customers require product to be washed. Various commercial washing systems are available and the product also needs to be spun dried after washing, again to maintain shelf life.

**Packaging**

Bulk ex-farm gate is generally shipped in Chep PB7 or similar bins (herbs & spices). This requires growers to have the correct handling equipment eg fork lifts. This product is generally unwashed.

Bagged product – various types of bags are used and information can be obtained from many packaging companies. Major supermarkets have their own packaging which growers are required to purchase and use. Bagging is typically by hand though there are opportunities for mechanisation of some lines.

Bunched product – Twice as much bunched product is presently being sold through supermarkets as bagged product. Product is hand bunched, therefore it is an expensive operation. Fresh product presentation will continue to change driven largely by supermarket requirements.

Loose product – this generally applies to spices, eg chilli, ginger.

**Processing requirements:**

Individual customer requirements can be quite specific. Samples of customer requirements for fresh bulk, fresh bagged and dried product are available from AHSIA.

**Financial information**

Because of the wide range of species/cropping styles it is impossible to give a true picture of costs/returns. The following financial information is a snapshot of: a machine harvested, field cropped, annual herb - basil, a machine harvested, field cropped, perennial herb - rosemary, a machine harvested field cropped spice - cayenne pepper, a protected cropping operation and a herb drying operation.
### Detailed financial analysis for machine harvested annual field crop, Basil. 10ha unit

<table>
<thead>
<tr>
<th>Cost</th>
<th>Annual Cost</th>
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<tbody>
<tr>
<td>Land</td>
<td>$50,000</td>
</tr>
<tr>
<td>Sheds/coldrooms</td>
<td>$90,000</td>
</tr>
<tr>
<td>Machinery</td>
<td>$63,000</td>
</tr>
<tr>
<td>Irrigation</td>
<td>$55,000</td>
</tr>
<tr>
<td>Working Capital</td>
<td>$50,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$33,800/ha</strong></td>
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#### Recurrent inputs/ha

<table>
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<tr>
<th>Amount</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Machinery operations includes depreciation</td>
<td>$266</td>
</tr>
<tr>
<td>Trickle tape</td>
<td>$1,690</td>
</tr>
<tr>
<td>Seed (kg)</td>
<td>$440</td>
</tr>
<tr>
<td>Urea (kg)</td>
<td>$60</td>
</tr>
<tr>
<td>CK 55 (kg)</td>
<td>$208</td>
</tr>
<tr>
<td>Insecticide</td>
<td>$200</td>
</tr>
<tr>
<td>Fungicide</td>
<td>$108</td>
</tr>
<tr>
<td>Irrigation (megs)</td>
<td>$456</td>
</tr>
<tr>
<td>Labour</td>
<td>$4,950</td>
</tr>
<tr>
<td>Harvesting</td>
<td>$3,600</td>
</tr>
<tr>
<td>Permits/testing/membership</td>
<td>$3,500</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>$1,950</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$17,428</strong></td>
</tr>
</tbody>
</table>

### Financial Analysis for machine harvested perennial field crop, Rosemary. 10 ha unit

#### Year 1

- **Revenue/ha ($4.00/kg)**: $0
- **Less recurrent inputs**: -$10,686
- **Gross Margin**: -$10,686
- **Less annual investment**: -$1,749
- **Net Margin/ha**: -$12,435

#### Year 2

- **Revenue/ha ($4.00/kg)**: $8,000
- **Less recurrent inputs**: -$8,433
- **Gross Margin**: -$433
- **Less annual investment**: -$1,749
- **Net Margin/ha**: -$2,182

#### Year 3

- **Revenue/ha ($4.00/kg)**: $10,000
- **Less recurrent inputs**: -$6,234
- **Gross Margin**: $3,766
- **Less annual investment**: -$1,749
- **Net Margin/ha**: $2,017

#### Year 4

- **Revenue/ha ($4.00/kg)**: $12,000
- **Less recurrent inputs**: -$4,541
- **Gross Margin**: $7,459
- **Less annual investment**: -$1,749
- **Net Margin/ha**: $5,710

### Financial Analysis for machine harvested annual field crop cayenne chilli. 10ha unit

#### Year 1

- **Revenue/ha ($2.00/kg)**: $30,000
- **Less recurrent inputs**: -$17,428
- **Gross Margin**: $12,572
- **Less annual investment**: -$3,380
- **Net Margin/ha**: $9,192

#### Year 2

- **Revenue/ha ($3.75/kg)**: $33,750
- **Less recurrent inputs**: -$21,946
- **Gross Margin**: $11,804
- **Less annual investment**: -$4,160
- **Net Margin/ha**: $7,644
Projected costs and returns for a herb drying operation processing 3000kg raw material/day of premium product, operating 250 days/year Excluding cost of land, buildings and services.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forklift</td>
<td>$15,000</td>
</tr>
<tr>
<td>Receival system</td>
<td>$10,000</td>
</tr>
<tr>
<td>Wash</td>
<td>$33,000</td>
</tr>
<tr>
<td>Rinse</td>
<td>$10,000</td>
</tr>
<tr>
<td>Spin</td>
<td>$120,000</td>
</tr>
<tr>
<td>Dryer</td>
<td>$50,000</td>
</tr>
<tr>
<td>Conveyor</td>
<td>$100,000</td>
</tr>
<tr>
<td>Dehumidifier</td>
<td>$100,000</td>
</tr>
<tr>
<td>Controls</td>
<td>$20,000</td>
</tr>
<tr>
<td>Power system</td>
<td>$25,000</td>
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<tr>
<td>Post dryer</td>
<td></td>
</tr>
<tr>
<td>Rubbing</td>
<td>$10,000</td>
</tr>
<tr>
<td>Sizing</td>
<td>$10,000</td>
</tr>
<tr>
<td>Grading</td>
<td>$20,000</td>
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<tr>
<td>Packing</td>
<td>$5,000</td>
</tr>
<tr>
<td>Storage</td>
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<tr>
<td><strong>Total plant costs</strong></td>
<td><strong>$538,000</strong></td>
</tr>
</tbody>
</table>

Daily operating costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
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<tr>
<td>Wages</td>
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<td>Power</td>
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</tr>
<tr>
<td>Washing</td>
<td>$50</td>
</tr>
<tr>
<td>Crop</td>
<td>$600</td>
</tr>
<tr>
<td>Overheads</td>
<td>$540</td>
</tr>
<tr>
<td>Investment cost</td>
<td>$729</td>
</tr>
<tr>
<td><strong>Total daily operating cost</strong></td>
<td><strong>$3,269</strong></td>
</tr>
</tbody>
</table>

Daily production costs and returns

<table>
<thead>
<tr>
<th>Crop</th>
<th>Dry matter</th>
<th>Production</th>
<th>Costs/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parsley</td>
<td>150</td>
<td>$21.60</td>
<td></td>
</tr>
<tr>
<td>Chives</td>
<td>300</td>
<td>$10.80</td>
<td></td>
</tr>
<tr>
<td></td>
<td>255</td>
<td>$12.71</td>
<td></td>
</tr>
<tr>
<td>Basil</td>
<td>255</td>
<td>$12.71</td>
<td></td>
</tr>
<tr>
<td>Dill</td>
<td>210</td>
<td>$15.43</td>
<td></td>
</tr>
</tbody>
</table>

Projected costs and returns for a protected cropping operation

Note**serviced land with proximity to metro market; minimum 10ha

Greenhouse with ridge vent, twin skin poly single screen, auto climate, hydroponic growing system, air & hydronic heating (5000m²)
Packhouse, coolroom, workshop, processing equipment.
Water storage, treatment & nutrient management

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>$150,000</td>
</tr>
<tr>
<td>Greenhouse</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Packing etc</td>
<td>$600,000</td>
</tr>
<tr>
<td>Water etc</td>
<td>$100,000</td>
</tr>
<tr>
<td>Working capital</td>
<td>$250,000</td>
</tr>
<tr>
<td><strong>Investment costs/unit</strong></td>
<td><strong>$2,100,000</strong></td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>$2,100,000</strong></td>
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<tr>
<td><strong>Annualised</strong></td>
<td><strong>$173,890</strong></td>
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<tr>
<td><strong>Revenue</strong></td>
<td><strong>$1,323,094</strong></td>
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Recurring input costs

<table>
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<tr>
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<tbody>
<tr>
<td>Cleaning</td>
<td>$8,258</td>
</tr>
<tr>
<td>Depreciation</td>
<td>$97,310</td>
</tr>
<tr>
<td>Labour</td>
<td>$687,467</td>
</tr>
<tr>
<td>Fertiliser</td>
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<td>$106,441</td>
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<td>QA</td>
<td>$10,423</td>
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<tr>
<td>Power</td>
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<td>Insurance</td>
<td>$16,000</td>
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<td>Maintenance</td>
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<td>R&amp;D</td>
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<tr>
<td>Seeds &amp; plants</td>
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<td>Sundry</td>
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<td>Telecom</td>
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<td>Travel</td>
<td>$13,880</td>
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<td><strong>Total Expenses</strong></td>
<td><strong>$1,349,844</strong></td>
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</table>
Bulk harvesting herbs

Key references

General information
http://www.ahsia.org.au

Minor permits
http://www.apvma.gov.au

Overseas seed supply
http://www.richters.com
http://www.cnseeds.co.uk

Research information
http://www.rirdc.gov.au
http://www.agr.gov.sk.ca
http://www.organicaginfo.org

Directory of Specialists in Herbs, Spices and Medicinal plants
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**Introduction**

Opportunities and challenges for Australian ginseng production have been demonstrated in forest floor gardens at Gembrook Victoria since early 1985. Since 1992 many other trials have been started in various south-eastern and south-western locations of Australia with mixed results. Organic aged roots from Gembrook gardens have been exported and are part of retail products for Australian sales. The most comprehensive data for current production are from Gembrook and other Victorian gardens.

Ginseng, known as an ‘adaptogen’, helps to restore the balance in the pituitary gland which, in turn, encourages the system to cure itself. Research shows *Panax ginseng* (Asian) has a hot acid action while *Panax quinquefolius* (American) performs in a cool or alkaline way. Generally speaking, ginseng grown on the forest floor is more medicinally potent than that from intensive field cultivation.

Recorded Australian imports of ginseng exceed 28 t/yr, with an estimated value of more than $15 million. In the last few years, diligent efforts by Australian Regions with successful trials

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**Key messages**

- Patience is a must
- Quality before quantity
- Never fast—never easy
- Grow with a conscience — grow green
- Slow but sure = good returns
Key statistics

- Imports = ca 28t.
- Exports = ca 65kg (to Dec '03)
- 150 growers are having continuing successful trials with anticipated combined harvests commencing in 2005
- The “gold rush” into planting that raged from 1992 - 1999 has settled to a realistic and sustainable level
- The total estimated planted area of Australian Ginseng Growers Assoc. gardens is about 100 ha. The area of non-member gardens is unknown
- About 80% of plantings are of American ginseng and 20% of the Asian species

Customs have lessened the amount entering the country undeclared, so this figure provides a more accurate picture of Australian consumption than previously available figures. It is considered that this figure will continue to escalate, due to the rising proportion of the population of Asian origin and heavier demands for natural health products in society in general.

With wild ginseng stocks from Asia and North America diminishing, plus growing demands for better quality, chemical-free products, there is clearly potential for Australian commercial ginseng production, as an export commodity and for import replacement.

Growers need patience and commitment to achieve results with this long-term crop.

Markets and marketing issues

Ginseng is traded by weight as dried or fresh whole roots, with different prices paid for approximately 40 market grades. Some 95% of all ginseng production is consumed in Asia. In major Asian and Japanese centres American ginseng is the preferred choice. The Koreans prefer their own product. As little was available or known about American ginseng until recently, Asian ginseng has dominated Australian markets.

Little private trading occurs in China or Korea although this should change with new government regulations. Trading in North America takes place at the farm gate, although co-operative or network marketing is becoming popular there. This type of marketing is being considered by Australian growers. Successful profits can also be made by growers who manufacture and market retail products.

Australian grown 7 year old roots, both fresh and dried, have been sold to Singapore based on the Wild American price plus 20%. Smaller quantities of aged fresh and dried roots are also being sold at similar prices within Australia. These are mainly private sales to Asian residents.

Singapore buyers are keen to purchase more Australian-grown ginseng to satisfy client demands for top quality roots.

Market trends are best assessed from North American information. Similar information from China and Korea is difficult to correlate. In 2003, North American production exceeded 2,500 t at prices that ranged from as low as $60/kg for Artificial Shade 4-year-old-roots to $1,800/kg for Wild American roots. Oriental production dwarfs the North American production but prices start at $25/kg with no records for wild ginseng.

The Australian Ginseng Growers Assoc. Inc remains committed to assisting its members to market as an entity. Continual appraisal of world market trends pinpoint the ongoing need for top quality...
aged roots. This is a niche market which is not being supplied from the rest of the world’s ginseng production. Sales will be directed both within Australia and overseas. The staging of IGC 2004 in Melbourne gave further direction for achieving top sales within this niche market. Australian growers are very excited about their potential to realise these goals in the near future.

Production requirements

Ginseng will not grow in the sun. It requires 80-90% density shade, either artificial or natural; a nitrogen poor soil which can range in structure from sandy to heavy clayey loam; an acid soil with pH between 4.5 and 7; and a climate with four distinct seasons to encourage the plants to progress through their cycle in order to reach maturity. A cold winter is required for stimulation of the root to encourage the following year’s growth. A good rule of thumb is, ‘grow ginseng with apples, not with bananas’. While the plants can survive hot summer days, they do not cope well with high humidity. Tropical or sub-tropical climates are not suitable.

Ginseng is not a heavy drinker but requires a well-drained soil which needs to be kept moist and cool. In times of adversity, ginseng is known to withstand droughts better than floods. Land on river flats subject to flooding, or at the bottom of potentially wet gullies would not be suitable. If required, ground level drip irrigation is better than overhead systems.

Normally unproductive steep slopes and/or forest floor areas where shade is so dense little else grows, can be quite suitable. Easterly or southerly aspects are generally preferable to north- or west-facing land. Beds should be raised to ensure good drainage.

Varieties/breeds

Ginseng (Panax spp.) belongs to the Araliaceae family, and is a slow maturing, woodland plant native to Asia and North America. From eleven known ginsengs, the two species with greatest medicinal and commercial value are Panax ginseng C.A.Meyer (native to Asia and sold as Chinese, Asian or Korean ginseng), and Panax quinquefolius L. (native to North America and sold as American or Canadian ginseng).

Both types are under cultivation in Australia, with the estimated ratio being 80% American and 20% Asian.

Australian-grown seed is not yet available for purchase. New gardens are planted with imported seed and/or Australian grown one-year-old rootlets.

So far, world-wide attempts to clone ginseng have been unsuccessful. Tissue culture is proving useful in research directed at control of disease in the cultivation of ginseng. Australian growers have become quite competent at controlling the germination of northern hemisphere seed so that it becomes acclimatised for Australian seasons.

Agronomy

There are three cultivation methods recognised: artificial shade, woods grown and wild simulated. Each growing method produces different results and consequently different market prices. Approximately 95% of the world’s ginseng production occurs under artificial shade. Wild simulated is the cheapest growing method and produces the highest returns per dried weight yield.

Soil testing for pH and nutrient levels should be done as part of site selection and bed preparation. Minimal tillage should be employed whenever possible. No tillage is used with wild simulated planting. Planting space should be free of debris and weeds, and beds should be raised to provide good drainage. Beds should run down slopes, not across them. Normal farm tilling machinery may be used in open ground. Most site preparation in a forest setting is carried out manually with normal garden implements, although some small mechanical devices may be
useful, taking into consideration obstruction from trees and their roots.

Imported seeds are planted in spring/early summer. Australian grown seeds are planted in late autumn/winter. After planting, mulch is applied to conserve moisture and to protect the plants from hard frosts. If shade structures are being used, frames should be erected but covering is not required until seed has germinated. To prevent damage by heavy snow, shade covers may be removed during winter. If required, install irrigation systems after planting.

The plants are fully deciduous perennials with dieback in autumn and new growth each spring as the natural cycle.

Weeding, re-mulching and addition of soil conditioners are part of winter maintenance. Application of fertilisers should be minimal to ensure better value crops. New beds for planting can be prepared in advance at any time. Apart from site preparation, planting, harvesting and drying time, approximately 100 hours/yr for each hectare of forest cultivation is required for maintenance. Artificial shade maintenance can require less time if it is mechanised.

Plants reach maturity during their fourth or fifth year under artificial shade and after six or more years when grown under trees.

**Pest and disease control**

Potential pathogens including *Rhizoctonia* spp., *Fusarium* spp. and *Pythium* spp. can destroy young plants. Although soil fumigation or chemical treatments are available, the majority of Australian growers prefer organic methods. Growers should be mindful that chemical treatments have the potential to leave residue on the roots, causing a reduction in market price. More importantly, natural therapies should not contain synthetic substances. Intensive planting in a monoculture garden can leave plants weak and more susceptible to disease.

Less intensive plantings generally allow better air circulation and reduce the risk of foliar transfer of fungal problems.

With approx 70% of gardens in virgin bush soil where beneficial fungi appears to provide the appropriate mycorrhizal action required for healthy growth, there is little evidence of fungal disease being a major hurdle in Australia. Similarly, forest floor gardens have not yet experienced any problems with pests.

Trials in previously cultivated or grazed soils have not been as trouble free. Various treatments have been applied to infestations of reticulate slugs (*Deroecerus reticulatum*), cockchafers (*Adoryphorus couloni* and *Aphodius* spp.), chevron cutworm (*Diarsia intermixta*) and corbies (*Oncopera* spp.) with mixed success. Rather than straw, “scratchy” mulches, such as rice hulls mixed with coarse sawdust, can be a deterrent, especially for slugs.

Animals such as possums, rabbits, kangaroos, wallabies and wombats are deterred by fencing. Growers with severe possum attack find it necessary to protect all plantings with small mesh wire enclosures or fully enclosed shade structures. Protecting ripe berries with netting prevents parrots from destroying seed production. Anchoring wire mesh firmly across the surface of planted areas prevents lyre bird problems.

**Harvest and processing**

Where planted grounds do not freeze, harvesting of the roots can take place throughout the dormant period, otherwise, all harvesting must be completed before the freeze occurs. Harvesting can be done either by hand or by mechanical methods, again depending on the chosen growing method. Mechanical harvest is
done with modified potato or bulb diggers. After harvest, roots are sorted, removing damaged or spoiled roots to avoid a reduction in sale price.

For dried root sales, each day’s harvest is washed, loaded onto mesh trays and placed on the bottom rack in the drying area. Each successive day’s harvest is added at the bottom level with previous trays moved up in sequence. Roots can be air dried in a temperature controlled heated building or in a kiln if quantities are larger. Dried roots are stored and transported in cardboard barrels and require dry atmosphere storage. Correctly dried roots can be stored indefinitely.

Fresh roots need to be harvested as close to sale as possible. They are washed and re-packed in a growing medium, such as peat moss, for transportation. Fresh roots are stored under refrigeration and are marketable only during the dormant period.

Security measures should be taken to guard against theft of harvested, stored and transported roots.

Ginseng products need to comply with the Australian Therapeutic Goods Act (TGA) and must be manufactured and sold under special Australia List numbers (AustL No). TGA licensed consultants can prepare a listing application for approval, although it is possible to do it yourself. Once TGA has granted the AustL No, it must appear on all packaging of the product.

Under the Convention on International Trade in Endangered Species (CITES) the U.S. government has listed Panax quinquefolius on Schedule 2.

Therefore, a CITES Permit needs to be obtained from Australian Wildlife Protection before any whole root product is exported, even though the roots are cultivated in Australia. This rule does not apply to export of Panax ginseng.

### Financial information

The formula for expenses (Table 1) uses a site comprising 100 beds, 18 m long by 1.5 m wide, which have been planted intensively (50 x 150 mm spacings) with 20 kg of seed. Shade is erected singly over each bed on a structure of posts and wire. The cost of the shade is listed as a total expense but should last for three successive crops. Mulch is spread at the rate of 3 bales per bed. Soaker hoses are used for irrigation and use of fungicides and soil additives is minimal. Costs for land, rates etc., machinery and tools are not included.

<table>
<thead>
<tr>
<th>Description of item</th>
<th>1st yr</th>
<th>2nd yr</th>
<th>3rd yr</th>
<th>4th yr</th>
<th>5th yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed – 20kg @$550 per kilo</td>
<td>$11000</td>
<td></td>
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<td>Shade cloth – 2000m @$3 per metre</td>
<td>$6000</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Treated posts</td>
<td>$2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Wire and miscellaneous hardware</td>
<td>$250</td>
<td></td>
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<tr>
<td>Soaker hoses – 2 per bed @$12 each</td>
<td>$2400</td>
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<tr>
<td>Mulch – 300 bales 1st yr @$2 per bale</td>
<td>$600</td>
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<tr>
<td>Mulch – top up 50 bales per annum @$2</td>
<td>$100</td>
<td>$100</td>
<td>$100</td>
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<td>Fungicide (copper oxychloride)</td>
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<td>$25</td>
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<td>Sub totals</td>
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<td>$24445</td>
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Projected income (Table 2) is based on the anticipated sale of varying quantities of surplus seed from the end of the third growing season, plus the income from a yield of organically grown dried roots at the end of 5 years. Seed sales are calculated on the possible yield, amount kept for own use and consequent surplus sold. The price obtained for seed is expected to fall as more Australian grown seed becomes available. The production of seed for own use will reduce set-up costs for successive years and should be taken into account for any planning budgets. A harvest of 908 kg (2000 lb) of dried roots is considered to be a good average, with an excellent crop being about 1589 kg (3500 lb). Some crops yield less than 908 kg per 0.4 hectare (approx. 1 acre).

Key references

Hosemans, F. and C. Ginseng Growing in Australia, Published by Gembrook Organic Ginseng Pty Ltd.


### Table 2: Ginseng production - income

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<thead>
<tr>
<th>Description of item</th>
<th>1st yr</th>
<th>2nd yr</th>
<th>3rd yr</th>
<th>4th yr</th>
<th>5th yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed sales @ $650/kg Grown 45kg (100lb) – Sold 22.5kg (50lb)</td>
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<td></td>
<td></td>
<td></td>
<td>$14,625</td>
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<tr>
<td>Seed sales @ $600/kg Grown 136kg (300lb) – Sold 90kg (200lb)</td>
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<td></td>
<td></td>
<td>$54,000</td>
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<td>Seed sales @ $550/kg Grown 136kg (300lb) – Sold 90kg (200lb)</td>
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<td>$49,500</td>
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<td>Root sales – 908kg (2000lb) @ $160 per kg</td>
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<td></td>
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<td>$145,280</td>
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<td>Possible total income</td>
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<td>$263,405</td>
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Jojoba

Peter Milthorpe

Introduction

Jojoba (Simmondsia chinensis), pronounced ho-Ho-baa, produces a unique oil (or liquid wax) which has great potential for use in cosmetics and industrial applications. The oil is crushed from peanut-sized seeds that are produced from plantations of hedge-row grown shrubs. This desert plant is extremely drought tolerant, and is well suited to a broad area of inland Australia where it offers not only stable production, but environmental benefits not offered by existing landuse practices. These will ameliorate some of our land degradation problems.

Jojoba oil has many attributes that make it highly attractive to the cosmetic and skin-care industry. Not only does the oil have very acceptable skin-feel properties and excellent moisturising ability, but also it is very stable and gives products a long shelf life.

The industry in Australia is now based on the use of high yielding cloned varieties especially selected for our climate. Since 1993, the area planted has increased to over 400 ha and most plantations have reached production age and are now producing seed. There are at least 25 commercial growers, most of whom are active members of the Australian Jojoba industry Association (AJIA), the peak body for the industry. There are seven other countries that also produce jojoba. Their production is based on the use of 'seeded' material. Australia is well placed to become a major producer of jojoba oil because of our varieties, amenable climate and the good technical skills of our farmers.

While good husbandry is a prerequisite in any agricultural enterprise, the timing of many of the operations in jojoba growing is not as critical as for some other crops, eg., fresh fruit harvest. This
Key messages

Select:
- suitable climate
- well drained soils
- suitable varieties
- good management strategies

Key statistics

- Managed jojoba plantations in Australia have increased to over 400 ha of clonal material planted on 25 farms
- Seed production has approximately doubled in each of the past 5 years to about 48t at present.
- Production will continue to increase rapidly as the stands mature and new plantings reach production age
- The industry will now rely on export markets for its products

Jojoba requires soils that have good internal drainage and not subject to flooding. Apart from pH, the chemical properties are less critical, as fertilisers can be used. Soils with a pH of less than 5.0 are generally not suitable for jojoba because of aluminium toxicity problems. Aspect is generally not important on land with an altitude of less than 350 m, but for higher areas aspect needs to be considered to reduce the risk of late and severe frosts that can cause damage at flowering.

Markets and marketing issues

Sales are still limited to the high price, low volume markets that match the current low world production of about 1 500 t/yr. The cosmetics and skin-care industry buy most of present production and use the oil in its natural form or modify it to a cream or wax. The majority of oil is consumed in the USA and Europe. In 2003 the world trade in jojoba oil was estimated to be worth $AUD 135 million. Current Australian production now exceeds local demand for the oil and growers are now reliant on developing export markets for their product. Increased interest from Asia suggests there is great potential for expansion in the next few years. A small percentage of industrial grade oil comes from second pressings of seed or solvent extraction of meal carried out by a few large producers. This oil is used as an additive in special lubricants.

Typical of agricultural commodities subject to the cyclical nature of production and demand, the world oil price for jojoba oil has fluctuated greatly since commercial production commenced about 25 years ago. There are indications that pricing has become more stable over the past 5 years and jojoba oil currently sells on the world market at about $US 200 ($AUD 10 500)/t.

Production requirements

Much of the inland cereal growing area of Australia is well suited for jojoba production. Varieties that are well suited to the climate of these areas have been selected, but other factors such as soil type and rainfall must also be considered. Jojoba should not be grown in areas receiving less than 450 mm rainfall annually unless supplemental irrigation is available or planting density reduced from the nominal density range of 1 000 to 1 250/ha. In areas where rainfall exceeds 600 mm per annum, the threat of fungal attack on leaves during wet winters increases dramatically.

Most cereal-growing areas are suitable for jojoba production.
Varieties

To ensure ease of management and to have only one crop annually, it is important that all plants in any crop follow a similar growth and fruiting cycle. This can only be achieved in jojoba by using cuttings from registered varieties. Seed should not be used for establishing a plantation.

Jojoba requires both male and female plants to produce seed. There are three female varieties (Barindji, Wadi Wadi, and Waradgery) suited to Australian conditions. They have been selected for their consistent high yields and are registered under the Plant Breeders Rights (PBR) Act. Two male varieties—Dadi Dadi and Guyambul—are prolific producers of compatible pollen, and are well suited for pollinating the selected female varieties. There is continued interest and activity within the industry to find new and improved varieties to add to the existing ones.

Agronomy

Field layout should be planned to ensure that the rows run on the contour on sloping land. This will minimise erosion, provide access and locate drainage areas, and ensure that the most efficient use of the land is made. Hence it is advisable to survey the site well in advance of any work. Jojoba is grown in hedge-rows on low banks spaced at least 5 m apart. The plants are spaced 1.6–2.0 m apart along the rows. Headlands of 5–10 m are needed at each end of the rows to permit machinery access.

Jojoba grows slowly in the first few years and has little competitive ability against fast-growing annual weeds. Good initial land preparation to reduce weed seed numbers assists in later management as it is much easier to work on a broad-acre basis than try to control weeds around individual plants. Small areas of jojoba can be established and maintained by using three point linkage machinery normally found on farms, but large plantations will require special equipment. Land should be fallowed at least 12–18 months before planting to build up soil moisture reserves and reduce weed seed populations. Banks should be constructed at least 3 months before planting to allow them to settle. It is advisable to limit the length of plant rows to 500 m as crop management may present problems, particularly at harvest. The initial fertiliser application should be banded along the rip lines at about the time of bank construction. Ideally it should be placed 15–20 cm below the plant line where it will be readily available to the jojoba but unavailable to weeds. Leaf tissue and soil tests should be used as a guide for subsequent fertiliser needs.

There are two main planting seasons each year. The first is in spring as soon as the soil temperature rises above 20°C at a depth of 10 cm. This gives the young plants maximum growing time before the onset of winter. The second is during autumn from late February until early March after the worst of the hot weather is finished. However, plants can be successfully planted during the heat of summer provided extra care is taken with watering during the initial part of the establishment phase. If the plantation is to be irrigated the layout should be designed to allow young plants to be watered by channels or from drippers.

Planting can be done by hand or with machinery. About 5% of plants need to be male and planted throughout the plantation to ensure adequate pollination of the female flowers. The newly planted cuttings need to be watered-in as soon as possible after planting. Follow-up waterings are most important to ensure the roots to grow out of the potting mix into the surrounding moist soil, especially so if planting occurs in hot weather.

Weed control is the most important operation after planting and it is critical that this is done effectively. Specially designed plant guards are now commonly used by growers to shield young plants and allow directed spraying of weeds. This is complemented by the use of residual pelleted herbicides on the inside of the pots. After the first seasons’ growth plant shaping can commence, using contact sprays and mechanical pruners to produce vase-shaped plants that can easily be harvested.

Pests and disease control

There are few pests and diseases in jojoba. Following planting, birds and rodents may be troublesome. Galahs and sulphur-crested cockatoos occasionally attack
young plants nipping them off near ground level, but rarely killing them. There have been several instances where white cockatoos have caused about 5% deaths in small plantings, but these problems are reduced by plant guards and by using scare guns. Rabbits and hares can do similar damage, especially when there is a shortage of green feed.

Aphid attack during spring has been recorded from several young plantings but has never been serious. Insecticides can readily control any outbreak, but experience has shown that natural predators do a better job. Spiders and birds have colonised some plantations and between them control most insect pests. Following fruit set, caterpillars (Helicoverpa spp) can attack the developing fruit. The caterpillars appear to invade over a short period of time, soon after flowering, before the capsule becomes too hard for the grubs to penetrate. Only isolated outbreaks have been recorded and, to date, none of the attacks has been serious.

Some plant deaths have occurred that have been attributed to soil borne pathogens, notably Fusarium oxysporum, attacking the roots. Research projects are currently being undertaken with Charles Sturt University and the Rural Industries Research and Development Corporation to deal with this problem. Black spot periodically infests new growth at some locations and these outbreaks mostly occur after periods of extreme wet.

Frost can affect the reproductive potential of the plant as well as the vegetative parts. The recommended varieties have been selected to minimise loss of yield potential. Vegetative damage can occur on new growth of all varieties and at all ages, especially in dry winters when severe frosts are more common. Frost damage is usually restricted to new growth made just before winter that hasn’t hardened off before the onset of winter dormancy. While it looks bad no lasting damage is done. The flower buds survive and the frosts have the effect of tip pruning, encouraging new lateral growth in the following spring.

### Harvesting and processing

Off-the-ground harvesters are used overseas. In 2003 companies in Israel and the USA had developed commercial harvesters. Harvesters for Australian conditions will be similar, with several prototypes based on brushing the seed into windrows and then picking it up with either a tray or vacuum being tested. After harvesting, the seed is cleaned of leaf and other debris, washed and dried, then stored until required for crushing. Crushing is carried out using standard oilseed presses. Once crushed, the oil is filtered and may be pasteurised and bleached before storing in sealed drums until required, or sold.

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**About the author**

Peter Milthorpe is Senior Research Agronomist, NSW Agriculture, at the Agricultural Research and Advisory Station, Condobolin NSW (see Key contacts for address). Over the past 25 years he has carried out extensive research into many aspects of jojoba. Varietal selection and pollination requirements have been main areas of research followed by the development of sound management strategies. In 1993 he commenced growing jojoba on the family farm.
Industry development

The Australian Jojoba Industry Association (AJIA) was formed 10 years ago and attracts members from all aspects of the industry, but has a majority of grower members. The association is active in promoting the industry through newsletters, meetings seminars and field days where there is a free exchange of ideas. The association also acts as the peak body for the industry and collects voluntary plant and oil levies from growers. This money is then appropriated for production and marketing research as directed by the members.

Marketing is a key factor in the success of any industry, more so in a new industry such as jojoba. The growers have formed a co-operative marketing company to oversee the operations from seed crushing to final distribution of the oil, ensuring the highest standards are maintained and that growers receive the highest returns for their product.

Table 1. Projected gross returns for jojoba ($AUD/ha)

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<th>Yield (kg/ha)</th>
<th>Seed sales ($/t) $4 500</th>
<th>Seed sales ($/t) $2 500</th>
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Financial information

A well managed plantation set out with properly selected varieties using 1 250 plants/ha will yield about 1 t of seed/ha after 10–11 years under rainfed conditions, and up to 2 t if irrigated. The main cost is the purchase and establishment of the seedlings (about $4 500/ha) with land preparation, planting and tree guards costing another $2 250. Further costs will be incurred if irrigation is used, the cost varying according to delivery method. Following establishment, plantation management costs should be budgeted for weed control and plant shaping until the crop starts production in year 4 or 5. Harvest costs are about $2.5/kg for hand picked seed from small plantations but should drop to $0.20–0.30/kg when machine harvested from larger plantations. Seed yields will increase from year 5 until to about year 12 when they will plateau. Indicative returns from a mature stand are given in Table 1.

Key references


Key contacts

NSW Agriculture has been responsible for most of the recent research leading to the development of suitable varieties and offers advice. Other State Departments of Agriculture or Primary Industries also have advisory officers to assist.

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Introduction

Herbal medicines are today well established in a number of market channels, and there exists widespread familiarity with the names of various common herbal remedies.

This is quite a different situation to that of 15 years ago, when Echinacea for example, never featured in mass market advertising.

As the trend continues towards a more health conscious aging population, herbal medicine is likely to continue to gain an even wider acceptance within the community.

In year 2000, the Secretariat of the Convention on Biological Diversity, estimated that global sales for all herbal products, totalled US$60 billion.

In 2002, import replacement value for the herbal medicine industry in Australia was estimated at $A400 million (Rich B, Cheras P, Myers S., 2002). This suggests there is an opportunity for an Australian herbal medicine industry to become a major export earner, in a premium quality market niche, differentiated from the general global supply.

Markets and marketing issues

Medicinal herbs have been traded around the world for many years. Botanical (herbal) raw materials are comprised of the plant parts: roots, barks, leaves/stems, flowers, seeds, fruits, resins. These materials are presented in either a whole or cut form and sifted to a consistently even particle size.

Market prices are usually determined by supply and demand, but generally tend to be stable. Most traded European herbs are priced at source in the range US$2.00 to US$6.00/kg. However, prices paid by end users of raw materials (manufacturers) would vary according to where in the supply chain the material is procured. There could easily be two ‘middlemen’ between the source of raw material and manufacturer of raw material. ‘Middlemen’ may simply be trading herb material sourced from various growers and collectors or in addition may add value by sorting, cleaning, cutting, and testing materials for supply to manufacturers. Prices for imported organic medicinal herbs may range from US$10.00 to US$20.00/kg, due to the more limited supply market. Prices for difficult to grow or rare herbs, may be as high as US$120.00 at source (or higher).

The principal primary market for these raw materials is to industry which manufactures:

- essential oils
- liquid extracts and tinctures
- herbal teas
- concentrated extracts (the form required for the manufacture of tablets)
- plant derived pure pharmaceutical drugs.

Leaving aside the essential oil and pharmaceutical drug market, there are at present in Australia, about six manufacturers directly using dried herbal raw materials for the manufacture of liquid extracts. There are a number of manufacturers using mostly imported concentrated extracts for the manufacture of tablets, functional foods and personal care products. There are also a number of herbal tea manufacturers using...
both imported and Australian grown herbs for various ranges of herbal teas in mass and boutique market channels. An example of the supply chain is provided in Figure 1.

As the expected Australian domestic and export market for herbal medicine develops, opportunities will arise for the development of a primary industry to supply and support the growth of this market. Access to export markets may be facilitated by the ‘clean green’ image that Australian agriculture presents to the world.

There are three other factors, which if considered in conjunction with the increase in demand for herbal medicines, also suggest that there will be future opportunity for the development of an Australian herbal primary industry.

1. Increasing unsustainability of wild harvesting. Up until the late 1990s, probably close to 70% of traded medicinal herbs (by number of herbs), were harvested from wild plant populations. Some harvesting practices known as ‘wildcrafting’ are defined by accepted harvesting protocols to ensure continuing viability of plant populations. However, many herbs are just gathered, without regard to the ongoing sustainable future supply. In a situation of an ever growing world demand for medicinal herbs, sooner or later, various plant species will become 'endangered'. Examples of enforceable prohibitions already applied to the trade in wild harvested plant species include: - *Prunus africana*um (Pygeum) and *Hydrastis canadensis* (Golden Seal).

2. As the market grows for herbal medicine, so too will the market and regulatory requirement for herbal raw materials to meet quality standards of safety and efficacy. As the international trade of substandard raw materials has long been a feature of this industry, there will be a greater opportunity for a primary industry in Australia to lift the bar on the quality of raw materials that is available.

3. The Australian Quarantine regulations for importing raw herbal materials into Australia are a significant barrier. It is now getting to the stage where it is very difficult to import raw botanical material without some form of Quarantine prescribed treatment. This results in an increase in costs, time delays and possible compromise to the quality of the raw materials. In a situation of an expanding market, this again suggests a greater opportunity for an Australian import replacement primary industry.

In supplying a consignment of herb to a manufacturer, a herb grower must follow certain steps, which are as follows:

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Figure 1: Supply chain example for various ranges of herbal teas in mass and boutique market channels
Purity – Is the level of extraneous matter within specification?

Efficacy – Determination of the presence and quantification for the active chemical constituents or marker compounds, through analysis such as – HPLC, Gas Chromatography, Mass Spectrophotometry.

Production requirements

Most medicinal herbs from Europe and North America will do best in temperate climatic regions. Within a climatic region there will be an optimum microclimate for a particular plant species.

Medicinal herbs generally do best in moderate to highly fertile, light textured soils with good moisture retention and drainage. Heavy soils may be acceptable for some crops but tend to be unsuitable for most root crops because of the extra difficulty (and cost) in harvesting and cleaning.

The various geographical and climatic regions in Australia will offer the growing conditions required by most medicinal plant species in demand, although almost everywhere in Australia herb production will need irrigation. Certain herb crops may be unsuitable for summer growing because of heat, lack of rain or, conversely, the intensity of summer rain.

Agricultural practices

Stringent quality requirements apply to the acceptance of medicinal herbs as raw materials for the manufacture of herbal medicines. The quality requirements are prescribed by the Australian Therapeutic Goods Administration through the code of Good Manufacturing Practice.

Three key standards against which herbal raw materials are assessed are:


2. **Purity** – herb and plant part must not be contaminated by extraneous matter including – moulds, foreign plant matter, incorrect plant parts of the specified plant, soil, stones or animal matter, pesticides and heavy metals.

3. **Efficacy** – the herb must possess the required level of medicinally active constituents.

The identity, purity and potency of a herb crop are affected by all cultivation and on-farm processing practices.

All herbal materials are exposed to a wide range of possible contamination sources on farm. To minimize such potential contamination, at the primary producer level, producers of medicinal herbs should be aware that in 2003, the World Health Organisation (WHO) published a code of Good Agricultural Practice (GAP) in a publication entitled *WHO guidelines on good agricultural and collection practices (GACP) for medicinal plants* (Geneva, 2003).
Elements of this code of practice when adopted into an on-farm crop management system, would assist in the consistent supply of medicinal herbs which meet requirements for identity, purity and efficacy.

The main elements addressed in this code document are as follows:

**Site Selection**
- conduct soil tests to ensure soil is free of chemical residue contamination
- select climatic area and soil type conducive to growing the proposed medicinal herbs
- the soil type, drainage, moisture retention, fertility and pH should be optimal for the herb selected to be grown. eg heavy clay soils are generally unsuitable for root crops. The application of fertilizers should be used sparingly, ideally as part of an organic management system. The ideal is to optimize the development of active constituents in plants rather than heavy vegetal growth
- medicinal herbs of the same species, grown at different sites may have significant differences in either growth habits, harvest yields and/or active constituents, due to the influences of soil and farm microclimate.

**Buildings & Equipment**
- all buildings and areas used for the handling of medicinal plant material must be of an appropriate standard (refer to the Code GAP)
- all equipment must be kept clean to prevent contamination of herb crops and harvested plant material.

**Documentation**
- all on farm processes (eg cultivation, planting, crop maintenance, irrigation, harvesting, post harvest preparation) should be documented
- every batch of dried herb must be assigned a unique batch number

**Personnel**
- all personnel engaged in the cultivation of medicinal herbs must be proficient in plant identification and crop management practices
- all personnel involved in the handling of medicinal plant produce should in all processing procedures, comply with applicable health regulations.

**Seeds and propagating material**
- the start of the raw material chain is the selection of correct seed, plant variety, cultivar and genotype, to ensure the correct primary identity of plant material and potential potency of the herbal material.

**Cultivation**
The cultivation of medicinal herbs is mostly undertaken on cultivated areas of less than 20ha, and often on areas of less than 1ha. The general principles of good plant husbandry including crop rotations should be followed.

- in terms of the intensive management required, herb production is somewhat similar to horticultural production. However, whereas the life cycle of a horticultural crop may be 3 - 6 months, herb crops usually have a much longer growing period, which increases the cost of crop maintenance. Different herb species may be annual, biennial or perennial and need to be managed accordingly. Annual crops may be harvestable within 12 months, whereas the other perennial type crops may need 12 - 20 months before the first optimum harvest time.

**Irrigation**
- in general, medicinal herb crops require irrigation, the extent of which depends on the climate soil type and rainfall. Overhead and drip irrigation systems have been successfully used, however overhead irrigation may lead to an increased problem of weed control.

**Crop maintenance and plant protection**
- specific herb crops may benefit from pruning, or topping at different stages in the growth cycle. In organic crop management systems, weed control is the largest component of crop maintenance.

**Harvest**
- medicinal plants should be harvested during the appropriate season to ensure the presence of active constituents within the herb
- the herb crop should be harvested at the optimal time of day and climatic conditions: avoiding periods of heavy dew, excessive humidity, or rain
- damaged plants or plant parts and extraneous plant materials and soil must be excluded
- freshly harvested plant material must be delivered as quickly as possible to the primary processing facility, to prevent the build up of heat and potential thermal degradation.
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<td>Flower</td>
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<td>Lemon Balm</td>
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<td>Olive Leaves</td>
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</tr>
<tr>
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<td>Paeonia</td>
<td>Root</td>
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<td>Flower</td>
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<td>Dan Shen</td>
<td>Root</td>
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<td>Fruit</td>
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<td>Baical Skullcap</td>
<td>Root</td>
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<td>Skullcap</td>
<td>Herb</td>
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<td>Saw Palmetto</td>
<td>Berry/Fruit</td>
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<td>Seed</td>
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<td>Sarsaparilla</td>
<td>Root/Rhizome</td>
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<tr>
<td>Solidago virgaurea</td>
<td>Golden Rod</td>
<td>Herb</td>
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<td>Root Leaf</td>
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<td>Stem Bark powder</td>
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<td>Inner Stem Bark</td>
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<td>Urtica dioica</td>
<td>Nettle</td>
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<td>Vaccinium myrtillus</td>
<td>Bilberry</td>
<td>Fruit</td>
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<td>Mexican Valerian</td>
<td>Root</td>
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<td>Valeriana officinalis</td>
<td>Valerian</td>
<td>Root</td>
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<td>Verbascum thapsus</td>
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<td>Verbenae officinalis</td>
<td>Vervain</td>
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<td>Viburnum opulus</td>
<td>Cramp Bark</td>
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<td>Vitex agnus castus</td>
<td>Chaste Tree</td>
<td>Fruit</td>
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<td>Withania somnifera</td>
<td>Withania</td>
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<td>Zingiber officinale</td>
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<tr>
<td>Zizyphus spinosa</td>
<td>Zizyphus</td>
<td>Seed</td>
<td></td>
<td>♦</td>
</tr>
</tbody>
</table>
Primary Processing
- harvested plant material should be shielded from direct exposure to the sun or rain
- freshly harvested medicinal plant materials should be inspected and checked for quality, ie appearance, size, colour, odour and taste
- prior to drying, plant material should be hand sorted, cleaned by vibration and/or washed to remove any extraneous plant parts and soil.

Drying
- the optimum way to dry herbal material is in a kiln, where heat and humidity can be controlled. The drier may be a closed de-humidification system or simple flow through hot air drying system. Other more sophisticated (and expensive) drying systems are available
- hot air should delivered through a heat exchange system. Herbal material should not come in contact with hot exhaust gases
- herbal material must be uniformly dried, to evenly remove moisture and prevent mould formation. A common way of ensuring uniform drying is to thinly and evenly spread plant material on racking which allows for the even circulation of drying air through the plant material
- final moisture content in herbal material should be no more than 10 - 12%
- ideally herb crops should be dried in a system where there is minimal potential for mould growth. This will require adequate ventilation, control of heat and humidity.
- most herb crops will be optimally dried at less than 60°C to avoid a change in colour or odour of the herb
- dried medicinal plant materials should be inspected, sieved, cut or winnowed to remove discoloured, mouldy materials, soil, stones or other foreign matter that may not have been detected during the primary processing.

Packaging
- processed herbal materials should be packaged as soon as possible after drying/processing, to prevent potential deterioration of product and protect against unnecessary exposure to potential pest attacks and other sources of contamination.
- appropriate packaging of herbs will prevent the herbs from re-absorbing atmospheric moisture. Best packaging materials are lined woven poly produce bags. For certain herbs, packaging in new wool bales is acceptable.
- if lined produce bags are used, herb material should be sufficiently dried, otherwise herb material will turn mouldy.

Storage
- packaged dried medicinal herbs are best stored in a dark, well ventilated building, off the floor, where daily temperature variations are limited and where the maximum temperature does not exceed 25°C.
- to prevent potential insect infestation due to the hatching of eggs, and assuming fumigation is not an option, packaged medicinal herbs should be frozen at -18°C for a minimum period of three days. eg dandelion root, angelica root are root crops which are particularly susceptible
- storage on pallets, away from walls.

Key messages
- Strong growth forecast for herbal medicines
- Meeting well defined quality parameters essential for herbal raw materials
- Opportunities for Australian primary producers

Key statistics
- Global sales for all herbal products valued at US$60 billion (2000)
Financial information

A full financial analytical model for medicinal herb production, using Echinacea purpurea as an example, is provided in the accompanying chapter on financial models. An analysis of this type should be conducted for each proposed medicinal herb crop.

The model presented, is based on a production area of 1ha, although the comment is made that this level of investment for 1ha is impractical. The investment presented in this model could probably facilitate larger scale herb production, up to about 6 ha. For less than one ha of production, less mechanisation (and capital investment) with greater labour input may be manageable.

Using the example of Echinacea purpurea, an estimate of yield depends on the planting rate per ha and the dried herb mass per plant. For example, assuming a planting rate of 50,000 plants/ha, a yield of 1.2–2.0 t/ha may be achievable, based on dry root mass per plant of 20–40 g, in the second season. Flowering tops, harvested in the first season, may yield up to 5.0 t/ha, based on a dry plant mass of 100 g/plant. The yield based on these calculations is somewhat lower than that assumed by the model.

It is probably useful to adopt a conservative approach to such calculations until an actual yield is achieved.

Examples of various risks which may impact on assumptions about yield and revenue are as follows:

- actual yield may vary according to the soil and regional ‘microclimatic’ conditions for the land to be cultivated
- unfavourable climatic conditions may result in plant loss within any growing season directly impacting on yield, which may, for Echinacea purpurea root be as low as 400kg/ha
- the lead time to the first harvest may be longer than 12 months, due to insufficient plant root growth to justify a harvest. Consequently, revenue return may be unachievable within this period
- the market for Echinacea flowering tops may be oversupplied as has been the case in recent years, revenue may be only a small proportion of total potential yield.

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About the author

Peter Purbrick joined MediHerb Pty Ltd in 1987 to assist with general production operations. From the early 1990s in the role of Purchasing Manager, Peter has specialized in sourcing herbal raw materials, liaising with growers and suppliers within Australia and overseas and has experience in establishing long term supply arrangements. Over the years Peter has contributed to publications and addressed conferences on a range of aspects of the emerging Australian herb industry.

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Paprika

Introduction

Paprika is a potential new crop for production in Australia. It is from the genus *Capsicum* that includes capsicums (bell peppers) and chillies. Condiment paprika is *Capsicum annuum* var. *longum* and it is characterised by having long, smooth, intensely deep red fruit with high dry matter content. The fruit is free of the pungent component of “hot” chillies, the chemical capsaicin.

The fruit can be harvested and sold as a vegetable, a sweet chilli. However, the major world uses are for the production of condiment paprika, which is the dried fruit that is milled to a fine powder, or for the production of oleoresin (pigment) by extraction from the condiment paprika. With increased consumer and regulatory demand for use of natural food colouring and flavouring the market for condiment paprika and oleoresin can be predicted to grow. Condiment paprika is a spice and colouring agent used in home cooking and in food manufacture, while paprika oleoresin is widely used in the food canning and smallgoods processing industries. Paprika oleoresin can also be used as a colouring agent in cosmetic and pharmaceutical products. Paprika seed oil is a highly valued seed oil in Asian cuisine.

Key messages

- Paprika is a potential new crop for Australia
- Australia needs to aim at high mechanisation and quality
- RIRDC is supporting breeding of cultivars for Australia
- PVR cultivars will be available in the next few years
- Processing and marketing needs to be developed

Key statistics

- Australia currently imports over 600t of condiment paprika at a cost of over $5 million
- A conservative estimate is that Europe, North America, Japan and SE Asia consume over 20,000t/year
Markets and marketing issues

Australia currently imports over $5 million of paprika products, including over 600 t of milling condiment paprika, from about 400 t in 1991. This rapid increase in Australian imports reflects current global demand, which is conservatively estimated to be over 20,000 t/year, in Europe, North America, SE Asia and Japan.

Production statistics from the FAO for 1999 indicate the major producers. It is likely that the total figures for both China and North America include hot chilli production as well. The traditional condiment producing countries of Morocco, South Africa, Israel, Slovenia and Spain have relatively constant production, but production in Zimbabwe is likely to have fallen greatly due to the political problems there. Hungary also had some problems with product quality.

Condiment paprika production of major producing countries

<table>
<thead>
<tr>
<th>Country/Region</th>
<th>Production in 1999 (Mt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morocco</td>
<td>12,000</td>
</tr>
<tr>
<td>South Africa</td>
<td>9,500</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>23,000</td>
</tr>
<tr>
<td>China</td>
<td>200,000</td>
</tr>
<tr>
<td>Israel</td>
<td>2,600</td>
</tr>
<tr>
<td>Hungary</td>
<td>48,000</td>
</tr>
<tr>
<td>Slovenia</td>
<td>6,100</td>
</tr>
<tr>
<td>Spain</td>
<td>6,000</td>
</tr>
<tr>
<td>North America</td>
<td>50,000</td>
</tr>
</tbody>
</table>

Paprika is traded as the “half-product” — the dried fruit after the removal of the caylx, or as the milled condiment paprika. The level of colour in these is a key specification, measured as ASTA (American Spice Trade Association) levels, a spectrophotometric measure of extractable colour.

As there is not yet a paprika industry in Australia, markets and marketing will have to be developed. Both condiment paprika and oleoresin from experimental growth and processing in Australia has received very favourable comment from both potential local and Japanese customers.

Production requirements

Capsicums and chillies are grown as field crops in several areas of Australia, in South Australia (Adelaide Plains and Riverland), NSW (especially the Sydney basin market gardens, and Narromine), and in various areas of Queensland (Bowen-Burdekin, and Bundaberg regions). These areas will be suitable for paprika, as will be processing tomato areas of the Murray basin.

Paprika is a warm season crop that requires about the same growing conditions as tomatoes. The plants are very susceptible to spring frosts, and grow poorly in the 5-15°C temperature range. Sowing too early in cool soils (September and early October) gives slow germination, and growth. Seedlings can also be produced for transplanting to enable earlier establishment and reduced seed use. High yields come with daily temperatures of 18-32°C during fruit set. High temperatures do not affect fruit set if moisture supplies are adequate. A deep, well-drained, medium textured, sandy loam or loam soil is best, as is a slightly alkaline soil pH (7.0-8.0). Saline irrigation water (> 1200 µS/cm) is not well tolerated, especially by seedlings.

Varieties/cultivars

Hungarian cultivars of paprika such as Szegedi 80, as well as US cultivars (not all of which are sweet), such as PapriQueen and PapriKing, have been used for trials in the Sydney basin and in the Hunter Valley by the University of Sydney.

There are currently no Australian-bred cultivars of paprika. However, the RIRDC-funded paprika breeding program at the Plant Breeding Institute, University of Sydney will be releasing a number of cultivars shortly, after Plant Breeders Rights are obtained. Important selection criteria in the breeding program are aimed at providing cultivars that will be suitable for Australian conditions, and also for possible production systems here, the most important being mechanical harvesting, to reduce costs. Selection is for semi-determinate growth habit, high productivity, synchronous early ripening of hanging fruit, resistance to diseases, high germination (for direct sowing) and a detachable pedicel or calyx (for mechanical harvesting), high dry matter, and high ASTA (colour content) with good aroma and taste.

Cultural practices/agronomy

Crop establishment and husbandry for paprika is very similar to that for field capsicum. Preparing soil involves various tillage treatments, followed by smoothing and listing and formation of raised beds. Irrigation should be before planting, of either seedlings or seed. High quality seed should be planted, aiming at 200,000 – 600,000 plants/ha, depending on the cultivar. Seed is planted 1.5-2 cm deep. Experience overseas
suggests that further covering with a further protective 7-10 cm cap of soil that is removed at the crook stage of seedling emergence can be beneficial. Seedlings are planted like tomato seedlings. Shallow inter-row cultivation may control weeds and increase soil aeration, and pre-emergent herbicides may also be useful. Advice from a weed specialist is important for this.

Paprika greatly prefers trickle or furrow irrigation to overhead irrigation, which can burn the leaves and fruits on hot sunny days, and overhead spray irrigation also contributes to disease spread. Fertilisation should follow recommendations for capsicum, with pre-plant application of nitrogen and phosphorous before tillage, or by banding 10cm below the seed at planting. As the crop grows, a steady supply of nitrogen is needed during fruit set to produce high yields.

Common diseases of capsicums include *Phytophthora* root rot, *Verticillium* wilt, *Rhizoctonia* root rot, and bacterial leaf spot. Seed fungicide treatments are effective against the three fungal soil-borne diseases (*Phytophthora*, *Verticillium*, and *Rhizoctonia*). Rotations help control of these diseases, so growing paprika after cereals (but not sorghum) or legumes is recommended, only repeating paprika after 3 or 4 years. Tomato crops also have a similar range of diseases and pests, so growth after tomatoes should be avoided.

Viruses are also likely to be important, with curly top virus, tomato spotted wilt virus, lucerne mosaic virus, and capsicum mottle virus known to occur. Control of the insect vectors of the virus will reduce the incidence of infection, as with rotations, and control of solanaceous weeds in the area.

**Harvest and processing**

Fruit can be harvested fresh like vegetable capsicums and sold as fresh sweet chillies in markets. However, for the industrial purposes of producing condiment paprika and oleoresin, mechanical harvesting will be vital for the economics of the industry. There is at present little experience with this. It may be that processing tomato or green bean harvesters can be modified to harvest paprika. One of the breeding aims of the RIRDC-supported program at the University of Sydney is synchronous early ripening, which will facilitate mechanical harvesting. Ethephon® can be used to stop flowering, hasten fruit maturity and defoliate the plants before mechanical harvesting, and fruit can be left on the plants to partially dry before harvest.

The harvest must then be dried (without overheating), slightly crushed and the calyx removed (half-product), and then milled to produce condiment paprika. The machinery and processes for these steps are still under development. Oleoresin production is a specialised process unlikely to be undertaken by producers.

**About the author**

Peter Sharp is the Director of the Plant Breeding Institute of the University of Sydney. He is an expert in the area of cereal molecular genetics, but has in the last few years collaborated with Nickolas Derera AM in developing paprika cultivars, with funding from RIRDC.

A RIRDC-supported PhD student is also developing a hybrid seed production system for paprika under his supervision.
Financial information

As there is not yet an established industry in Australia, complete information in this area is difficult to provide. However, crop establishment and husbandry costs are likely to be similar to those of capsicum, which are about $10,000-12,000/ha.

The cost of mechanical harvesting, drying and production of half-product and then condiment paprika by milling in Australia is not known at present. Trials in NSW indicate reasonable yields of 25t/ha of raw paprika, which will produce about 4,000 kg of milled condiment paprika with a store value of about $25,000. This would produce about 350kg of oleoresin with a value of about $35,000.

It must be emphasised that the price of condiment paprika is highly dependent on quality, as measured by ASTA. In New York recently, Hungarian product at 120 ASTA was about $US 3,900/t while South African product at 80 ASTA was about $US 1,800/t. Clearly, the breeding and production of paprika in Australia will need to concentrate on the high ASTA market (ASTA over 200).

Key references


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Alternative oil seeds for Australia

Clive Francis and Margaret Campbell

Introduction

The Australian oilseed industry is almost solely dependent on canola (*Brassica napus*) despite the diversity of soils and climates and the threats from disease and insects. The disease blackleg (*Leptosphaeria maculans*) builds up rapidly and prevents close rotation even with cultivars bred for improved resistance. Canola is not adapted to poorly drained soils and needs high levels of fertility for its success. A single oilseed system based on *B. napus* is unlikely to be the best fit for all environments and disease exposures. For long-term stability other oil seed crops are needed in the system to satisfy the increasing demand, particularly if the ‘new’ oil seeds have oils of different and better qualities than canola, either for culinary, pharmaceutical or industrial purposes. To be an acceptable alternative or compliment to canola, any new oil seed will need to have a readily marketable, higher value oil and or produce equivalent or better yield in a given environment. There is now a range of alternatives of varied market prospects.

Research is being conducted on a range of alternative oilseed species suitable for Mediterranean environments in Australia. The species are being evaluated as

The plants

The Mustards

Indian or Oriental, Brown Mustard, *Brassica juncea* and Ethiopian Mustard, *Brassica carinata* are closely related to canola, with a very similar habit but often taller. Mustards tend to have a higher tolerance to water stress, insect pests and diseases. Yields have often been better than canola especially in drier areas. The highly variable Ethiopian mustard is almost completely immune to blackleg but has been neglected as a crop species in Australia.
The oil from the yellow seeded Oriental mustard is a mainstay of Indian cooking. Main use elsewhere is as a condiment in a wide range of mustards. Dijon mustard employs seed of brown mustard. They have potential for the medium to low rainfall environments of Australia. The oil of some of the lines contains a very high proportion of erucic acid, which gives them potential as industrial oil or for biodiesel fuel.

Ethiopian Mustard produces a lot of biomass, more than any of the other mustards. The leaves are often used as a vegetable in Ethiopia. The colour of the leaves can vary between a bluish green and a deep burgundy.

**White or English Mustard** (*Sinapis alba*): The ‘hot dog mustard’ of USA, has a niche market as a condiment. Generally the seed yield is lower than the other mustards due to less seeds per fruit, although the seeds themselves are bigger.

In their current high glucosinolate, high erucic forms, there is restricted local opportunity for production of mustard seed for condiments or mustard oil but there is a future potential for export and as biodiesel. Ethiopian mustard, being highly resistant to blackleg, is a candidate for crosses with canola quality *Brassica napus*, as has already been done in Canada and Germany. It appears worthy of a program for reselection for low glucosinolate and reduced erucic acid within the best yielding genotypes of the species.

**Crambe**
*Crambe abyssinica* is established as an industrial oil crop in USA with an exceptionally high concentration of erucic acid (>60%). Tolerant of a range of herbicides and easy to grow, the crop has potential in the medium rainfall areas but seed yields, as distinct from the husked harvest product, have been generally lower than canola. The lightweight pod makes transport expensive and hence the need for an oil extraction plant in the near vicinity to the farmer sources.

The small round Crambe fruit contain just one or two seeds. The whole fruit is harvested as a unit with the pericarp intact.

**Camelina or False Flax**
*Camelina sativa* has a high level (35%) of Omega 3 fatty acid (Alpha Linolenic acid) combined with higher antioxidant levels than other oilseeds. The crop is low maintenance, adapted to sandy soils where it is capable of outyielding canola. Its early vigour makes it competitive with weeds. It has considerable potential, as in Europe, as a food and health oil but is currently mainly used in the cosmetic industry as a base for skin creams and lotions.

Camelina oil, seed and seed meal are marketed in Finland by Camelina Pty Ltd. For further information on their camelina products see their web site at http://www.camelina.fi/.

**Golden Linseed**
*Linum usitatissimum* is grown for the health food market and is sold both as seed and as Flax oil. The high Omega 3 content of the oil (> 55%) makes it desirable as a health food supplement but detracts from its keeping quality. High lignan content is an added health benefit. Well adapted to southern Australia, earlier flowering varieties are needed.
Linseed is typically more tolerant of waterlogging with a greater tolerance to herbicides than the other species in this study. Linseed flowers can be white or shades of pale blue. The stems of the plants can be used for fibre and to make linen.

Garden Stock
*Matthiola incana*, more commonly known as an ornamental garden plant, is a perennial and relatively slow growing. Weed control early in the growing season is essential. Once established, it is hardy and can be long lasting but its yield potential is not yet clear. It is drought tolerant and some lines appear adapted to salinity. More than 60 per cent of the total fatty acid content of the seed consists of Omega 3. It is potentially very valuable as a health food supplement. Omega 3 fatty acids are reported to confer a low incidence of arteriosclerosis and heart disease in humans, as is the case of ethnic diets containing fish oils.

Noog or Niger
*Guzotia abyssinica* is more suited to subtropical; warmer areas but has potential as a spring or summer crop in certain areas of southern Australia. *Niger* oil sells for a premium over other food oils in Ethiopia due to its preferred taste and pale yellow colour. In Nepal, the ground up seed is used as a condiment. The whole seed has a strong US market as birdseed. Yields in tropical Australia can exceed 1.5 t/ha but maximum yields require the presence of a pollinator.

Borage and Echium
*Borago officinalis* has limited potential in other than cool high rainfall areas. It shatters badly and harvesting can be a problem. The oil in the seeds of Borage contains 22% Gamma Linolenic acid (GLA), a valuable fatty acid essential for good health. The seed oil of Evening Primrose, the more commonly known source of GLA contains only around 10% GLA. Borage oil is currently sold in capsules as ‘Starflower Oil’ in health food shops. The near relative, Salvation Jane (*Echium plantagineum*), a common weed, contains even better health oil characters with both GLA and Omega 3 fatty acids and as a bonus, the anti inflammatory, stearidonic acid. Like Borage, shattering is a problem and being a cross fertilising species a high bee population is needed for maximisation of yield.
Salvation Jane or Patterson’s curse: *Echium plantagineum* is a common sight in many places in Australia. The seed oil is potentially valuable for its anti-inflammatory properties and as an aid in wrinkle reduction.

**Markets and marketing issues**

The projected marketing study will provide definitive answers to likely prices in dollar terms and will define more accurately the potential area of production. The project is expected to result in the release of new oilseed opportunities for Australian farmers.

**Oil content and quality**

The oil content and quality are vital ingredients in defining the value and end use of the alternative oilseeds.

Oil colour can be a selling point for cold pressed oils and in this respect Camelina and Niger produce attractive pale coloured first press oils.

**Health foods**

The health food market favors oils high in the essential fatty acids, Omega 3 (Alpha linolenic acid) and GLA (Gamma linolenic acid).

**High Omega 3 oil**

There could be a new and better health product for Australian consumers. Cold pressed Camelina oil with 36% Omega 3 and unique antioxidant (tocopherol) levels. This represents a big potential market but may require considerable input to satisfy the Australian food standards agencies, though accepted as a food oil in Europe.

Levels of Omega 3 in linseed are over 50%. This coupled with high lignin content make the seed itself a highly marketable product. Golden seeded lines, especially if organically grown, attract high prices $1300–$2000/t on the UK market. Linseed has an increasing market. Oil from brown seeded varieties is usually put into capsules, the golden seeded varieties are either sold for oil or the whole seed is sold as a health product. Golden seeded varieties attract a premium of approximately $150/t, but it must be organically grown. This year 8100ha will be sown to linseed in UK with the biggest market in organically grown linseed of both types.

The Garden Stock (*Matthiola incana*) has even higher levels of Omega 3 fatty acids with some 60% of its oil comprising this essential fatty acid.

**Table 1. Oil and fatty acid contents**

<table>
<thead>
<tr>
<th>Species</th>
<th>Niger</th>
<th>Camelina</th>
<th>Linseed</th>
<th>Stock</th>
<th>Crambe</th>
<th>Borage</th>
<th>Echium</th>
<th>Canola</th>
<th>Ethiopian</th>
<th>Oriental</th>
<th>White</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil content (%)</td>
<td>36.0</td>
<td>35.0</td>
<td>37.0</td>
<td>24.0</td>
<td>28.5*</td>
<td>35.0</td>
<td>20.0</td>
<td>40.0</td>
<td>38.5</td>
<td>38.5</td>
<td>31.0</td>
</tr>
<tr>
<td>Palmitic (16:0)</td>
<td>9.3</td>
<td>4.8</td>
<td>6.3</td>
<td>8.6</td>
<td>1.9</td>
<td>11.5</td>
<td>7.1</td>
<td>4.3</td>
<td>3.1</td>
<td>4</td>
<td>2.6</td>
</tr>
<tr>
<td>Stearic (18:0)</td>
<td>3.3</td>
<td>2.8</td>
<td>5.2</td>
<td>4.3</td>
<td>0.7</td>
<td>4.0</td>
<td>2.9</td>
<td>2.1</td>
<td>2.1</td>
<td>2</td>
<td>1.1</td>
</tr>
<tr>
<td>Oleic (18:1)</td>
<td>14.1</td>
<td>16.1</td>
<td>17.4</td>
<td>14.0</td>
<td>14.3</td>
<td>16.2</td>
<td>14.7</td>
<td>59.0</td>
<td>10</td>
<td>34</td>
<td>14.5</td>
</tr>
<tr>
<td>Linoleic (18:2 n-6)</td>
<td>75.5*</td>
<td>16.2</td>
<td>18.3</td>
<td>11.8</td>
<td>9.5</td>
<td>36.7</td>
<td>18.0</td>
<td>20.2</td>
<td>16</td>
<td>27</td>
<td>10.3</td>
</tr>
<tr>
<td>Linolenic (18:3 n-3)</td>
<td>36.1</td>
<td>56.2</td>
<td>61.5</td>
<td>6.5</td>
<td>4.1</td>
<td>34.1</td>
<td>10.0</td>
<td>13.0</td>
<td>12</td>
<td>10.4</td>
<td></td>
</tr>
<tr>
<td>Omega 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linolenic (18:3 n-6) GLA</td>
<td>22.3</td>
<td>9.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eicosenoic (20:1)</td>
<td></td>
<td>14.2</td>
<td>1.2</td>
<td></td>
<td>1.0</td>
<td>5.0</td>
<td>9.0</td>
<td>11.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erucic (22:1)</td>
<td>2.8</td>
<td></td>
<td>60.1</td>
<td>3.6</td>
<td>47.2</td>
<td>11.0</td>
<td>36.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stearidonic (18.4)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Our best line is a moderate erucic acid selection of Indian Mustard – normally at least 30% erucic

**Table 2. Oil colour and cold press extraction results**

(Oil extraction – first press of 1000 gm of seed)

<table>
<thead>
<tr>
<th>Species</th>
<th>Oil extracted (ml)</th>
<th>% extracted (first press)</th>
<th>Oil colour *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canola</td>
<td>350</td>
<td>83.3</td>
<td>7 A, (Yellow)</td>
</tr>
<tr>
<td>Niger</td>
<td>310</td>
<td>86.0</td>
<td>6 D (Pale yellow)</td>
</tr>
<tr>
<td>Camelina</td>
<td>300</td>
<td>81.1</td>
<td>5 D (Pale straw)</td>
</tr>
<tr>
<td>Linseed</td>
<td>275</td>
<td>88.0</td>
<td>8 A (Yellow)</td>
</tr>
<tr>
<td>Crambe</td>
<td>225</td>
<td>72.5</td>
<td>7 B (Yellow)</td>
</tr>
</tbody>
</table>

* Colour grading RHS color chart of the Royal Horticultural Society. Kew Gardens, UK.
Health benefits of Omega 3 consumption
• improved regulation of blood pressure
• reduced risk of cardiovascular disease and blood clotting
• lower risk of bowel and prostate cancers
• improved foetal and infant development
• treatment of rheumatoid arthritis and some forms of depression.
Source: CSIRO Division of Plant Industry

High GLA oils
Borage marketed as Starflower oil, has significant levels (20–25%) of GLA (gamma linolenic acid) - twice as much as the widely marketed Evening Primrose oil (9-12%) GLA. Echium oil contains not only as much GLA as Evening Primrose oil but 30% Omega 3 as well. As an additional bonus it contains the valuable anti-inflammatory Stearidonic acid with reports of 10–14%.

Health benefits of GLA 3 consumption
• atrophic eczema
• reduction of cholesterol levels
• treatment of mild hypertension
• reduction of premenstrual tension.
Source: Horrobin (1984)

The mustard market
A relatively small market for seed for condiment mustard production exists in Australia. Mustards in South East Asia however, are a major industry, with India and its neighbours, Bangladesh and Pakistan importing more than 100,000t annually from Canada. This could well represent an opportunity for Australian farmers if the market could be established with a reliable supply chain.

The industrial oil market
Crambe oil is used as an industrial lubricant. Crambe abyssinica has potential as an industrial fatty acid feedstock as a source of erucic acid. Erucic acid is used mainly as erucamide, an effective non-stick agent in polyolefin films for wrapping food, plastic bags, shrink-wraps, lubricants, plasticisers and foam suppressants. It can also be converted to nylon 1313, or hydrogenated to behenic acid, which also has many applications in the manufacture of rubber, pharmaceuticals, cosmetics, fabric softeners, hair conditioners and rinses.

Crambe oil is a very effective lubricant, and is much more biodegradable than mineral oils, so it may be used alone or as additives for the textile, steel and shipping industries. It is based as an industry in North Dakota USA but has proven unstable in terms of grower interest. A UK market for 30–50,000t exists established by John K Kings and Sons. This would entail the oil extraction and import into UK. This could be met from Australia as refined oil. The seed export and handling is made more expensive by the adherence of the fruit coat, doubling the volume of seed for transport and undoubtedly making container shipping too expensive.

In recent years, the production of Crambe in North Dakota has fluctuated as the commercial players involved in the industry have changed and supply has proven unreliable. Its future will depend upon both the future of bio-renewable resources together with innovative research to develop additional markets for the crop. It faces competition from easier to handle HEAR cultivars of B napus and potentially from B juncea selections.

New quality oils
Niger is highly prized for its edible oil qualities in Ethiopia, India and Nepal. Polyunsaturated with some 80% linoleic acid, its composition closely resembles that of sunflower oil but is more attractive in colour. In addition, there is a substantial birdseed market in the USA. Despite the availability of markets in Australia and a good overseas demand for this tropical or subtropical crop, it has yet to be fully exploited in Australia except by a Kununurra producer seed R B Des(s)ert Seed Co. Tapping into the USA birdseed market is an attractive aim.

Production requirements
Niger is regarded as a tropical or subtropical species. It is frost sensitive, but was tested in these experiments under winter rainfall conditions in southern Western Australia. The Ethiopian lines are more vigorous, slightly later, and more tolerant to cooler temperatures than the Indian subcontinent lines. It is tolerant of poorly drained soils and but prefers relatively fertile loams. The presence of bees is important
to sustain adequate yield and if possible production should be coupled with a commercial honey producer.

The mustards are more widely adapted than canola and will out yield it in lower rainfall areas (350 mm or less). Like canola, loamy, relatively fertile soil is preferred. Shorter growing lines especially for the white mustard are the preferred type for harvesting. They are relatively non-shedding compared to Canola and can be directly machine harvested.

Camelina, despite its small seed, nevertheless establishes quickly on a range of soil types and rainfall regimes in southern Australia as a winter-sown crop. It is frost resistant. Our research indicates an adaptation to sandy soils not favored for the production of canola or the mustards.

Linseed is well adapted to southern Australia over medium to high rainfall, but current cultivars tend to be later maturing than the other oilseeds. It has some special properties being tolerant of a much wider range of herbicides than the other alternative oilseeds. This is important, as good weed control is most import for a species which lacks early growth or seedling vigour. It is also far more tolerant of poor soil drainage than the Brassicas in this study.

Crambe grows aggressively in Southern Australia on both loams and sandy soil. It’s seedling vigour and spreading habit allows it to compete well with weeds and it is one of the easiest of the oil seeds to generate a vigorous crop. It retains its seed husk at harvest and in comprising some 50% the weight, makes transport over any distance an expensive exercise relative to the other alternative oil seeds.

**Varieties**

The emergent varieties are yet to be named. Current advanced generations include two selections of Camelina, an Indian (oriental) mustard selection, two Ethiopian mustards and a golden linseed.

Seed of Niger is commercially available. As of the end of 2004 commercial quantities (sufficient seed for 100 hectares plus) of Camelina, Indian and Ethiopian mustards are planned to be available to interested parties. Similar quantities of the golden linseed selection would be available in the following year.

**Crop agronomy**

Seed yields confirmed the highly variable nature of the harvestable yield of the oil seeds. This is a consequence of the diversity of environments chosen for the preliminary yield trials and the fact that oil seeds are sensitive to biotic as well as edaphic and climatic factors. The poor yield of canola sown at 5 kg/ha near Meckering in 1999, reflected aphid damage on the one hand whilst the sandy relatively infertile soil of this site produced a low yield of all species. Crambe is vigorous and well adapted, but yields (seeding rate 15 kg/ha of husked seed) include the pod husk, which does not separate from the seed on harvest with conventional machinery so that actual seed yield, is some 50% of the figure in table 1. Amongst the species it was the most prone to shattering and the yield figure

### Table 3. Alternative oilseeds mean yield (kg/ha)

<table>
<thead>
<tr>
<th>Species</th>
<th>Niger</th>
<th>Camelina</th>
<th>Linseed</th>
<th>Crambe</th>
<th>Borage</th>
<th>Canola</th>
<th>Ethiopian Mustard</th>
<th>Indian Mustard</th>
<th>White Mustard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed yield (kg/ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northampton 1999</td>
<td>300</td>
<td>167</td>
<td>1761</td>
<td>902 *</td>
<td>396</td>
<td>1,428</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meckering 1999</td>
<td>60</td>
<td>188</td>
<td>592</td>
<td>715 *</td>
<td>455</td>
<td>197</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Miling 2000</td>
<td>180</td>
<td>1940</td>
<td>1850</td>
<td>2535 *</td>
<td>95</td>
<td>1883</td>
<td>2486</td>
<td>2755</td>
<td></td>
</tr>
<tr>
<td>Wagin 2000</td>
<td>56</td>
<td>1290</td>
<td>952</td>
<td>1438 *</td>
<td>99</td>
<td>850</td>
<td>1777</td>
<td>2330</td>
<td></td>
</tr>
<tr>
<td>Miling 2001</td>
<td>1000</td>
<td>1590</td>
<td>1900 *</td>
<td>55</td>
<td>2460</td>
<td>1900</td>
<td>2350</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Wagin 2001</td>
<td>1015</td>
<td>700</td>
<td>1700 *</td>
<td>68</td>
<td>Shatter</td>
<td>1200</td>
<td>2370</td>
<td>830</td>
<td></td>
</tr>
<tr>
<td>Northam 2001</td>
<td>820</td>
<td>730</td>
<td>1220 *</td>
<td>830</td>
<td>870</td>
<td>1110</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Merredin 2001</td>
<td>1920</td>
<td>440</td>
<td>1840 *</td>
<td>1540</td>
<td>1210</td>
<td>1340</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mingenew 2002</td>
<td>590</td>
<td>210</td>
<td>660 *</td>
<td>780</td>
<td>710</td>
<td>550</td>
<td></td>
<td>666</td>
<td></td>
</tr>
<tr>
<td>Mingenew 2003</td>
<td>1050</td>
<td>1300</td>
<td>1870 *</td>
<td>1390</td>
<td>1310</td>
<td>1440</td>
<td></td>
<td>690</td>
<td></td>
</tr>
<tr>
<td>New Norcia 2003</td>
<td>420</td>
<td>1,300</td>
<td>1630 *</td>
<td>2130</td>
<td>2190</td>
<td>2020</td>
<td></td>
<td>850</td>
<td></td>
</tr>
<tr>
<td>Best yield</td>
<td>729</td>
<td>2360</td>
<td>2003</td>
<td>2685 *</td>
<td>455</td>
<td>2460</td>
<td>2746</td>
<td>2755</td>
<td>890</td>
</tr>
</tbody>
</table>
is likely to be conservative. With crops new to the Mediterranean environment, more research is needed on optimisation of seeding rate, harvesting methods, weed control strategies and time of sowing. Despite the limitations of the field trials, it is nevertheless clear that both linseed on poorly drained soils and Camelina (on deep sandy soils) can be the equivalent or better in yield than canola. There is every indication that Indian and Ethiopian mustard are capable of out yielding canola as they did quite significantly (p < 01) at the two lower rainfall sites sown in 2000. The non-shattering character of the mustards obviates the need for windrowing and is an important cost saving ($25/ha) advantage.

The yields of the small seeded Camelina sativa were particularly promising at recommended seeding rates of 4 kg/ha. Although in this case not significantly better than canola, the figures do indicate that, particularly on sandy soils, the species has significant potential. Given that there was no real basis on which to select from the available restricted germplasm base for this species, it is well worth more intensive investigation with additional genotypes now at our disposal. Where blackleg is a problem, it maybe that Camelina could prove to be a highly profitable cleaning crop given the attractive qualities of its oil in terms of its potential food quality and health benefits.

The Borage selections used were local garden types. It did not yield well even when hand harvested in quadrats. This is not to say other higher yielding lines might not be found. The species however is an obligate out crossing species and thus needs bees. It will as a consequence always be highly variable in yield. A more important difficulty is the highly shedding nature of the seed head whereby the seed begins to shed well before the stems and branches are mature. This will mean heavy yield loss with conventional harvesting even when windrowing is employed. It can be expected that Echium would encounter the same problems. Losses of more than 60% are reported in USA (Simon et al 1990). Despite its valuable oil profile in terms of its gamma linolenic acid content, its yield is always likely to be unreliable and difficult to harvest. However if prices are anything like those in USA (around US$3.20 kg), it may still find a niche market as it has in the UK where it is a regular part of the rotation of some farms (Nicholls 1996).

Niger was not adapted to the colder winters at most sites but the normally frost-free environment of Northhampton (729 kg/ha yield) showed that there is some potential for a winter rainfall crop. Such a yield is consistent with average yields (approximately 500 kg/ha in the centers of its cultivation in Ethiopia, Nepal and India (Getinet and Sharma 1996). Some cultivars are reported by these authors to have a margin of cold tolerance. Such lines are to be found from the highlands of Ethiopia or Mid-Hills of Nepal. Being a cross-fertilised species, bees are important and were in abundance at Northampton. Depending on the premium for the oil and the high value, albeit restricted birdseed market, further evaluation of the now extensive gene base is indicated in the subtropical areas of Australia as a winter sown crop in Northern Australia or as spring-sown crops in the winter rainfall areas where supplementary irrigation may be available.

Farmer groups like the Western Australian No Till Farmers (WANTFA) see alternative crops suitable for no till agriculture as environmentally friendly. The Mustards, Camelina and Crambe are well suited to no till farming as has been demonstrated at the farmer group field days. Fertiliser requirement can be closely aligned with those for canola. The lack of Triazine resistance now so popular with Canola growers is however a disadvantage in no till systems which in fact are often dependent on the use of herbicides.
No adverse changes to the farming environment are foreseen. A potential benefit is a weed-inhibiting (allelopathic) characteristic reported for Camelina, a useful character if it applies to common weeds in our agricultural areas. It is known as a minor weed in flax but not recorded as a problem in other crops. It does not have seed dormancy.

**Pests and disease control**

Blackleg, *Leptosphaeria maculans*, is the most serious soil borne disease of the Brassicas. Rotation, sowing onto clean land and resistance are the only practical controls. The new mustards and Camelina are far less susceptible to black leg than Canola. This is especially the case with Camelina and the Ethiopian mustards, which appear immune. This provides the opportunity for shorter rotation than currently practiced for Canola to be used should they prove profitable.

Canola and the mustards are susceptible to attack by diamond back moth (*Plutella xylostella*) the caterpillar stage of which attacks both the leaves and developing fruit. Again the mustards, especially Ethiopian mustard, are less susceptible than commercial Canola varieties. Insecticides containing cypermethrin are proving useful in Canada. The use of synthetic pyrethroids is not proving very effective and resistance can quickly develop occasioned by the frequency of spraying necessary to control the caterpillars.

Aphids are an occasional problem with all the species but again the mustards, perhaps related to the spicy glucosinolate levels, are less prone to attack. Recommended sprays like Pirimor will greatly reduce the infestations whilst remembering that spray and application cost $15–25/ha and if used too frequently, development of resistance may prove a problem.

**Harvest and handling**

With the exception of Matthiola, all the winter growing oil seed crops can be direct headed with conventional machinery provided the harvest is timed to be as soon as the crop is ripe. For the mustards the screens and machinery settings should be as for Canola whilst finer screens may need to be on hand for the small seeded Camelina. Delays can result in harvest losses in the Indian mustard lines and Camelina is also prone to seed loss and sometimes lodging if harvest is delayed. Despite the vigilance needed, the harvesting does represent a cost saving on the need to swath. Of the oilseeds under test the maturity ranges over one month from early November to mid December.

Matthiola, a perennial, may not set seed until year two although the varieties selected for further evaluation have all produced seed in their first year of production albeit somewhat late in the season (mid January)

The large scale crops can be delivered in bulk or packaged in bags for container shipment. Oil milling would of course relate to bulk and subsequent package in bottles for market of Camelina or mustard oils. Species with a high value health food market, such as linseed, would normally be in sealed bags. The product would then be repackaged by the health food chains. The oil of this species for health food use needs to be

**Table 4. Approximate maturity of lines available**

<table>
<thead>
<tr>
<th>Species</th>
<th>Approximate maturity, Miling, WA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oriental mustard</td>
<td>Early November</td>
</tr>
<tr>
<td>Camelina</td>
<td>Mid November</td>
</tr>
<tr>
<td>Early Canola (Karoo)</td>
<td>Late November</td>
</tr>
<tr>
<td>Crambe</td>
<td>Mid November</td>
</tr>
<tr>
<td>Ethiopia mustard</td>
<td>Early November</td>
</tr>
<tr>
<td>White mustard</td>
<td>Early December</td>
</tr>
<tr>
<td>Golden linseed</td>
<td>Mid December</td>
</tr>
<tr>
<td>Matthiola</td>
<td>January</td>
</tr>
</tbody>
</table>
encapsulated due to instability resultant from the high level of Omega 3 fatty acid or after careful cold pressing, kept refrigerated in dark bottles. If the ultimate use is for furniture oil or cricket bats such a precaution is of course unnecessary.

**Financial information**

Start up costs of mustards or Camelina can be closely equated with a TT canola for bulk trade. Such comparison, as in the table, must however be treated with caution as the price may well depend on the scale of production. It is unwise to compare profitability of an initially small crop like Camelina or golden linseed initially perhaps a few hundreds of tonnes with larger crops of 500,000t like canola. The results may also be soil type specific.

The table is constructed based on a medium rainfall 350 –500 mm rainfall canola growing area in WA. Mustards may well be more profitable than Canola in drier areas and on wet soils linseed is likely to be relatively more profitable. The important issue is however that a range of oilseeds can be grown profitably provided the markets are in place.


For Camelina and the linseed which might be handled in bags the freight and handling is estimated at $50.

Table 5: Estimated costs and gross margins for some of the alternative oilseeds and canola

<table>
<thead>
<tr>
<th>GROSS INCOME</th>
<th>Treatment</th>
<th>Oriental mustard</th>
<th>Golden linseed</th>
<th>Golden linseed organic</th>
<th>Camelina</th>
<th>Canola</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain yield (Net price/t)</td>
<td>1.5 t/ha @ ($290)</td>
<td>0.80 t/ha ($450)</td>
<td>0.60 t/ha ($1400)</td>
<td>1.0 t/ha ($430)</td>
<td>1.4 t/ha @ ($340)</td>
<td></td>
</tr>
<tr>
<td>Total Income /ha</td>
<td>$435</td>
<td>$360</td>
<td>$840</td>
<td>$430</td>
<td>$476</td>
<td></td>
</tr>
<tr>
<td>VARIABLE COSTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed</td>
<td>20.00</td>
<td>60.00</td>
<td>60.00</td>
<td>25.00</td>
<td>24.75</td>
<td></td>
</tr>
<tr>
<td>Fertiliser</td>
<td>Agstar</td>
<td>43.50</td>
<td>43.50</td>
<td>43.50</td>
<td>43.50</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Urea</td>
<td>38.50</td>
<td>38.50</td>
<td>38.50</td>
<td>38.50</td>
<td></td>
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<td>$496 /ha</td>
<td>$152 /ha</td>
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Key references


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Introduction

The advent of machine harvesting triggered the reestablishment of the coffee industry in Australia in the mid 1980’s and the Australian industry is now making its mark on domestic and export markets. However, continued investment is required to maintain a high quality and consistent product capable of competing successfully in a highly competitive world market.

Coffee growing in Australia appears an attractive proposition at first glance. We import virtually all of our 48,000 tonnes of raw coffee (called dry green bean (DGB)) into a domestic market worth over $600 million; we can produce a distinctive high quality Arabica coffee suitable for the rapidly growing roast and ground market which has grown by 28% over the last 5 years; we do not have the major pests and diseases of other coffee producing countries, and can therefore produce a “clean” product; we have drastically reduced our production costs by harvesting mechanically; and we have enjoyed a price premium (over double the world price) on our domestic market.

However, as the production volume increases there are significant issues facing the industry as our product starts to compete in the highly competitive world coffee market. Australian producers will have to overcome industry fragmentation and become highly efficient in their production costs and produce an internationally accepted grading system and specifications if they...
are to be successful in the long term. Whether the price premium can be maintained will depend on the ability of the Australian industry to produce a consistent high quality product and the success of marketing strategies to exploit the comparative advantages and market opportunities for the “new” product. A price premium is seen as essential for the viability of the Australian industry.

There are now four coffee growing regions in Australia – the tropical tablelands of Far North Queensland, the central Queensland coast, subtropical south-eastern Queensland and north-eastern New South Wales (see Table 1).

Australia imports around 12,000-15,000t of Arabica coffee annually for the Roast and Ground market. Australia's total production of 500t DGB (dry green bean) in 2002 is only 1% of the total volume of coffee imported or 6% of the total volume of Arabica imports.

### Markets and marketing issues

The world coffee market is enormous. Almost 8 million tonnes of the raw product, Dry Green Bean is traded annually, worth over $US10 billion with a retail value (roasted) of over $US50 billion.

At present the world is awash with cheap coffee, largely Robusta and low quality Arabicas. As a result of continuing unsustainable prices, in order to survive, many producing countries are improving the quality of their coffee to target the upper, ‘boutique’ or gourmet end of the market where price premiums are significant. Specialty coffees such as single origin, shade grown, 'Rainforest Alliance', ‘Fair Trade’ and various accredited organic and ‘natural’ grown coffees are attracting price premiums because of their social and environmental appeal. This category is gaining momentum internationally, but from a very small production base and it is this expanding but highly competitive market that Australia’s fledging industry has the capacity to target in both the domestic and export markets. Our ‘disease free’ status and natural production systems already in place are attractive comparative advantages which could be exploited in marketing Australian coffees on the world market.

Competing in this market will not be easy and Australia faces major challenges with its very small production volume (500t) and a fragmented industry. Gaining credibility as a reliable and consistent supplier is paramount in this highly competitive international market. A few larger producers in Australia have already successfully initiated export development programs through brokers to Europe, Japan, USA, New Zealand and Hong Kong.

The current rate of growth in demand for Roast and Ground coffee in Australia is 6%. This equates to approximately 1,000t of extra volume each year for Arabica coffee on the Australian market. This volume far exceeds the expected total Australian production in 2007/08 of just 1,600t.

Australia’s domestic market is still highly attractive for high quality Australian grown Arabica.

### Key statistics

**Australian production**
- Qld – 400t
- NSW – 100t
- Exports – 100t
- Imports – 48,000t

**Key messages**
- Machine harvesting essential
- Highly competitive world coffee market
- Premium prices essential for viability
- Attractive domestic market for limited supplies
- No major pests or diseases.
- International grade specifications required

<table>
<thead>
<tr>
<th>Region</th>
<th>Area Planted (ha)</th>
<th>No. of Growers</th>
<th>Production of Dry Green Bean (DBG) 2002</th>
<th>Expected Production of DGB in 5 years 2007/8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Far North Queensland</td>
<td>350</td>
<td>10</td>
<td>300</td>
<td>800</td>
</tr>
<tr>
<td>Central Queensland</td>
<td>120</td>
<td>4</td>
<td>85</td>
<td>250</td>
</tr>
<tr>
<td>South-eastern Queensland</td>
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<td>10</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>North-eastern NSW</td>
<td>250</td>
<td>120+</td>
<td>100</td>
<td>500</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>740ha</strong></td>
<td><strong>144+</strong></td>
<td><strong>495t</strong></td>
<td><strong>1,600t</strong></td>
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</table>
Coffee. A standard price of $8-$9/kg DGB has operated for over 10 years, compared to the average price for imported high quality Arabica of $3-$5/kg DGB. As production increases over the next five years these price premiums will be challenged.

Internationally, coffee is traded as Dry Green Bean (DGB) as a commodity, and prices are set in New York based on an international grading system. The NY commodity price sets the price for all trading around the world; however individual sellers, brokers, buyers and roasters will negotiate the price for individual lots based on its quality versus the benchmark of the NY stock price.

The negotiated price for individual lots of DGB coffee is based on a sample of coffee supplied to the buyer. Price is determined by the quality of the sample on visual appearance and the number of defects (size of bean, colour, broken beans, extraneous matter, etc) and the cupping quality.

Currently most of the locally produced coffee from smaller producers is ungraded and sold within the region through local roasters and labels directly to retail outlets. Trading of DGB and roasted coffee outside the region is being undertaken by the larger producers who are exploring new domestic and export markets as supply exceeds local demand.

**Production requirements**

Coffee originated as an understorey plant in the highland tropical rainforests of Ethiopia. These areas are frost-free, have mean daily temperatures of 20°C and an average annual rainfall of 1800-2000mm well distributed but with a dry season of 3-4 months. The important factors in site selection in Australia for coffee production based on machine harvesting are as follows:

**Temperatures**

The cultivars grown today in Australia prefer a relatively mild frost free subtropical climate with mean temperatures between 15°C and 25°C and as a consequence coffee does well in elevated tropical areas. Temperatures below 7°C and above 33°C slow growth and reduce production. Small diurnal variations in temperature (that is day/night) are also preferred. Coffee is highly susceptible to frost and even short periods below 0°C will defoliate the bush.

**Rainfall**

The rainfall pattern is probably one of the most critical requirements in the choice of a suitable site for coffee production based on mechanical harvesting. For machine harvesting to be successful a reasonable synchronisation of flowering and fruit ripening is required. The rainfall and irrigation pattern control the flowering pattern to a large extent. In Far North Queensland with a reliable dry season during flowering
(winter/spring) and where there is irrigation, flowering can be controlled by deliberately water-stressing the trees and then heavily irrigating. Controlling flowering is not practical in the subtropics because of the lack of a distinct dry period and the extended maturity period for coffee on the tree. A reliable dry season and cool temperatures during fruit ripening (winter for Far North Queensland and spring for the sub-tropics) are also required to aid machine harvesting (see Figure 1). Wet and warm conditions during fruit ripening can dramatically reduce harvested yields (because of fruit drop). For the rest of the year reasonably well distributed, high rainfall is preferred. This allows for good fruit growth and the development of large beans. Good irrigation can overcome the need for high rainfall.

**Soil**

The soil needs to be well drained and aerated, as coffee does not tolerate waterlogging. A free draining depth of at least 0.5-1.0m is preferred. Where coffee is grown on more fertile volcanic soils, irrigation and fertilizer management is much easier than on sandy soils.

**Altitude**

Overseas literature recommends an altitude of 900-1200m for arabica coffee cultivation. However, this altitude really relates to suitable temperature and rainfall patterns. Research in Australia and growers' experience has shown that good quality coffees can be grown at altitudes from 15-900m and the higher latitudes of the sub-tropics above frost level.

**Slope**

Flat ground is preferred for machine harvesting, but hydraulic levelling on the machine allows it to harvest up and down slopes of up to 15% and side slopes of up to 6-8%.

**Shade**

Shade is not required for coffee production. Where adequate nutrition and irrigation are provided, yields are greater without shade.

**Wind**

Coffee trees are very sensitive to wind damage which can severely reduce productivity; therefore, windbreaks are essential. Wind can cause ring-barking in young trees and also cause them to lean over, which interferes with the harvester.

Given these climatic requirements many areas along the Queensland and Northern New South Wales coast are suitable for coffee production.

**Varieties**

Initial plantings were based on the local cultivar Kairi Typica and Bourbon, Arusha, Caturra and Blue Mountain imported from PNG. Yields were disappointing with only 0.5-1 t/ha green bean. Some newer cultivars have now been evaluated by QDPI and NSW Agriculture. The recommended cultivar for North Queensland is Catuai Rojo, because of its high yield and quality, dwarf stature and late maturing time. For the cooler subtropical areas of Southern Queensland and Northern New South Wales, K7 is preferred for the warmer sites and a local selection CRB is suitable for cooler locations. These varieties produce high yields of good quality, large beans and are tall growing.

**Agronomy**

Being highly self-pollinated, coffee is propagated by seed and therefore does not need grafting. To avoid the risk of “off-types” resulting from cross-pollination, seed should be selected from proven trees in blocks of the one variety. Seedlings are available from...
specialist nurseries, particularly for mechanical planting. However, most growers raise their own seedlings. Seed is available from existing growers or the QDPI.

Seedlings are raised in seed germination beds under 50% shade and then transplanted into polythene planting bags at the 2-3 leaf stage. Seed takes 4-8 weeks to germinate. The plants are then gradually sun hardened and are ready for field planting at 20-30cm tall in about 8-12 months. Some growers have planted seedlings bare rooted from seed beds to reduce costs. Planting is usually carried out at the start of the wet season.

Trees are planted in hedgerows for ease of machine harvesting, weed control, fertilising, irrigating, spraying and mowing. Trees are spaced between 0.75m and 1.0m apart within the rows and 3-4m apart between the rows (depending on the cultivar and the climate). This gives plant densities of 2500-4400 plants/ha. A ground cover is usually established between the rows to reduce erosion.

Before planting the ground is usually deep ripped and cultivated along planting lines. Trees are planted into mounds (30-40cm). It is important that rocks, sticks and stumps are cleared from the field to enable the harvester to operate smoothly.

Windbreaks should be established before field planting, as trees are sensitive to wind damage. *Pinus caribaea* and Bana grass (*Pennisetum* spp.) have been used successfully as windbreaks in Far North Queensland. In the subtropics Sorghum provides excellent protection for the first two years when planted within 1m of each coffee row on the windward side.

Coffee trees are fairly slow to establish in the field for the first 12-18 months because of inherently slow growth rates and poorly developed root systems. Therefore weed control in the early establishment period is critical. The planting rows should be mulched and kept weed free 50cm either side of the plants. Pre-emergent and post-emergent herbicides are used but young trees are sensitive to spray drift.

Once trees are established heavy shading from the trees canopy reduces the need for herbicides. Some problems have been experienced with climbing vine weeds (eg. *glycine* (*Glycine clandestina*) and *sirato* (*Macrotilium atropurpureum*)). Trees start to crop after 2 years but cannot be machine harvested until 3 years of age (because of size). Full production is not reached until year 4 or 5. Yields of 1.5-2.0t/ha dry green bean (DGB) could be expected in Far North Queensland and up to 2.3t/ha in the subtropics.

Coffee trees grown intensively under full sun have a very high nutrient requirement. Before planting, fertilisers are incorporated into the planting strip (especially phosphorus) and soil pH is adjusted to 5.5-6.0. Fertiliser is then banded along the rows at 4-6 week intervals. As trees come into full production (year 4 and 5) 300-400kg of N and K/ha and 15kg P/ha are needed. Foliar fertilisers are often applied in times of peak need. Common nutrient deficiencies experienced in Australia have been Zn, Fe, Cu and Mg. Fertigation is proving cost effective in supplying the required nutrients to the coffee plant with minimal waste. Special mixes have been formulated for use in coffee.

Coffee requires a plentiful supply of water all year round except during the late stages of floral development (September-November) when a period of water stress can be used to manipulate flowering in far north Queensland under tree and overhead irrigation have been used. Overhead irrigation has been used to protect young trees from frost on small plantations. The irrigation requirement is around 3-7ML/ha/year. Under subtropical conditions monitoring moisture...
use by the tree using hand held electronic sensors is recommended to assist in scheduling irrigation according to plant needs. Yield increases of 25% have been achieved with strategic irrigation as well as an increase in bean size. Irrigation requirements of 1-2ML/ha/year have been required under subtropical conditions. Full details of research results are available from the RIRDC project publication titled ‘Irrigation of Coffee in the Subtropics – Best Management Guidelines’.

**Pest and disease control**

Australia is fortunate to be free of the two most serious and widespread coffee diseases, coffee berry disease and coffee rust. Coffee trees in Australia have only a few pest and disease problems and these are not serious. Green coffee scale (*Coccus viridis*) and mealy bug (*Planococcus spp.*) are the two most common pests. Both attach themselves to leaves and young branches and draw nutrients from the tree. In large numbers they cause a general decline in tree health, affecting yield. Ants are often associated with scale and mealy bug infestations. Sooty mould grows on the sticky residues produced by the scale and mealy bugs and covers the leaves reducing photosynthesis; this also contributes towards the decline in tree health. In warm, dry environments, scale and mealy bug can become widespread and may need to be controlled chemically. White oil, refined water miscible oil and Lorsban (in Queensland only) have been used successfully.

Research trials have shown that where there are only minor infestations, natural predators (parasitic wasps) and the disease (*Verticillium*) usually keep populations under control. In the subtropics natural predators and good management (nutrition and irrigation) are usually adequate to control these pests. Control spraying with paraffin oil may be required for heavy infestations.

The only significant disease in coffee trees is cercospora (*Cercospora coffeicola*), a fungus which causes leaf spotting and defoliation and attacks fruit, causing premature ripening. It is most prevalent in warm wet weather, in nurseries and early field establishment, usually where nutrient levels have not been adequately maintained. In severe attacks repeat sprays of foliar copper will control the fungus.

**Harvesting and processing**

The harvester is a large self propelled three or four-wheel machine which straddles the rows of coffee. Within the harvester frame are two vertical shafts which carry hundreds of fibreglass fingers (40-50cm in length). The fingers vibrate and rotate through the bushes as the harvester moves forward down the row (3ha/day). The fruit is dislodged from the branches by the action of fingers and is caught on a catching frame which transports the fruit to storage bins on the harvester.

An Australian developed (QDPI) coffee harvester is now commercially available (manufactured by CASE International in Brazil) and the American built Korvan harvester is the latest machine currently in operation in Northern NSW. Other machines for use on smaller plantings and steeper land have been evaluated, including a tractor drawn harvester and hand held harvesters which remove cherries from individual branches. But these have not proved very successful. High labour costs generally make it uneconomic to harvest coffee by hand ($6/kg vs. $0.60/kg for machine harvesting).
As ripening commences, the coffee fruit changes from green to red, then to dark red-purple and eventually black when over-mature. There are two processing methods to obtain green bean which is used for roasting, both require specialist processing equipment including a mechanical drier. The simplest method is ‘dry processing’ where coffee is harvested over ripe and then dried to 10-12% moisture. The dried skin and parchment is then removed by hulling, leaving green bean coffee. This method is commonly used to process robusta coffee and produces a lower quality product than ‘wet processing’. In wet processing, coffee is harvested as ripe red fruit. The fruit is pulped to remove the two seeds from the skin (Figure 1). The seeds are then fermented or passed through a demuscilager to remove the sticky mucilage layer around them and then washed and dried to 11% moisture. The parchment and silver skin are then removed by hulling and polishing, leaving green bean coffee. The bean is referred to as ‘green bean’ because of its colour. It normally takes between 6-7kg of fruit to produce 1kg of green bean coffee. This method of processing produces the best quality coffee. Most of the coffee produced in Australia is processed using the ‘wet’ method. The problem with this method has been that all immature green cherries must be removed to produce top quality coffee.

When machine harvesting is used (as opposed to hand-harvesting), cherry samples for processing often include various amounts of over and under-mature fruit as well as mature ripe, red cherry. These samples when processed using traditional processing equipment produce very poor quality coffee.

Until recently this was the major problem of the newly established Australian coffee industry. New processing systems have now been developed. One developed by QDPI uses floatation, size grading and selective tyre pulping to separate fruit of different maturities, so that top quality coffee can be produced even from samples with mixed fruit maturities. Another system being imported uses a cherry classifier which separates cherry of different maturities by selectively pulping fruit through a screen. Care must be taken not to pollute the environment from the waste produced in the factory.

Coffee growers usually process their coffee to the dry green bean stage. Equipment to colour sort and size grade is required for this. The green bean is then sold to processors for blending and roasting. However, some of the Australian growers roast, grind and package their own coffee and do some of their own marketing. Quality is assessed by bean size, freedom from defects and liquor quality. Prices are significantly better if you sell the bean as speciality or gourmet coffee. No central marketing group body or co-operative exists so individual growers must develop individual marketing plans. There have been some attempts at group marketing, although these have not been very successful.

Coffee harvester showing the vertical shaker shafts (inset). The fibreglass fingers remove the cherry by vibrating within the canopy. Cherry is collected and conveyed to a storage bin on the side of the harvester.

The ten stages of coffee cherry ripening from immature (green) to over-mature (black)
Financial information

An economic assessment of coffee production in North Queensland was undertaken (Hosegood et al 1988, Hosegood 1991 and Hassall and Associates 2004). These economic studies estimated farm profitability for machine-harvested coffee, establishment costs, rates of return and break-even yields and prices.

Hosegood investigated the profitability of a new 20ha plantation and a 10ha plantation on an existing farm, with both farms using contract harvesting.

Both studies found that these plantations were marginal for the yields and market prices at that time.

The conclusion from those reports was that a yield of 2t green bean/ha and a price of $4/kg are required to make coffee production profitable.

In the report by Hassall and Associates, they found a 20 ha plantation required a capital outlay of $410 000 (year 1). Establishment costs were around $10 000/ha and operating costs $3000/ha (year 2 & 3 ) and $5000/ha thereafter. Using a yield of 1.6 t/ha and $6/kg they found an internal rate of return of 13 %.

For the subtropics the following budget summary is based on the costs and returns of establishing and growing 1ha of coffee on the North Coast of New South Wales.

The study by Planning and Management Project Pty Ltd (1999) was sponsored by RIRDC. The report estimated establishment costs at $22,000/ha; this includes a technology fee, land preparation, irrigation, seedlings and planting. If the technology fee is removed industry leaders indicate this figure may be reduced to $15,000/ha (or $5/tree at 3000 plants/ha).

Maintenance costs were $5,000/ha, harvesting (contract) costs were $1,200/ha, and processing (contract) costs were $2,300/ha. A yield of 1.15t/ha in year 4 and 2.3t/ha from year 5 on with an 80% recovery was used. A selling price of $8/kg for DGB was assumed. This study estimated a gross margin of $2,300/ha, which rises to $3,600/ha if the reduced establishment cost is used.

First commercial yields are expected in the third-fourth year after transplanting. Full commercial yields are expected five years after transplanting where conditions are good. Some form of tree rejuvenation (pruning) will be required in years 7-10, depending on variety, to maintain the trees in a productive and manageable state for harvesting.

There is a reduction in yield in the year following pruning. Stumping (pruning to 30cm above ground level) may be required after year 10 depending on climatic conditions, production history and management. No production occurs for two years after stumping, which should be done on a rotational block basis to maintain cash flow.

Key references


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James Drinnan (B.Agr. Sc., Ph.D.) is a Senior Horticulturist, Queensland Department of Primary Industries, Centre for Tropical Agriculture, Mareeba. In his 10 years of coffee research James studied the physiological aspects of coffee production, including flowering behaviour, water relations and growth patterns. In 1992 he completed a Ph.D. on coffee flowering at the University of Queensland.

David Peasley, (WDA) is a Horticultural Consultant based in Murwillumbah. Since 1984, David has evaluated coffee varieties, harvesting systems and irrigation strategies for coffee in the subtropics. He organised the first coffee marketing summit in 1990 to determine the market potential for Australian coffee and has undertaken overseas consultancies on coffee. He is Chair of the Australian Coffee Industry R&D Advisory Council.

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Coffee
Japanese green tea

Audrey Gerber

Acknowledgement is given to Ange Monks, the author of this chapter in the first edition of this publication.

Introduction

Green tea (Camellia sinensis var. sinensis) is traditionally consumed in Japan as a beverage renowned for its health giving properties. The Japanese market represents approximately 20% of the world green tea market. In recent years the per capita consumption of traditional green tea has declined, forcing companies to investigate alternative marketing strategies to attract the younger generation. Significant growth has consequently occurred in the canned beverage market which now occupies close to 15% of the market. In addition, the individual components in green tea are undergoing analysis and extraction to assess their potential for use in cosmetics, as nutrition supplements, as flavours and fragrances and as disease cures and preventatives.

Projected consumption in Japan of green tea as a beverage vastly outweighs potential domestic production. Consequently many Japanese companies are sourcing production outside Japan. Japanese markets for green tea however are very demanding and high quality product is required.

Traditional bulk agriculture markets such as Africa and China are considered unsuitable due to inferior tea quality. Australian agribusiness has a reputation among Japanese markets for professional management and high quality products.
Research and development programs funded by RIRDC have been carried out over many years in Tasmania and elsewhere and interest in R&D on this crop has come from a number of states over the years. Commercial green tea production in Australia currently takes place in NE Victoria, initiated by the Japanese beverage marketing company, Ito En. Ito En perceives a rapid and continued increase in the demand for prepared green tea sold in PET bottles or cans by vending machines in Japan.

Investigation by company sponsored agronomists indicated that the climatic conditions of NE Victoria are suitable for commercial production of Japanese style green tea. The significant progress of the green tea industry in Victoria can largely be attributed to the contribution of the Australian Green Tea Growers Association (AGTGA), assisted by Commonwealth funding. In addition, Ito En Australia Ltd has a strong financial and personal commitment to the growth of a sustainable industry.

Interest in green tea production is increasing in Western Australia and New South Wales due to the attention of another Japanese company seeking to develop the crop in Australia. The Manjimup and Pemberton area in Western Australian and the area inland from Gosford are considered suitable. In both areas commercial plantings have yet to occur, although production of rooted cuttings and assessment of suitable areas is occurring in anticipation.

Green tea production for the Japanese market is an intensive horticultural enterprise. Once established, plants can continue to produce commercial harvests for 30 years. During the establishment phase, however, maintenance of the young plants is labour intensive. In order to optimise economies of scale a 10 ha production unit is considered economically viable. To manage this size unit mechanical production techniques are required. The opportunity exists, and is being implemented in NE Victoria, for neighbouring farms to share equipment.

Markets and marketing issues

Japan currently consumes approximately 100,000 t of green tea per annum, 90,000 t of which are produced domestically. The balance is imported and any future expansion of consumption in Japan must be met by an increase in imports as domestic production cannot expand.

In the current situation green tea produced in Australia is designed for Japanese markets. The fresh leaf will be processed locally into crude tea and shipped to Japan for final grading, blending, further processing where required, and packaging. A processing factory requires significant capital to establish and run. Consequently fresh leaf is the marketed commodity and it is unlikely that individual farms will process the fresh leaf and market a finished product.

Small-scale production for niche domestic markets may be possible using mini-processors designed for experimental work. Established black tea companies in Australia have begun marketing green tea, based largely on imported product.

Current commercial plantings in Australia consist of 50 ha in NE Victoria with the first harvest due in spring 2004. Strategic planning within the industry aims at a total of 250 ha planted by the end of 2006. Projections of Japanese consumption indicate that the leaf from 10,000 ha will be required within the next 10 years to fill Ito En’s markets. Other Japanese companies are also showing interest in Australian production of green tea to fill projected market expansion.

Key messages

• Domestic consumption of Green Tea in Japan exceeds production
• Market growth requires new production areas
• Japanese companies have confidence in Australian agriculture
• Traditional production techniques require modification for Australian conditions
• Minimum production size for economic viability
• Processing requires specialised equipment

Key statistics

• 50% increase in Japanese consumption expected over the next decade
• 50 ha commercial green tea currently established in Victoria
• 250 ha required in Victoria by 2006
• Market share of canned green tea to rise to 40 % of Japanese domestic consumption
Production requirements

Green tea plants require a period of cold induced dormancy to produce the chemical compounds which contribute to the health giving properties. A long summer growing season encourages shoot growth enabling repeated harvesting. Although the plant can withstand cold conditions during winter the young tissue is sensitive to frost, and early spring frosts will ruin the first harvest. High temperatures during the growing season may inhibit growth thus reducing yield. Plant growth in NE Victoria is considered satisfactory despite summer temperatures over 35°C.

Active growth occurs through summer and, unless summer rainfall exceeds 1,000 mm, irrigation is required. In the establishment phase (from planting to first harvest) more frequent irrigation is required due to the shallow root of the young plant. Preliminary estimates indicate that green tea requires 4-ML water per ha during the growing season. Drip irrigation is considered the most efficient system, although use of overhead sprayers may also be suitable. The latter tends to encourage inter-row weed growth.

Green tea plants require deep, well-drained acidic soils. A soil pH of 4.5-6.0 (H2O) is considered ideal, with a useable soil depth of 60 cm. The requirement of green tea plants for good drainage tends to suggest that gently sloping sites are ideal, however, provided soils are well drained, flat sites are also suitable. Steep slopes should be avoided due to manoeuvrability and safety issues involved with the specialised machinery required. Pruning or skiffing and harvesting techniques result in the formation of a continuous horizontal canopy thus eliminating the need for specific row orientation. In general north-facing slopes will provide a longer growing season, however, depending on local climate, the cooler conditions provided by south and south east facing slopes may be advantageous. Coastal areas may present problems with wind blown sand and spray causing damage to tea plants.

Varieties

Cultivars currently grown in Australia are Yabukita, Sayamakaori and Okuhikaori. Cultivars vary slightly in their growth rate and, therefore, time of harvest. This information is used, together with local climatic and topographic variation, to spread the harvest between farms in NE Victoria. This strategy enables equipment to be shared. The precise interaction of growth rate and harvest time with climate in Australia has yet to be quantified. Both Japanese companies currently interested in Australian green tea production have a number of other cultivars and seedlings undergoing trials for suitability to local conditions. Access to plant material is largely restricted to growers linked with specific companies.

Cultural practices/agronomy

Experience in Victoria indicates that standard site preparation a year before planting significantly reduces the weed problem experienced during the establishment phase. The use of appropriate herbicides or annual crops reduces the seed bank of weeds in the soil.

Where sub-surface compaction needs to be broken to facilitate root growth and drainage, deep ripping may be required. Soil analysis will indicate amendments needed prior to planting, eg pH amendment, phosphorous addition. For mechanical planters to operate effectively the surface soil must be light and friable. Equipment currently used for mechanical planting is either a modified vegetable seedling planter or a modified

Green Tea farmers in Victoria participate in training sessions and field days
tobacco planter. In both cases rooted cuttings in plug trays are manually fed into a feeder chute. Equipment is commonly shared between farms. Plant spacing is either 40 cm apart in single rows (14,000 plants/ha), or in double rows (22,000 plants/ha). Individual farm equipment directs the choice of planting density. Initial yields may be lower due to a longer time taken to form a complete canopy, but estimations are that mature yields will not differ with a lower planting density.

Young plants have shallow roots and require immediate watering following planting and frequent watering until established.

In Victoria planting is done either in spring when the soils are first dry enough to work or in autumn after the first rains (autumn break).

During the establishment phase weed control requires vigilant attention. Strategies vary between farms, depending on equipment available, but most use a combination of targeted herbicide treatment, manual removal and inter-row mowing.

Canopy management during the establishment phase involves repeated, well-timed pruning or skiffing.

New growth is cut back to promote branching which encourages the plant to form a low, spreading bush. A two-man hand held sickle-bar trimmer is suitable, although specialised ride-on equipment is available in Japan.

Nitrogen is required both to support the vigorous new growth that is harvested and to form leaf chemical compounds which contribute to quality. Fertilisation through irrigation lines enables targeted and well-timed nitrogen application for optimum growth while restricting run off or leaching. Phosphorous and potassium are also required as part of a balanced nutrition programme. Any fertiliser addition should be based on leaf and soil analyses.

The first harvest from green tea plants is possible four years after planting, leading up to a mature size harvest in the 6th year and every subsequent year.

Depending on plant vigour 3-5 harvests are possible in a growing season, spaced approximately six weeks apart from late spring/early summer. Harvesting is done mechanically using specialised equipment that straddles the plants.

DPI Victoria is currently managing a series of R&D projects, funded by HAL and Ito En, with the long-term aim of developing best practice management strategies.

Many of the current agronomic uncertainties relating to commercial production of green tea in Australia will be clarified to

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**About the author**

Audrey Gerber is an Industry Development Officer for the Primary Industries Research Victoria (PIRVic) branch of DPI Victoria, based at Ovens in North East Victoria. She works with New and Innovative Industries to identify barriers to industry growth and help to find ways to overcome them. The Green Tea industry and the Wildflower industry in Victoria are currently offered assistance. Roles include organising and presenting training sessions, managing and conducting R&D and promoting interaction within the industry.
climatic conditions in Australia are significantly different from Japan to anticipate that post harvest deterioration may differ in rate and pattern. Current practices in Japan need to be assessed and refined where appropriate. A transport and storage strategy suitable for Australian conditions is currently under consideration, investigating storage and transport under conditions of low temperature and high humidity.

Processing of Japanese green tea involves 6 steps and requires specialised equipment for steaming, rolling and drying. During this process the weight of tea reduces by 70-80%. A processing factory, financed and managed by Ito En Australia Ltd, will be established in NE Victoria in time for the first commercial harvest. The initial equipment has the ability to process the leaf from 130ha, and the factory will expand with additional units of equipment to keep pace with the anticipated growth of the industry.

Financial information
The key factors in an economic analysis are price and yield. Yield data from different sources varies greatly as does price, which is dependent on quality and market destination. Until this information is available from commercial green tea production in Australia any financial information is only an estimate. An economic analysis produced by Department of Natural Resources and Environment (now DPI Victoria) assesses cash flow scenarios of different combinations of price and yield. Yields ranging from 8.6 t/ha to 18 t/ha was matched with prices for fresh leaf of $1.17 /kg to $0.40 /kg. For economies of scale a 10 ha plantation was analysed.
The capital required for establishment of ten hectares of green tea is estimated at $130,000. This includes the purchase of general farm equipment (including a second-hand tractor), purchase and installation of irrigation equipment and fencing. It is assumed that the green tea buyer will supply specialised harvesting equipment. Annual running costs are higher in the first year (approximately $6,500/ha), decreasing to approximately $3,500/ha in year four and subsequent years. Owner/operator labour is costed at $15/hr.

**Key references**


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Olive oil

Susan Sweeney and Gerry Davies

Introduction

Olive oil is an international commodity. The development of a local industry must therefore be considered in an international context. Australia has the climate, physical resources, horticultural infrastructure and expertise to support a modern olive industry. However, other southern hemisphere countries also have the resources and have also started developing their own olive industries. In addition, the production resources are in demand by other horticultural industries within Australia.

Despite this, olives, particularly for oil production, have become a substantial horticultural industry based on existing domestic demand and the potential for the development of export markets.

The health benefits of olive oil and the continuing interest in Mediterranean cuisine, ensure that it is a popular choice for consumers across the world. Nevertheless, locally produced olive oil must be able to compete against other vegetable oils with similar chemical characteristics and alternatives, including imported olive oils, which may be cheaper.

Markets and marketing issues

Olive oil markets are dominated by Spain, Italy, Greece and Tunisia which account for approximately 85% of world production and a similar percentage of consumption.

World olive oil consumption has risen by almost one million tonnes over the past twelve years. The perceived health benefits, a continuing interest in Mediterranean cuisine and promotion by the controlling body...
of the industry, the International Olive Oil Council, are all stimulating market demand for olive oil, particularly in countries not traditionally associated with olive oil such as the USA and Japan.

In 2002/3, Australia imported 32,748 t of olive oil (30% extra virgin) valued at $139 million. The average annual growth rate of olive oil imports has been 17% for the past ten years in Australia. There are no accurate figures for local production of olive oil but it was estimated at about 1,500 t in 2003 (D. Taylor, pers. comm.). This figure will grow rapidly as the estimated 8 million trees planted in Australia in the last 10 years come into full production (Sweeney, 2002).

Strong local demand and the potential for exports have seen a renaissance in the Australian olive industry. It has been estimated that output from recent plantings can provide most of the demand for olive oil on the domestic market within five to ten years. It is important therefore for the local industry to quickly develop both the domestic and export markets for Australian olive oil.

The growth in interest in olive oil production is undoubtedly driven to some extent by the high prices ($22 to $65/l) which are currently being achieved by some locally produced oils. In contrast, lower quality imported oils are retailing at $8 to $12/l in supermarkets. This implies that the import price is around $4/l or less. Australian extra virgin oil either needs to compete with this low import price or differentiate itself sufficiently for consumers to pay a higher price.

A reasonable price, acceptable taste and reliable supply of sufficient volumes of consistent quality oil are all required to gain acceptance and shelf space in supermarkets. This is important in underpinning the growth of the industry.

Economies of scale and modern production techniques based on worlds’ best varieties and practices can place Australia in a strong competitive position. Even so, it must be recognised that there is competition from other southern hemisphere producers, and from other vegetable oils such as canola.

**Production requirements**

The olive originated in the Mediterranean region and will grow well in areas of Australia with a similar climate ie cool, wet winters and warm dry summers. They will produce in other areas as long as they have the correct chilling requirement (winter temperatures fluctuating between 1.5°C and 18°C) and summers long and warm enough to ripen the fruit. The trees can suffer severe damage at temperatures less than -5°C. Hot dry winds or rain at pollination in late Spring may reduce fruit set. As well, significant rain at harvest-time, may reduce the extractability of oil from the fruit due to the higher water content in the fruit. This appears to be particularly problematic for fruit normally grown for table olive production, such as Manzanillo.

The shaded areas on the map show regions in Australia with similar climatic regimes to traditional olive growing areas in Europe. There are other areas not indicated on this map where olives are grown successfully. However, long term economic viability is yet to be determined. Recent results from the National Olive Variety Assessment Project, funded by RIRDC, show that olives grown in the cooler, more southerly latitudes in Australia, produce higher levels of oleic acid in the oil, a positive
characteristic than olives grown in the more northerly latitudes of Australia.

Olives will grow in most soil types as long as they are well drained and have a subsoil pH range between 6.5 – 8.5. Steep slopes should be avoided if it is intended to use machinery, especially mechanical harvesters, which may not operate efficiently at slopes greater than 17°C (30%).

Tree spacing is generally around 250-300 trees/ha to optimise yield and light interception at maturity. Some growers are experimenting with higher density hedgerow plantings with the aim of increasing early yields and straddle harvesting the trees, much like wine grapes. These high density plantings require greater management input and as mentioned are still in the experimental stage.

Olives can be grown without irrigation but water stress will significantly reduce yields. Californian research has shown they need approximately 1000 mm of irrigation plus rainfall annually to produce maximum yields. Good yields are possible using less water but this requires careful irrigation management to ensure minimal water stress during critical growth stages.

**Varieties**

There are many different oil varieties available in Australia although DNA typing is showing that some varieties with different names are actually the same. Some of the more commonly known varieties include Arbequina, Barnea, Californian Mission, Coratina, Frantoio, FS17, Koroneiki, Leccino, Nevadillo Blanco, Pendolino and Picual. All have their own particular characteristics such as oil yield, organoleptic (taste and smell) characteristics, resistance to stress, productivity, tree vigour, time of ripening and ease of harvest and all of these characteristics should be thoroughly researched before a choice is made. Probably the best advice though is to research what your market wants and then determine whether these varieties will grow in your particular environment.

Nearly every olive variety will benefit from some form of cross fertilisation with another olive variety to optimise yield. Experimental work is still determining which varieties pollinate other varieties best. In general, it is best to have at least 3 to 4 different olive varieties to optimise cross-pollination. Different olive varieties should be within at least 30 m of each other, preferably closer.

Due to the current confusion in olive variety identification in Australia, planting stock should only be purchased from reputable nurseries with good quality control and DNA certified varieties. Any waiting period should be spent developing a business plan and preparing a site.

**Agronomy**

Although olive trees are hardy, to yield well they require the same high level of management as other commercial tree crops, particularly in their first few years of growth.

Soils should be tested for their nutrient status before planting, as many corrections are easier to make without trees in the ground. Olive trees will respond to fertilisers and it is important to take regular soil and/or foliar samples for nutrient analysis. As well as ensuring a correct balance of trace elements, a combination of NPK should be applied half in autumn and half in spring.

Young trees are vulnerable to strong winds and should be staked or trellised, particularly if a single straight stem is required for mechanical harvesting. Protective

![Portable catching frame for small scale harvesting of olives](image-url)
paper or foil wrapping around the trunk will protect the young tree from sunburn and herbicides. Competition from weeds can be a major problem for young trees but is easily managed by using herbicide along the tree row leaving a strip of pasture in the middle of the row which is regularly slashed.

The young tree will need to be pruned to encourage it into the correct shape (usually vase or conical) to optimise efficient removal of olives by mechanical shaking. Once this is achieved the tree should be pruned every year to maintain the shape and tree health by allowing air and light to enter and circulate through the tree canopy. If the trees have been planted specifically for straddle harvesting, protruding limbs that may obstruct the harvester will need to be controlled. Olive trees are biannual bearers and pruning at the correct time during “on” years will encourage more shoots and subsequent fruit growth in the following “off” year.

The time from planting to first harvest is variety dependent and also dependent on management techniques. Some varieties will come into commercial bearing at only 2-3 years of age. Most olive varieties though will take at least 4-5 years and even longer if not cared for properly. Maximum production is generally achieved by years 7-8. Young trees can be induced to yield earlier by correct irrigating, fertilising and pruning.

**Pest and disease control**

A major advantage of olives is that they are relatively pest and disease free in Australia. Very few chemicals should be needed for successful olive cultivation and it has good potential to be grown organically, particularly in drier areas. If pesticides must be used, the National Registration Authority has information on which chemicals are permitted for use on olives and under what conditions they can be applied.

The most common pest is black scale which also affects citrus. Olive Lace Bug (not to be confused with beneficial lace wings) can also be a problem, particularly in the Eastern states. The Curculio beetle or weevil is a common pest in new plantings that were formerly pasture.

All of these pests can be controlled but they should be positively identified and expert advice sought to minimise indiscriminate spraying of broad spectrum insecticides which will also kill beneficial insects.

The main fungal problem is peacock spot which results in leaf fall and poor fruit set. It is more common in humid areas and correct pruning to allow adequate air flow through the leaves will help keep it under control. Anthracnose, or fruit rot can also affect olives. Copper sprays can be used for both of these fungal diseases.

Olives are also harmed by some soil borne pathogens such as phytophthora, verticillium and nematodes common to other fruit trees. If the site has been previously used as an orchard the soil should be tested for these organisms and fumigated if necessary.

The olive knot bacterium which produces galls on trunks and branches, has recently been identified in Australia on isolated properties. Sound orchard management and hygiene should keep this disease under control.

**Harvest, handling, packaging, storage, post-harvest treatments and processing**

Olives have traditionally been harvested by hand but for an economically viable large scale operation mechanical harvesters are essential. Mechanical shakers can either shake olives off individual limbs or vibrate the whole trunk.

Over-row harvesters similar to grape straddle harvesters can also be used on small trees. Other mechanical harvesters that comb the foliage are being developed by enterprising local engineers. Correct training and pruning of trees is crucial for mechanical harvesters to be able to operate efficiently.

Fruit should be transported to the processing plant under optimum conditions and processed as soon as possible.
Mechanical straddle harvester for large scale harvesting of olives (Photo: Boundary Bend Estate)

as possible after harvest to reduce oxidation and fermentation which will produce faulty oil.

Impeccable hygiene is vital at the processing plant to produce a fault free oil. Modern processing plants that crush the fruit, mix the resulting paste and then separate the oil from the paste in one continuous process are usually employed. Traditional mat presses are generally not recommended as it is extremely difficult to keep the mats scrupulously clean. A continuous process system with a capacity of 1.5 t of fruit per hour, will cost around $500,000 although smaller, cheaper machines suitable for boutique operations are also available.

Olive oil has a quality grading system based on chemical and taste tests. Virgin olive oils (extra virgin, virgin and ordinary virgin) are obtained solely from the fruit by mechanical or physical means without using chemical extractants or excess heat (greater than 28°C) that will alter the characteristics of the oil. Extra virgin olive oil is considered the best quality grade and is the primary focus of most olive oil producers in Australia.

Refined olive oil is obtained from virgin olive oil by refining methods used to improve the odour, flavour and taste. Olive oil (sometimes labelled pure olive oil) is a blend of refined and virgin olive oil. The olive pomace (solid material left after the first oil extraction) can be treated with solvents to extract the remaining oil to produce olive pomace oils suitable for human consumption.

Olive oil should be stored in air tight and light proof containers at a constant temperature below 22°C to slow down the onset of oxidation which causes the oil to go rancid. Even under ideal storage conditions though, olive oil quality will deteriorate over time and it should be consumed within 1-2 years after production.

Financial information

Establishment costs will vary considerably for each site. To simplify matters in the following example the price of land, irrigation headworks and special soil preparations are not considered. These costs though, particularly irrigation headworks, may be significant. After these, the major establishment costs are the trees and irrigation system. Trees cost between $5 - $10 each depending on age and source.

Irrigation reticulation varies from $1,000 to $4,000/ha depending on system design and labour costing. Professional soil surveys and irrigation system designs are highly recommended to optimise irrigation efficiency. With a further $1000/ha for ripping and soil amendments, establishment costs lie in the order of $3,000 to $7,500/ha (assuming a standard planting density of 250 trees/ha).

Annual gross return for a mature grove (maturity reached by about year eight for an intensively managed grove) is determined by tonnage, oil percentage and price. Assuming a planting density of 250 trees/ha; 50 kilograms of fruit/tree with 20% oil (specific gravity 0.91):

Key statistics

- World olive oil production (2002/03) 2,515,000 t
- World olive oil consumption (2002/03) 2,641,000 t
- Australian olive oil imports (2002/03) 32,748 t ($139 million)

Key messages

- Maximise productivity by variety selection and management
- Minimise costs through mechanisation and economies of scale
- Understand and develop markets
- Nurture industry growth through coordinated organisation
• 250 trees x 50kg = 12,500 kg of fruit
• 12,500kg x 20% = 2,500 kg of oil
• 2,500kg / 0.91 = 2,750 L of oil (approx.) = 140 drums (20L drums) of oil.

Production costs (pesticide, pruning, fertilizer, irrigation, herbicide picking and processing) are between $6,000 and $8,500/ha depending on whether the fruit is hand picked or mechanically harvested.

By substituting the ‘world parity’ price for oil of $4/L into the equation above, the gross return is $11,000 giving a gross margin of between $2,500 and $5,000/ha. The gross margin does not include capital costs which may make the overall venture unprofitable unless a large enough area is planted to achieve economies of scale.

The yield figures given above are reasonably high under Australian conditions and can only be consistently achieved by carefully managed groves. However, niche or speciality marketing may achieve higher prices for the oil. Sensitivity analyses on yield and price should always be done to determine what could be realistically achieved in your situation.

The important issues are to use the best varieties and management practices eg irrigation, to ensure high fruit and oil yields and design the grove to accommodate mechanical harvesting to reduce costs. Throughout the production and processing system attention to quality is essential.

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The RIRDC website contains a number of useful olive research reports. Follow the links to New Plant Products Research Reports

The Australian Olive Association web site has contact details for all regional olive associations.

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Plant fibre crops

Introduction

Plant fibre crops produce cellulose, which is used in a wide range of manufactured and industrial products. Cotton is the dominant plant fibre crop globally. Other plant fibre crops produced and traded globally are Flax (*Linum usitatissimum*), Hemp¹ (*Cannabis sativa*), Jute (*Corchorus spp.*), Kenaf (*Hibiscus cannabinus*), Roselle (*Hibiscus sabdariffa*), Ramie (*Boehmeria nivea*), Coir (*Cocos nucifera*), Sunn Hemp (*Crotolaria juncea*), Abaca (*Musa textilis*), Sisal (*Agave sisalana*) and Henequen (*Agave fourcroydes*). Many other plants are used for fibre on smaller scales or for particular applications in the countries of production. In addition, fibrous by-product of many other crops is used for fibre, such as cereal straws and bagasse (the fibre of the stalk of sugar cane after pressing).

Most of the plant fibre crops are “bast fibre” crops, meaning that the valuable fibre is derived from the bast (bark) fraction of the stem. The inner part of the stem is the “hurd”, a softer woody core. The bast fibre crops include Hemp, Kenaf, Flax, Jute, Ramie, Roselle and Sunn Hemp.

The plant fibre crops discussed in this chapter are those relevant to ongoing development in Australia: primarily Flax, Hemp, and Kenaf. Other crops that may be of interest or potential but have not undergone significant research or development effort are included here but in less detail: Ramie, Sunn Hemp, Roselle, Sisal, Henequen and Jute. Cotton is now a major crop in Australia, with an approximate annual value of $1.2 billion. Other plant fibre crops are less suitable to Australia due to limited production areas or relatively high labour requirements.

Plant fibre crops, particularly Hemp and Kenaf, have recently received renewed attention for production in Australia and overseas with the identification of increasing fibre demand globally, particularly in the manufacturing industries. Whereas, synthetic fibre production, wood fibres and cotton dominate the market, these sources are finite and in some cases environmentally damaging. The demand, therefore, for sustainable plant fibre crops is set to increase dramatically due to population increases and manufacturing substitution.

Markets and marketing

Plant fibre crops have traditionally been marketed internationally for a number of long-standing uses including carpets, furniture, pulp and papers, textiles, cordage, canvas, building products, non-woven textiles, insulation materials and fuel. More recently, newer markets have emerged for bast fibres, including plastics, poly-composites and glass fibre replacement. These applications have opened new markets in the building sector, automotive components and plastics industries. Hurd product has achieved considerable market share in absorbency and animal bedding markets.

Traditional markets for other plant fibre crops continue, with some development into the automotive markets as well. Jute for example, is used extensively in non-woven textiles and carpets. Traditional international markets tend to remain for plant fibre crops

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¹ Hemp, in this chapter, refers to “Industrial Hemp” or “Industrial Cannabis”. Industrial Hemp has been bred to contain low levels of THC, the drug component of marijuana. Levels of THC permissible in Australian Hemp crops vary according to state legislation. Industrial Hemp in Australia is grown under state government licence.
produced in areas with variable supply and very low costs of production relevant to low quality end uses, such as geotextiles or non-woven materials.

Flax, Hemp and Kenaf have undergone significant research and development internationally as a source of bast fibre for these new and existing markets. Currently, these markets are developing rapidly with projected shortfall in supply of bast fibre internationally within the next five years.

In the European automotive market, for example, natural fibre usage is currently 40,000 t annually. Demand is expected to increase to 150,000 t over the next five years, in the automotive manufacturing industry alone. Of this demand, the hemp market share is expected to increase from 12% currently to about 65%, equating to 100,000 t of hemp fibre required annually. It has been estimated that European production capacity for hemp fibre is capped at about 60,000 t annually due to land availability and production costs. Further shortfalls in bast fibre requirements for alternative industries are projected but are not clearly quantified.

The paper pulp market globally only uses approximately 10% non-wood pulp sources due to the historical availability and cheapness of wood sources internationally. With the shift to sustainable resources for manufacturing and the near depletion and increasing costs of available wood pulp sources, paper-manufacturing industries, especially in Asia, have moved to increase non-wood pulps for paper production.

In the Australian context, while research has identified these markets and private companies are actively pursuing them, supply capacity remains critical to secure contracts to these markets. Supply capacity depends both on production and processing.

Production requirements

Hemp is well adapted to both temperate and subtropical climatic zones as an annual summer crop. Kenaf is a spring-summer crop in tropical and sub-tropical regions and flax is predominantly a temperate summer crop or subtropical region winter crop. Most of the other plant fibre crops are adapted to the semi-arid or wet tropical climates. These are discussed individually below.

Hemp: Hemp is a genetically diverse species, with varieties adapted to a wide range of latitudes and climatic zones. It is a summer annual, short-day flowering plant. Until recently, all developed fibre varieties in the world were bred in Europe and therefore adapted to longer summer daylengths than in most of Australia. This meant that fibre varieties flowered prematurely in all but the highest (i.e. farthest south) latitudes of Australia, limiting productivity and yield. Recently, plant breeding and selection in industrial hemp in Australia by private companies has focussed on developing varieties suitable to Australian production, particularly the sub-tropics where higher summer rainfall and summer temperatures implies higher production capacity. These varieties have consistently achieved much higher fibre yields than previous trials of European varieties.

Hemp requires well-structured soils with high nutrient and water availability. It has been grown in trials in most states of Australia with varying success depending on varieties and agronomy. Best production conditions rely on well-prepared seedbed, well-fertilised soils, regular irrigation or rainfall and good sunshine conditions. The fibre crop grows for approximately 100-120 days. In temperate regions, hemp can only been grown in the summer months, in subtropical and tropical regions there may be scope to extend this with varietal development. Hemp is intolerant of waterlogging and trials with flood irrigation in various areas of Australia have shown reduced yields compared with overhead irrigation.

Kenaf: Kenaf is a subtropical and tropical plant capable of high biomass production over summer growing period. It prospers under high rainfall and sunlight conditions. It is a relative of cotton
and hibiscus and is a short day (autumn) flowering species. It is more diverse than hemp in its tolerance of soil conditions and could be grown under a range of dryland or irrigated conditions in northern Australia. It is highly drought tolerant with a broader harvest window than hemp.

*Flax:* Flax fibre is produced in Australia largely as a by-product of linseed (grain) production. Production is therefore limited by the market capacity for linseed grain. Flax can be grown solely for fibre in both temperate regions in summer and subtropical regions in winter. Flax varieties specifically for fibre have been developed and are available overseas, growing taller and less branched than linseed varieties. Flax requires good soil moisture and nutrient availability and is susceptible to dry periods.

*Sunn hemp:* Sunn hemp has been trialled recently in southern and western wheatbelt areas as a summer leguminous cover crop rather than as a fibre crop. It generally requires moderately rich lighter loam soils for fibre production but it will tolerate heavier soils.

Other fibre crops that may be of interest to Australia have been or are being trialled. Sunn hemp, roselle and ramie are typically similar to kenaf in their adaptation to subtropical areas with some tolerance of drier conditions. Roselle is listed as a significant weed species in Western Australia and the Northern Territory and is naturalised across large areas, which may cause problems for adoption as a crop species. Other bast fibre plants such as henequen and sisal are adapted to drier climates such as semi-arid northern Australia. They are intolerant of waterlogging, with shallow root systems preferring lighter well drained soils.

**Varieties and cultivars**

The availability of seed remains a hurdle for most growers of new bast fibre crops.

*Hemp:* Hemp seed is available in Australia only where imported or grown under relevant state licence. Varieties and cultivars imported from Europe or Canada, the only commercial sources of industrial hemp cultivars, are generally unsuited to Australian conditions except far southern Australia. Imported seed can be poor quality and expensive. Private researchers have recently been developing varieties suitable for Australian cropping, however seed stocks are generally limited.

One grain variety of industrial hemp "Finola" has recently been granted PBR in Australia but is primarily suitable for Tasmanian climatic conditions. Other European varieties such as Futura 77 and Kompolti have achieved reasonable yields in Tasmania and Victorian trials. Subtropical varieties developed by Ecofibre Industries Limited in Queensland have achieved viable yields in trials in Victoria, New South Wales and Queensland, significantly improving on yields of European varieties.

*Kenaf:* Kenaf varieties predominantly grown in Australia are Everglades 71 and Guatemala 4, both well adapted to Queensland tropical and subtropical conditions. Both varieties have performed well in Queensland and northern New South Wales trials over the last few years.

*Flax:* The flax industry in Australia has used residue from linseed grain varieties and has not developed or imported fibre flax varieties commercially. While specialised flax fibre trials are available internationally (Europe and Canada), in Australia the flax industry remains dependant on the residual fibre from linseed crops and therefore varieties are those selected for linseed production (eg Argyle, Glenelg, Linola). Trials using European flax cultivars in Tasmania in the early nineties showed increased bast fibre yields over traditional varieties. Factors to consider for flax varieties include time to maturity, disease resistance, branching and susceptibility to lodging.

Adaptation to local climatic and edaphic conditions will be imperative in the choice of varieties of bast fibre crops for Australia. Maturity time relative to local daylength is the key determinant.
of yield, therefore varieties suited to local summer daylength conditions will need to continue to be developed for the bast fibre industry.

**Agronomy**

**Hemp:** Industrial hemp grows in both temperate and subtropical through to tropical climates, requiring high light, nutrient availability and moisture conditions. Hemp is intolerant of waterlogging and prefers well-structured soils with high organic matter and near neutral – slightly alkaline pH. Hemp is intolerant of compaction and anaerobic soil conditions at germination and establishment, which has caused poor results in Australian trials including trials under flood irrigation.

Plant population is critical to crop structure, total stalk yield and bast fibre yields. Trials on optimum plant populations in Australian conditions have been inconclusive, although showing yield reductions at higher rates recommended by European trials. Current recommendations are between 100 and 200 plants/m². Sowing rates in kg/ha depend on the seed weight count, which may be between, for example, between 15 and 30 g for 1,000 seed count. Recommended sowing rates (e.g. 45 – 65 kg/ha) need to take into account 1,000 seed weight and Australian cropping conditions for yield relative to density.

Industrial hemp is typically a summer crop that is harvested after onset of flowering. Earlier trials in Australia using European varieties have generally flowered early, thus limiting stalk yield. Choice of variety is critical to yield in any location and sowing date will depend greatly on the daylength response of varieties relative to local summer conditions. Later flowering varieties enable longer planting windows for the same period of vegetative growth. Varieties may flower prior to mid-summer if planted too early in the spring, with limited yield due to reduced temperatures, moisture availability and onset of flowering.

Researchers in Queensland have focussed on developing and trialling suitable subtropical varieties with a view to achieving higher stalk yields.

Nutrient availability is a major determinant of biomass yield and hence fibre yields. Hemp is a nitrophilic crop and trials have shown increased yields up to 250 kg/ha of N, 120 kg/ha K and 40 kg/ha P. Comprehensive trials for detailed nutrition and fertiliser requirements need to be conducted for Australian production.

**Kenaf:** Kenaf grows best in tropical and subtropical conditions where daily mean temperatures are above 20°C. Kenaf is sown at a rate of approximately 10-15 kg/ha to achieve a density of 250,000 to 400,000 plants/ha. Plant spacing has little effect on yields and row configuration can be adapted to suit farming and harvesting equipment. Seed should be planted in mid to late spring in irrigated crops or immediately following onset of wet season rains in dryland crops. As kenaf is a high biomass crop, nutrient requirements are high. Fertiliser applications should aim to meet the requirements of the crop, for example 100kg/ha N, 17 kg/ha P and 220 kg/ha K for a 20 t/ha crop.

**Flax:** Fibre flax needs abundant moisture and cool weather during the growing season. It grows best on well drained soils of loamy or clay loam texture. The crop is intolerant of acidic, alkaline or saline soil conditions. Higher nutrient availability leads to higher yield and quality of fibre but as root systems are not extensive, nutrients need to be readily available in the root zone. A fibre
The flax crop grows to approximately 90–120 cm in 3–4 months. A fine seedbed with a sowing rate of 80–110 kg/ha is necessary for good crop establishment. Flax is not as competitive as many other fibre crops and early weed control is important. The timing of harvesting of fibre flax is critical to fibre quality. The fibre is harvested once the lower two-thirds of the stem has turned yellow, usually about one month after appearance of flowers.

**Sunn hemp:** Sunn Hemp grows best in the tropics and subtropics on well-drained alluvial soils with a sandy loam or loamy texture. Overseas recommendations for seeding rate and row spacings vary greatly (e.g., 5 – 60 kg/ha, at 30 cm – 1m rows). For fibre production in Australia, rates are generally higher (10-15 kg/ha) than recommended for seed production or as a green manure crop (3-5 kg/ha). Row configuration and plant density would need to be trialled under local conditions for optimum fibre production. Sunn hemp is currently being trialled as a rotation crop in wheatbelt areas of Western Australia and other areas of southern Australia. Trials as a rotation/cover crop have demonstrated that inoculum is required for successful growth.

**Jute:** Jute is a tropical short day plant that grows in the summer months. It requires at least 1,000 mm over the growing season but is not tolerant of waterlogging in the early growth stages. It is grown traditionally in river valleys and delta areas, requiring fine seedbed preparation with high rainfall or irrigation. Seed is sown at approximately 5–10 kg/ha, aiming for a final plant density of about 35–40 plants/m². Plants are harvested early pod stage, by hand in the current countries of production.

**Ramie:** Ramie is a perennial crop growing over 7 –20 years. It requires a warm humid climate with annual rainfall or irrigation of at least 1,000 mm fairly evenly throughout the year. Ramie tolerates a wide range of soil types, preferably slightly acid (pH 5.5–6.5) but is intolerant of water logging. It is usually propagated from rhizomes or stem cuttings that are planted every 30–50 cm in rows 70–80 cm apart. The crop grows multiple stems from underground rhizomes, achieving 1-2.5 m in height. Ramie can be harvested up to 6 times a year in good conditions, current harvesting is done by hand as stems should be harvested at a particular stage of maturity. For high production, high nutrient levels, particularly, N, P and K, should be maintained.

**Sisal and Henequen:** Sisal and Henequen are fleshy perennials with a productive life of 6 to 20 years. The plants consist of a short thick stem bearing a rosette of long fleshy pointed leaves. Propagation is by suckers or bulbils, which are grown in nurseries and then planted out into 1 m spacings in rows about 3-4m apart. Plants are generally grown on well-drained sandy loam soils containing lime but will also grow on well-drained clay soils. Crops have a high requirement for calcium, nitrogen, potassium and magnesium.

**Roselle:** Roselle has similar growing requirements to kenaf although there have not been extensive trials in Australia to date.

**Pest and disease control**

Plant fibre crops, where the economic product is cellulose from the stem rather than a fruit or flower product, have very low pest and disease problems. In most cases, where there are pests and diseases present for a species, the

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**About the author**

Tanya Jobling has worked with Ecofibre Industries Limited in Brisbane since 1999, coordinating hemp and other bast fibre crop research trials and commercial production throughout Australia. She has a background in developing agricultural industries since completing postgraduate studies at the University of Queensland. Her current research projects include developing hemp agronomy, new variety trials in hemp and kenaf, germplasm research, fertiliser trials for hemp fibre and seed production, farming systems research using bast fibre crops in rotation and developing regional supply capacity of fibre crops to a potential mill. Ecofibre Industries Limited is a private Queensland based company developing the bast fibre industry through research and marketing, implementing production and processing in Australia.
tolerance threshold is high relative to the economic damage.

In hemp crops in Australia, many pests have been recorded but few have warranted control. In fibre crops, Heliothis (*Helicoverpa* spp.), Red Shouldered leaf beetles (*Monolepta australis*), Green Veggie Bug (*Nezaria viridula*), Jassid (*Batrocomorphus angustatus*) and Lucerne Flea (*Sminthurus viridis*) have been recorded. Fungal attack has caused minor occurrences of plant death in trials in Queensland and New South Wales and has been identified as species of *Sclerotium rolfsii*, or White Mould. The infection has been more prevalent in clay soils or where frequent watering occur, creating a wet-dry cycle which encourages the disease. In no cases of fibre crops were these pests or diseases present in large numbers or at economically damaging levels. In hemp grain or seed crops, control of Heliothis and Green Vegie Bug may be required. In cooler moist conditions of southern Australia, *Botrytis* (*Botrytis cinerea*) in hemp grain crops may be a problem.

Root knot nematodes (*Meloidogyne* spp.) have been identified in the root systems of hemp in cropping soils where nematodes are known to be a problem (e.g. sugar cane areas). In some cases, infection with nematodes is thought to be the cause of considerably reduced plant yields.

In kenaf trials in Australia, pests have been noted but few have been problematic. Root knot nematodes have severely infested plants and affected yields in some trials, in areas where root knot nematodes are known to be a problem. In some trials, Red Shouldered leaf beetles (*Monolepta australis*) have completely defoliated young plants, causing one trial to be terminated.

On the whole however, kenaf and hemp are quite tolerant to the wide range of pests and diseases that have been identified in the crop but caused little economic damage. By their nature of production being the economic product from the plant stalk, plant fibre crops suffer little economic damage from most pest species, particularly insects, unlike fruit, leaf or flower product crops. In this respect, plant fibre crops are considered low risk and low management crops for production systems.

### Harvest, handling and processing

Harvesting plant fibre crops in Australia has required mechanisation of processes that are largely manual in other countries of production. Many of the minor plant fibre crops will be unsuitable to broadacre planting in Australia unless viable mechanised harvesting, handling and processing can be developed.

In practice, the bast fibre crops are cut, dried in field and baled after a period to enable retting of the fibre. Retting is the process in which microbes (fungal and bacterial) break down the fibre stem enabling easier separation of fibres in processing.

Machinery for harvesting has been a major developmental project for the bast fibre crops in Australia. For hemp, specialised machinery from Europe has been imported and new equipment is being developed in Australia. Offset sickle mowers have also been used.

### Table 1. Suggested yields, costs and returns for commercial bast fibre crops in Australia

<table>
<thead>
<tr>
<th>Crop</th>
<th>Expected yields t/ha</th>
<th>Gross farm gate return per tonne</th>
<th>Variable cost of growing per ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenaf</td>
<td>10 – 15 irrigated</td>
<td>$75-$120</td>
<td>$500 – $800 irrigated</td>
</tr>
<tr>
<td>Flax</td>
<td>1 – 3 irrigated</td>
<td>$150 - $200</td>
<td>$300 – $500 irrigated</td>
</tr>
<tr>
<td>Hemp</td>
<td>6 – 12 irrigated</td>
<td>$160 - 220</td>
<td>$600 – $900 irrigated</td>
</tr>
<tr>
<td></td>
<td>4 – 7 dryland</td>
<td>$400 - $600 dryland</td>
<td></td>
</tr>
</tbody>
</table>

Note that flax fibre is available as the stubble of linseed crops and that therefore, gross returns for these crops are not reflected in the stalk price.
but these are only an option where total biomass is relatively low. For kenaf, harvesting using sugar cane harvesters and forage harvesters has been trialled. Where hemp and kenaf are grown as high biomass crops, i.e. over 10 t/ha, specialised harvesters will be required for optimum stalk return.

Bast fibre crops are typically windrowed when mechanically harvested and left to dry in the paddock for one to four weeks, depending on conditions. The stalks should reach a suitable stage of retting and moisture content below about 12% to be baled. Conventional raking and baling equipment can generally be used.

The high biomass, low value nature of the bast fibre crops poses a handling cost issue for the fibre industry in Australia.

Traditionally, the processing facility needs to be located as close as possible to the source of raw material, minimising transport costs of raw stalk bales. Given the larger scales of production in Australia, the bast fibre industry has recognised that raw material needs to be significantly compacted or semi-processed on or close to site of production to reduce transport costs.

Processing for the main bast fibre crops (hemp, flax and kenaf) has been the major impediment to reaching markets for the bast fibre industries in Australia to date. Bast fibre process consists of separating bast (outer bark fraction) from hurd (the inner light woody core).

The proportion of bast to hurd varies between species and varieties within species and there are identified markets in Australia and globally for both bast and hurd fractions.

Capital investment in bast fibre processing facilities in Australia has been the focus of several private companies with several trial or pilot operations currently in place or proposed.

Harvesting and pre-processing of other fibre plant crops such as jute, roselle, sisal and henequen is done by hand in countries where they are currently produced. Australia is unlikely to be able to compete with the low cost production of these crops.

Financial information

Detailed economic analyses of agricultural production costs and returns are not currently available for the two major crops undergoing development, namely hemp and kenaf. This is because the majority of the research and development is being conducted and funded by private companies and individuals and the information developed is therefore commercial and proprietary. In addition, research directions are skewed towards specific commercial outcomes rather than being general in nature.

The key financial components of including bast fibre crops in any farming systems are that they are typically low risk, low input crops, which have associated benefits of rotation cropping in nutrient return to the system through organic matter and break crops for other major crops such as sugar cane, cotton or grains.

Whilst detailed economic analyses for major bast fibres in Australia are not available, research undertaken to date has enabled some generalised figures to be developed. These are presented in Table 1. These figures will vary greatly depending on crop yield, fibre quality, distance to processing, costs of processing, location, farming infrastructure and systems of production. Commercial returns for other plant fibre crops are not established for Australian production systems. Returns from minor plant fibre crops in Australia will depend on there being a bast fibre or plant fibre industry currently established into to which to sell these plant fibres, rather than being able to market smaller quantities of plant fibre independently (with the possible exception of local niche markets).

For plant fibre cropping to be viable, the proximity to regional processing is paramount, enabling growers to sell to the processing facility and the processor to market substantial volumes of fibre to both global and local markets. These markets are primarily in the major manufacturing industries requiring large supply capacity rather than entry-level niche production.

There is currently no commercial processing of plant fibre materials in place in Australia but a number of companies are developing regional processing facilities. Once these are in place, growers in these areas will be able to achieve returns for crops grown. Harvesting, baling and transporting costs for high biomass crops such as hemp and kenaf can be considerable.

It should be noted that hemp cropping is subject to state legislation in Australia, with Tasmania, Victoria and Queensland currently enabling licensed commercial production of industrial hemp and New South Wales and Western Australia currently permitting smaller scale trials and research. Licence and compliance obligations and costs vary from state to state and should be factored into production costs.
Key references


See websites listed above under key contacts. Also:


and other state agricultural departments for relevant notes on new bast fibre crops and State conditions for growing industrial hemp.

Key contacts

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Key messages

- Demand for plant fibre is increasing globally, particularly in the manufacturing industries
- Proximity to regional processing is critical for plant fibre cropping to be viable
- Currently no commercial processing of plant fibre materials in Australia
- Commercial production of industrial hemp is subject to state legislation and is currently only permitted in Tasmania, Victoria and Queensland

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Introduction

In Australia, the term ‘specialty mushrooms’ is generally used to refer to those varieties of mushroom that are well-known overseas and have increasing popularity with Australian consumers. While certain varieties of specialty mushrooms are grown commercially in Australia, they are not yet considered an industrial scale crop (as for the white button mushroom in Australia, or as the specialty varieties are grown overseas).

Currently in Australia, there are several varieties of specialty mushrooms produced commercially and marketed for fresh consumption. These include *Lentinula edodes* (shiitake); *Pleurotus* spp. (oysters); *Flammulina velutipes* (enoki or enokitake); *Auricularia* sp. (wood ear) and *Hypsizigus marmoreus* or *tessulatus* (shimeji or bunashimeji). Growers have also experimented with *Grifola frondosa* (maitake).

Recent years has also seen the development of a market for mushrooms collected from the wild and sold through wholesale markets in the larger urban areas, or sold directly to restaurants and hotels. The varieties involved in this market are those for which cultivation methods have yet to be developed or whose cultivation methods are complex and not commercially viable. These include such varieties as *Lactarius deliciosus* (pine mushrooms); *Boletus* spp. (ceps, porcini, slippery jacks); and *Morchella* sp. (morels).

Data on Australian production of speciality mushrooms, and import of these mushrooms into Australia are not available.

As far as we know, there is no formal list of speciality mushroom growers in Australia, and some of these growers belong to the Australian Mushroom Growers Association (AMGA). Members of AMGA grow the common cultivated mushrooms *Agaricus bisporus*.

Several specialty mushroom species are not currently allowed to be imported into Australia. Work on the Import Risk Analysis (IRA) for edible mushrooms was initiated in 1998, initially looking at 39 mushroom species. Biosecurity Australia is about to re-commence the IRA process.

Markets and marketing issues

Demand for specialty mushrooms is increasing each year as the increasing European and Asian populations seek mushrooms with which they have been familiar in their own countries. Competition is strong from imported fresh, dried and canned mushrooms at competitive prices from China.
and Asia, and on occasions from California and New Zealand. The importers of specialty mushrooms sell their product to supermarkets at a lower price than Australian-grown specialties. However, quality and shelf life are obviously major concerns and food safety standards are now favouring the freshly grown Australian products.

With approximately 80 per cent of Australians buying mushrooms at least once a fortnight, a large percentage have bought specialty mushrooms in the last six months. Market research has shown that consumers would buy more specialty mushrooms if they knew how to use them, or if their stockist carried them more regularly. Retailers and buyers need educating about ways in which to prepare and use specialty mushrooms. When paying a premium price for an apparently gourmet product, consumers like to get best value from the product.

Many small-scale producers deal directly with restaurants, hotels and retail outlets, so by-passing the usual wholesale route. This contributes to the difficulty of obtaining accurate industry production figures or locations. There is no official monitoring body for specialty mushrooms, although the AMGA maintains a watching brief.

Impediments to market development continue to be lack of consistency in quality and supply; lack of R&D into Australian production techniques; poor knowledge of pest and disease problems; competition from cheap imports (especially from China); and food safety issues.

Although there is great demand in Japan, China, Korea, Taiwan, Singapore and other South-east Asian countries, and although Asian foods produced in Australia are highly sought after at present due to the clean fresh image, there appears little chance of development of an export market for specialty mushrooms.

**Varieties and production requirements**

Commercial scale mushrooms production occurs in environmentally-controlled growing facilities inside temperature and humidity controlled rooms. Submicron filtration capability minimises pest and disease entry into the growing rooms, although insect and microbial pest and disease still have to be controlled on all crops. Mushrooms are therefore somewhat independent of location in terms of climate. However, there are two vital aspects to mushroom growing; the first being substrate production, the second being the growing itself.

Specialty mushrooms grow on a range of different substrates under different environmental conditions. This generally means that different crops cannot be grown together in the same facility and separate growing rooms are needed for each type of mushroom. The type of substrate that specialty mushrooms use for growth can be basically divided into two types, reflecting the natural ecological habits of the fungi. Some mushrooms grow on straw-based composted substrates, while others require wood-based substrates. The substrates are mainly agricultural and industrial waste materials such as cottonseed hull, cereal straw, wood chips, tea waste etc. Nutrient supplements such as wheat and rice bran, vegetable oils such as sunflower oil, cottonseed oil etc are added to the substrate.

In contrast to the substrate used for growing the common mushroom Agaricus bisporus, substrate for specialty mushroom does not require a composting process. The substrate is only pasteurised to eliminate pathogenic organisms before the addition of starter culture (spawn) of the desired mushroom. This reduces the cost of producing speciality mushrooms considerably.

The production process of specialty mushrooms requires fewer steps than those of the common mushroom. For instance, there is no need for covering or ‘casing’ the substrate for initiating the production of mushroom fruit bodies. This brings further significant savings in the cost of producing speciality mushrooms.

Unlike the common Agaricus white button mushroom industry where the substrate is produced by specialist manufacturers and distributed to farms, most specialty mushroom growers are required to produce their own substrates. The skill in formulating an ideal

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Specialty mushrooms

Enoki
Substrate from Australian materials to mimic substrates used overseas is often the key to growing success.

Matching the correct substrate to the right strain is also a major issue in Australian mushroom production. Mushrooms can potentially grow on many different wood-based substrates, but whether they produce viable, quality yields is dependant upon the strain/substrate/environment combination. Small-scale producers may produce their own spawn, or cultures are now available throughout Australia from commercial spawn suppliers.

The primary ingredient used for Pleurotus spp. production is chopped wheat straw or cottonseed hulls or mixtures thereof. For production on wheat straw, the material is milled to a length of about 2 to 6 cm. The pH of the material is adjusted with limestone to about 7.5 or higher to provide selectivity against weed mould, and after completion of pasteurisation at 60°C for one hour, the substrate is cooled to 25°C or less and spawned with the desired strain.

Production of Pleurotus spp. on cottonseed hulls has some advantages over straw-based production systems in that chopping of the hulls is not required. The pasteurised, supplemented hulls are spawned and filled (12 to 15 kg) into clear or black perforated polyethylene bags which are then stacked horizontally in racks and then incubated at 23° to 25°C for 12 to 14 days. Sometimes the bags are removed after the substrates have been fully colonised by the mushroom. Fruit bodies emerge from the top and sides of the substrate and can be repeatedly cropped. In Asia, the ease of growing oyster mushrooms makes them a popular crop for production in low-technology operations.

Eucalypt sawdust is the most popular basal ingredient used in synthetic formulations of substrate used to produce shiitake (Lentinus edodes). Other basal ingredients that may be used include straw and corn cobs or mixtures thereof. Regardless of the main ingredient used, starch-based supplements such as wheat bran, rice bran, millet, rye, corn, etc. are added to the mix in a 10% to 40% ratio (dry wt) to the main ingredient. These supplements serve as nutrients to provide an optimum growing medium.

Once the proper ratio of ingredients is selected, they are combined in a mixer and water is added to raise the moisture content of the mix to around 60%. The mix is filled into plastic bags and sterilised in an autoclave for one hour at 120°C, cooled and inoculated at a substrate temperature of 25°C or less with shiitake spawn. After a 20 to 25 day spawn-run, the bags are removed and the substrate blocks are exposed to an environment conducive for browning of the exterior surfaces (15-17°C or higher, depending on the strain being cultivated). As the browning process nears completion (four weeks), primordia (the initial stages of the formation of mushroom fruit bodies) begin to form about 2 mm under the surface of the substrate indicating that it is ready to produce mushrooms.

Key messages
- Specialty mushrooms are not an industrial scale crop in Australia
- Many small scale producers deal directly with restaurants and other retail outlets
- Demand for specialty mushrooms is increasing
- Market development is being impeded by lack of consistency in quality and supply
- The key to growing success is formulating the correct substrate
Primordium maturation is stimulated by soaking the substrate in water (12°C) for three to four hours. Soaking allows water rapidly to displace carbon dioxide contained in air spaces, providing enough moisture for one flush of mushrooms. Approximately 9 to 11 days after soaking, mushrooms are ready to harvest.

The cycle for synthetic medium cultivation lasts approximately 4 months from time of inoculation to cleanout. Biological efficiencies for this method may average from 75% to 125%.

Substrates for the cultivation of Enoki (Flammulina velutipes) are primarily sawdust and rice bran; 4:1 ratio. These are mechanically mixed and filled into heat resistant bottles with a capacity of 800 to 1,000 ml. Sawdust consisting primarily of Cryptomeria japonica, Chamaecyparis obtusa or aged (9 to 12 months) Pinus spp. appears to offer the best yields, although eucalypt-based substrates have been developed in Australia. After filling into bottles, the substrate is sterilised (four hours at 95°C and 1 hour at 120°C), cooled to 25°C or less, and mechanically inoculated. The inoculated substrate is incubated at 18 - 20°C for 20 to 25 days. When the substrate is fully colonised, the original inoculum is removed mechanically from the surface of the substrate and the bottles may be placed upside down for a few days. At the time of original inoculum removal, the air temperature is lowered to 10 - 12°C for 10 to 14 days.

To further improve quality during fruiting, temperatures are lowered to 3 - 8°C until harvest. As the mushrooms begin to elongate above the lip of the bottle, a plastic collar is placed around the neck to support the long stalk of the mushrooms. This collar serves to hold the mushrooms in place so that they are long and straight. When the mushrooms are 13 to 14 cm long, the collars are removed and the mushrooms are pulled as a bunch from the substrate.

Auricularia spp. production now represents about 14% of the total cultivated mushroom supply worldwide. Auricularia auricula and A. polytricha are produced commonly on a substrate consisting of sawdust, cotton seed hulls, bran, and other cereal grains or on natural logs of broad-leaf trees. For cultivation on natural logs, members of the oak family (Fagaceae) are preferred, but many other species of both hard and softwoods may be used.

For synthetic medium production of Auricularia, the substrate may be composted for up to 5 days or used directly after mixing. In either case, the mixed substrate (about 2.5 kg wet wt) is filled into heat resistant polypropylene bags and sterilised (substrate temperature 121°C) for 60 min. Composted substrate is prepared by mixing and watering ingredients [sawdust (78%) : bran (20%) : CaCO3 (1%) : sucrose (1%)] in a large pile. The pile then is covered with plastic and turned (remixed) twice at two-day intervals. For direct use of substrate, a mixture of cotton seed hulls (93%), wheat bran (5%), sucrose (1%), and CaCO3 (1%) is moistened to about 60% moisture and then filled into polypropylene bags.

After the substrate has cooled to 25°C or less, it is inoculated with either grain or sawdust spawn. The spawn then is mixed into the substrate either mechanically or by hand, and the mycelium is allowed to colonise the substrate.

Temperatures for spawn run are maintained at about 25°C±2°C for about 28 to 30 days. Light intensity of more than 500 lux during the spawn run may result in premature formation of primordia. Temperature, light intensity and relative humidity all interact to

Specialty mushrooms
influence the nature and quality of the fruit bodies grown

Shimeji is usually produced in polypropylene bottles containing a mixed sawdust-based substrate similar to that developed for enoki. After the completion of vegetative mycelial growth (spawn run), bottle lids are removed and the colonised substrate subjected to environmental conditions known to stimulate fruiting.

When the mushrooms are mature, the entire cluster of fruiting bodies is removed from the bottles. Only one flush of mushrooms is harvested prior to mechanical removal of the "spent" substrate from the bottles. The bottles then are refilled with fresh substrate and the process is repeated.

Pest and disease control

The pests and diseases that cause problems for specialty mushrooms are similar to those experienced in the Agaricus industry, namely weed moulds, fungal, bacterial and viral infections, flies and nematodes.

While chemical and physical control protocols are in place for the Agaricus industry, pest and disease control for specialty mushrooms is still in its infancy. Methods are being developed by producers and consultants as new problems are encountered.

The Australian Pesticides and Veterinary Medicines Authority (APVMA) will in the future require registration of chemicals to be used in the production of specialty mushrooms and pest and disease control data will be required to support such registration.

Harvesting, post-harvest treatments & processing

Specialty mushrooms are hand-picked in situ. This requires skilled workers who can make decisions on maturity, quality and size as they pick. Depending on market demand, pickers will be required to select mushrooms of a specific size and need to be able to distinguish between first and second quality fruit bodies.

Currently supermarket retailers repackage specialty mushrooms in brand packaging – arranging mushrooms in plastic film-sealed trays. There are few fresh specialty mushrooms available for hand selection as consumers can do for Agaricus. Prolonging shelf-life of mushrooms has been the subject of much research and various packaging regimes have been promoted. Mushrooms remain a highly perishable commodity, consisting primarily of water.

Medicinal benefits

The antitumor polysaccharide, β-(1-3)-D-glucan, isolated from H. marmoreus shows very high activity and has been the subject of much research. Dried mushroom powder from this mushroom is believed to stimulate the radical-trapping activity of blood. Excessive free radicals in the blood stream are believed to hasten the aging process.

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Morel species collected in Tasmania: (a) *Morchella deliciosa*/*Morchella elata*; (b) *Morchella deliciosa*; (c) *Morchella esculenta* var. *angusticeps* (syn. crassipes); (d) *Morchella elata* (Source: Specialty Mushroom Production Systems: Maitake and Morels, RIRDC Publication No 04/024)
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Key references


Stott, K., and Mohammed, C., 2004 Specialty Mushroom Production Systems: Maitake and Morels, RIRDC Publication No 04/024


About the authors

Tan Nair’s major area of research is mushroom science with reference to disease management, composting technology, casing technology, and cultivation of specialty mushrooms.

He is a current elected member of the Council of International Society for Mushroom Science, Life Honorary Member of the Australian Mushroom Growers Association, Professional Member of the American Mushroom Institute, and Coordinator of the FAO Network on Conservation and Utilisation of Mushroom genetic Resources for the Asia Pacific Region. Research work also covers the field of viticulture. Publications include 64 referred articles in reputable scientific journals, 8 book chapters, editor of 8 proceedings of international conferences, and 50 extension articles in trade journals.

Andrew Broderick graduated with a PhD in fungal spore production for the pharmaceutical industry, Aston University in Birmingham (UK) 1981. From 1981 to 1991 he was a Research Scientist in New Zealand researching and developing fungal waste recycling fermentation processes. For the past thirteen years he has been undertaking research into Australian wild fungi and commercial Agaricus at the University of Western Sydney. He is currently Senior Lecturer and Head of Academic Programs for Horticulture and Viticulture and Winemaking at UWS.

From 1991-1994 he was the National Training Manager for the Australian Mushroom Growers Association. He is also a founding member and Vice President of the World Society of Mushroom Biology & Mushroom Products.
Stevia

Introduction

Stevia (Stevia rebaudiana Bertolli) is native to South America, originating from the Tropic of Capricorn area of eastern Paraguay, where it has been used to sweeten local teas and medicines for hundreds of years. The extract from stevia - steviosides (steviol glycosides) - has been used extensively in a number of countries, notably Japan, China, Korea and Brazil, for over thirty years in a wide range of food products as a non-sucrose and no-calorie sweetener (it is 250 – 300 sweeter than sugar gram for gram).

With increasing world-wide concern that excess consumption of calories in sucrose is contributing significantly to the rising incidence of obesity, type II diabetes and tooth decay, alternatives to sucrose are being consumed in increasing quantities. Most alternatives used are man-made chemical sweeteners, some of which are not suitable for all uses (being not heat-stable). These chemicals are not regarded as ‘natural’ food products and there is also growing concern about the safety of some of them. Steviosides have been shown to be safe to use and are suitable for a wide range of uses, in cooked foods as well as drinks, confectioneries and the like. They are suited to diabetic and weight loss diets and are beneficial and not detrimental to dental health.

Stevia and its extracts are not yet (March, ’04) approved by Australian authorities (FSANZ) for commercial use as a food ingredient, although they can be used as a “novel food”. It appears that enough research data to obtain registration approval are now available.

Stevia has traditionally been grown in low-labour-cost

Key messages

- Stevia is still an experimental crop in Australia
- Stevia is a good, safe, non-chemical, no-calorie alternative
- The health food market is limited
- Approval as a food ingredient will lead to a significant industry
- There are no processing facilities in Australia yet
- Seedling production is a specialist’s job
- Production levels are not established for Australia
- Reliable mechanisation of harvesting is still undeveloped
- International prices for stevioside are widely variable
countries using labour-intensive techniques for propagation (using cuttings) and harvesting (hand cutting or stripping of leaves). Trials of commercial, mechanised growing of stevia were commenced in Australia in 2002 by Central Queensland University and have shown that seedlings can be grown and transplanted on a commercial scale (using seed imported from China). Appropriate mechanised harvesting and handling procedures have not yet been demonstrated.

There is currently no large scale growing of stevia or stevioside extraction in Australia. Stevia production will require a mix of husbandry skills: crop establishment by planting out seedlings using herb and vegetable crop skills, harvesting and drying similar to lucerne growing (but with much more delicate handling) and processing with parallels to similar technology in the sugar industry.

**Markets and marketing**

The main stevia producing areas are China, especially north China, and Brazil/Paraguay in South America, the latter near its natural place of origin. The main stevioside consuming countries are Japan, where chemical sweeteners were banned around 1970, and China, South Korea and South American countries. In the USA stevia is currently only approved as a “nutritional supplement” and not as a commercial sweetener and so is mainly sold direct for home consumption through mail/internet order and health food outlets.

The main market in Australia will be for sugar replacement in soft drinks, juices, milk, yoghurt and icecream products, sauces, jams, biscuits and other confectionery. Steviosides can be mixed with sugar to give reduced and low sugar products as well as used alone for non-sugar products. Dried stevia leaves and extracts have very long shelf life and can be easily transported, so any future Australian market will be equally open to imported product and local production. Stevia will initially compete with chemical, non-sucrose sweeteners. The Australian soft drink industry uses approximately $70 million of sugar/sweetener per year, of which more than 20% is non-sucrose.

Any future processor of stevia would probably market direct to manufacturers and retailers. Marketing in conjunction with sugar is a possibility.

There is a growing market for certified organic stevia products both within Australia and overseas, particularly in the USA and Canada. Produce from China or South America will have difficulty meeting certification requirements, so the organic market could become an opportunity for specialist producers in Australia. The health food market now mainly imports from South America, often via the USA.

The world price of stevioside powders varies with production and demand volumes. It was very low in 2002/03 (down to approximately $US 20/kg) from very high in the late 90’s (over $US 60/kg). This is from well below to well above the equivalent raw sugar price, to achieve the same degree of sweetness. A premium over world price for high quality Australian stevioside cannot be assured.

**Production requirements**

Although originating on the Tropic of Capricorn, stevia can be grown over a wide climatic range: from the equator (Indonesia) to the extreme latitudes of St Petersburg (60°N). Once established, it can tolerate frosts but not long periods under snow. It is grown as a perennial (3 to 5 years) in temperate to warm climates but as an annual in colder regions. For high leaf production irrigation is considered essential; under conditions of moisture stress leaf growth stops and flowering can be initiated. Even with good irrigation, temperatures over 35 – 40°C with low humidity can be stressful and induce premature flowering. Coastal and tableland situations would seem to be preferred in northern Australia.

Day length can influence stevioside content and leaf production. Long days increase stevioside production and short days can initiate flowering. Therefore more frequent summer harvesting is required in the tropics (with shorter day lengths) than in Victorian and Tasmanian latitudes.

Acid to neutral soils are preferred. Well-drained soils seem desirable, although once established stevia can thrive with wet feet on a waterlogged subsoil. Production as a row crop or on low beds, of two
to three rows per bed, is required. This crop is suitable for quite small areas of production (even half a hectare).

Preferred regions for production in Australia have not been established. Latitude effects are part of the investigations by CQU. An accessible outlet for the stevia leaves will be a prime consideration, although once dried the leaves can be stored and transported without loss of quality.

**Varieties**

Under its natural conditions the wild stevia population is very variable in height, leaf shape and size, overall appearance and stevioside content. Selection has produced many varieties. Off-types occur frequently in most populations, being one reason for the traditional vegetative propagation. Many varieties produce very little or no viable seed.

Some breeding and selection programs overseas, especially in China, have resulted in varieties which also produce good quality seed. This seed is always then sown into nursery areas for later transplanting. Breeding and selection programs have also produced varieties with higher total stevioside content of 14 – 16% of leaf dry-matter compared to the common lines of 8 – 10%. Stevioside quality has also been improved (quality is a measure of taste and is usually defined as the ratio between the glycosides Rebaudioside-A and Stevioside).

Availability of seed limits the choice of varieties for Australia. The ‘best’ varieties have not yet been identified for possible growing areas here. In future, seed production of selected lines may be possible in Australia, although mechanised production would be required. Because seed size is extremely small (1 – 2 million/kg), freight on seed is not an issue but seed quality (germination) is.

**Agronomy**

Experience in Australia is limited and overseas growing practices are the best guidelines. Seed can be difficult and very slow to germinate and initial seedling growth is also slow; therefore seedling production is best left to experienced nurseries. A clean seed bed for planting into is essential to reduce weed problems. No chemicals are registered for weed control in stevia; there are suggestions that “Fusilade” and “Treflan” may be suitable. Overseas, hand weeding is generally used. Planting time should avoid the risk, for the first month, of hot weather (over 30°C) or waterlogged soils. In northern Australia a March to May planting out may be best.

Plant densities of 50 – 80,000/ha should be aimed for, with 20 – 25cm between plants in the row. Row spacing will depend on equipment used. Planting under plastic mulch has been successful in controlling weeds but plastic may interfere with mechanical harvesting (picking up) and could also restrict crown development and multiple stem production for second or subsequent ratoons.

Fertiliser requirements are moderate, at 50 units of N, 25 of P and 50 of K per year, with a maximum of twice that sometimes being suggested. Fertiliser is best split into two to four applications and can be applied through the irrigation water.

Irrigation is essential; small quantities frequently may be required after transplanting, with the irrigation interval being increased once seedlings are established. Underground trickle irrigation works well, especially in hotter, northern areas. Sprays can be used, although large travelling irrigators are likely to damage plants with their large droplet size.

Harvesting is required when flowers appear or when the lower leaves start to dry off. Stevioside content in the leaves falls when they dry on the plant as well as when flowering commences. Topping of seedlings early after planting out will induce more branching. Harvesting will also induce branching and multiple stems. In moist, tropical areas (17oS) the first harvest can be as early as 6 weeks after planting out and the next harvest 6 – 8 weeks later, before the longer days reduce the problem of premature flowering. Varietal selection may, in future, overcome early flowering. In cooler regions, with longer days in summer, two to three harvests a year can be expected.

Plants are expected to ratoon for three years before replanting is required. First crop plants may be susceptible to lodging. Multiple stems with subsequent harvests help make the plants less liable to lodging.
Pests and diseases

Pests and diseases are not expected to be a major problem. Young seedlings, especially in the first one to three weeks after germination, are susceptible to insect damage and protection is required. Once established, insect damage is not common, although a few caterpillars have been seen to chew the occasional leaf. The leaves are probably too sweet for most insects.

Fungal diseases have been recorded in moist conditions, hence the suggestion to avoid spray irrigation in the tropics. Young seedlings can be susceptible to soil fungi in overwet and warm conditions (possibly Phytopthora, Rhizoctonia or Sclerotinia). Some sudden death of healthy young seedlings has occurred in Australia. Mature plants seem to be much less susceptible to disease.

Harvest, drying and handling

Harvest yields of 2 tonnes dry weight of leaves per hectare per harvest are commonly recorded overseas. The leaf to stem ratio varies between 45% and 65% of leaves. At 50%, 2 tonnes of leaves is 4 tonnes of total stem and leaf (‘hay’). This is a relatively light hay crop which could be dried quite readily in the field. Provided humidity is low, drying in under twenty-four hours and sometimes ten or twelve hours is possible. Mowing with a conditioner to crush the stems, which is not done with hand-harvesting, will hasten drying.

The best equipment and method of picking up the dried crop is not yet known, as it has not been trialled in Australia. A conventional round baler may be adequate but leaf loss will need to be watched. If beds are mulched with plastic or weed mat, this may interfere with picking up; suction or airdraft collection may be more appropriate. Because dried leaf is worth about $2,000/t, any leaf loss is expensive and wrapping of bales for transport may be desirable.

As with any hay, drying needs to be carried out quickly to retain stevioside quality. If stored without adequate drying, leaves and stems can quickly (2 – 4 hours) overheat and thus lose quality. Once dried, stevia can be stored in the dry for long periods (years) without loss of quality.

The location of processing facilities could influence the type of handling and transport. There are no stevioside extraction facilities in Australia at present. The use of sugar cane processing technology and equipment is being considered in Queensland, although equipment at most sugar mills will be too big for stevia.

Table 1: Crop Costs per Hectare

<table>
<thead>
<tr>
<th>Item</th>
<th>First Year $</th>
<th>Second &amp; Third Year $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land preparation/cultivation</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>Bedding</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>Herbicides</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Seedlings &amp; planting out</td>
<td>6,500</td>
<td>0</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Irrigation, water &amp; pumping</td>
<td>200</td>
<td>250</td>
</tr>
<tr>
<td>Labour, weed control etc</td>
<td>300</td>
<td>1,000</td>
</tr>
<tr>
<td>Harvesting (per ha contract x 3)</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Freight (4 t leaf = 8 t hay @ $37/t)</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Sundry</td>
<td>1,300</td>
<td>500</td>
</tr>
<tr>
<td><strong>Total cost for the year</strong></td>
<td><strong>10,100</strong></td>
<td><strong>3,450</strong></td>
</tr>
<tr>
<td><strong>Total 3 year cost</strong></td>
<td><strong>17,000</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Average cost/year</strong></td>
<td><strong>5,600</strong></td>
<td></td>
</tr>
</tbody>
</table>

Note: Excludes cost of irrigation system, any herbicides and artificial drying.

Financial information

There is no experience or hard data in Australia on which to base financial forecasts of income or expenditure.

The largest cost (Table 1) will be associated with the purchase and establishment of seedlings, which are likely to cost about ten cents a plant planted out. As this cost can be spread over more than one year, it would be a significant cost saving if the crop ratooned for three years and not one or two.

Harvesting and drying costs will be reasonable if harvest is fully mechanised and the crop can be sun-dried in the field. If artificial drying is required, for example in the wet tropics, then this cost will be much higher. Transport costs...
of dried stevia to the processing mill will depend on where the processor is located and this is not yet known.

Income estimates (Table 2) are even harder to forecast than costs because at present there is no established market for stevia leaves in Australia and the basis on which growers would be paid is unknown. It could be assumed that payment will be based on stevioside content and quality. The payment could be based on a percentage of the stevioside powder wholesale price, at perhaps 65%, or could be a negotiated fixed price for a season.

The estimates in Table 2 show returns if the grower receives 65% of a ‘low’ price or an ‘average’ price. Annual yields are not known at this stage and a range of possible yields is used. If prices are not ‘low’ and good yields and quality are obtained then there is potential for a reasonable profit. If prices and yields are not good there is, as with other crops, a fair chance of a loss.

### Reference


### About the author

Andrew Rank (B.Ag.Sc., Dip.Agr.Ext.) has been an agricultural consultant for over thirty years. Experience has included farm level dryland crop, livestock & irrigated production in low rainfall, temperate and tropical regions as well as regional & industry level planning, development, research and economic projects in Australia & overseas. He first became aware of stevia in 1984 in SE Asia and, with CQU, has been researching it since 1999. He visited some production areas in China in 2001 and is co-ordinator, for CQU Plant Sciences Group, of a RIRDC funded stevia project, which includes fifteen growing sites from the Atherton Tableland, Qld, to Burnie, Tasmania.

### Table 2: Crop Income/Year/Hectare – Variable Yields & Prices

<table>
<thead>
<tr>
<th>Yields</th>
<th>Low Price ($20/kg)</th>
<th>Average Price ($30/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 t leaf @ 10%    = 200 kg St/ha</td>
<td>4,000 $</td>
<td>6,000 $</td>
</tr>
<tr>
<td>2 t leaf @ 15%    = 300 kg St/ha</td>
<td>6,000 $</td>
<td>9,000 $</td>
</tr>
<tr>
<td>4 t leaf @ 10%    = 400 kg St/ha</td>
<td>8,000 $</td>
<td>12,000 $</td>
</tr>
<tr>
<td>4 t leaf @ 12.5% = 500 kg St/ha</td>
<td>10,000 $</td>
<td>15,000 $</td>
</tr>
<tr>
<td>6 t leaf @ 10%    = 600 kg St/ha</td>
<td>12,000 $</td>
<td>18,000 $</td>
</tr>
<tr>
<td>6 t leaf @ 12.5% = 750 kg St/ha</td>
<td>15,000 $</td>
<td>22,500 $</td>
</tr>
</tbody>
</table>

Note: Yields in second & third year are likely to be higher than first year. St = total steviosides content of leaves.
Table olives

Acknowledgement is given to Susan Sweeney and Gerry Davies, the authors of the chapter on the olive industry in the first edition of this publication.

Introduction

Table olives are popular with Australians. Most table olive products eaten by Australians come from Spain and Greece. Table olives either whole, cracked, stuffed, marinated or incorporated into pastes, are eaten with bread and cheese, with salads and cold collations and cooked foods.

Australia is now emerging as a significant table olive producing country. The development of the table olive industry must be considered in a national and international context because of its potential economic importance. The success of the Australian table olive industry will depend on capturing a significant proportion of the domestic market and the development of international markets. To date, only relatively small amounts of Australian table olive products are available and these for predominantly domestic consumers. Production however, estimated at around 4000 t/year, is increasing. Some processors are targeting international markets. Sustained growth of the table olive industry will depend on advances in efficient production and market development.

Table olive activities can be divided into four categories:

- growing
- primary processing
- secondary processing
- marketing.

Since 1995 there has been intense interest in the commercial potential of an Australian olive

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Stanley Kailis and David Harris

Figures and maps illustrating regions with table olive varieties and supporting boutique scale table olive enterprises. Regions of existing and emerging small to medium scale table olive processing activities.
industry. Major olive plantings have already been established in New South Wales, Victoria, South Australia, Queensland and Western Australia, although accurate statistics on plantings or productive olive trees in Australia are unavailable.

One estimate is that around 8.5 million trees have been planted. Current production of raw olives is low because many of the trees have not reached their commercial potential. Based on an average seasonal production of 25 kg of olives/tree, the potential table olive crop is 20,000 t/yr representing only 1% of the world production which in the export market is of greater significance. There can be an overflow in olive production between table olives and oil production. However there are some specialised varieties that are low in oil and can be used predominantly for table olive production. It is envisaged that the two industries will coexist with high quality hand picked olives being used in table olive production and culls and oil specific olives used for olive oil production.

### Markets and marketing issues

Australian table olive products are mostly marketed by processors to the food services industry in bulk, or through specialty food outlets. The olive industry, like the wine industry, has adopted tourism as a major strategy in marketing table olive products with other foods in regional Australia. Uptake of Australian table olives by national supermarkets has been slow due to high prices, low levels of availability and a lack of products such as pitted and stuffed olives. It is expected that existing imports will persist because of traditional trading patterns of importers, wholesalers, retailers and consumers. Competition from other Southern Hemisphere producers is another threat.

Currently most olives come from South Australia and Victoria. This will change when recently planted orchards in Western Australia, New South Wales and Queensland reach commercial production levels. A number of olive enterprises are making substantial investment in table olive production facilities.

World table olive production reached a record level of 1,748,000 t for the 2002/2003 season representing an increase of more than 18% on the previous season and more than 30% increase compared to the average of the previous four seasons (Table 1). For the same period the European community (EC), Turkey and Syria produced over 60% of the worlds’ table olives with the USA, Morocco, Algeria and Argentina also being significant producers.

Table olive consumption has also increased markedly with the EC, USA and Turkey accounting for 60%. Exports for the 2003/04 season are expected to be around 481,000 t representing 33% of world production, with the EC, Morocco, Turkey and Argentina

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<td>4.5</td>
<td>17.5</td>
<td>Negligible</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 1. Table Olive Statistics in Tonnes x 1000

![Australian table olives](image)
accounting for nearly 90%. Major importing countries were the USA, EC, Brazil and Canada accounting for 65%.

Imported table olives, black and green, are either sold in bulk by wholesalers to the food services industry or repackaged by third parties into consumer size quantities and sold at retail outlets. The latter includes all types of olives, olive pastes, tapas and hors d’oeuvres.

Australians consume around 0.7 kg of olives/person/yr, making them one of the largest consumers per capita outside those living in and around the Mediterranean. Australian table olive imports have nearly doubled since 1992/93. This marked increase is a significant indicator as to the popularity of olives in Australia and is a clear indicator for Australian growers and processors as to demand. Australia accounts for 3% of world table olive imports, 13,000 t in the 2002/03 season with a value of nearly $40,000,000, mostly from the EC which account for nearly 6% of their exports. For the 2003/04 period, production of Australian table olives is expected to be 4,500 t, a 12.5% increase over the previous season. Export of Australian table olives is negligible.

**Production requirements**

Australia has the physical resources, horticultural infrastructure and food processing expertise to support a modern table olive industry.

The olive, *Olea europaea*, produces fruit when winter temperatures fluctuate between 1.5°C and 18°C and summers are long and warm enough to ripen the fruit. The trees and fruit can suffer severe damage at temperatures of minus 5-10°C.

Hot dry winds at pollination may reduce fruit set and productivity, may desiccate young trees and break limbs in mature trees. Most Australian olive groves are irrigated or can be sustained by rainfall (600 and 800 mm/yr). Rain at pollination may reduce fruit set and productivity. Olives can withstand drought, though fruit production is reduced. Hail or frost damaged olives are unsuitable for table olive production.

Olive trees will grow in most soil types as long as these are well draining and not prone to water logging. Soils that are slightly acid to near neutral are advantageous. Planting sites with slight slope facilitate both air movement and water drainage as flat areas with poorly structured soils are susceptible to waterlogging. As steeper slopes are prone to erosion planting should be along contours. Olive trees require direct sunlight for growth, initiation of fruit buds, fruit yield and quality. Radiation levels in Australia are often more than sufficient for olive fruit production and only a problem when trees receive substantial amounts of shade. To maximise radiation, olive trees are best planted on north facing slopes with tree rows in a north - south orientation.

Olive trees bear fruit 2–3 years after planting depending on planting stock age. Pollination and fruit set occur in late spring, fruit grow over summer and ripen during autumn/winter. Seven to ten years after planting, trees can produce 25 to 50 kg olives/tree and possibly up to 100 kg olives/tree, depending on alternate bearing patterns. Poor cropping over three successive seasons indicates a major problem with the grove and, if this cannot be corrected, it signifies poor commercial prospects.
Key messages

- World table olive production is increasing
- World table olive consumption is increasing
- Australians are eating more table olives
- Australian table olive production is increasing
- Australia needs to target national and international table olive markets

Key statistics

- World production of table olives (2002/03) 1,748,000 t
- World consumption of table olives (2002/03) 1,657,000 t
- Australian production of table olives (2002/03) 4,000 t
- Australian consumption of table olives (2002/03) 17,000 t
- Australian exports of table olives (2002/03) negligible
- Australian imports of table olives (2002/03) 13,000 t

Varieties/cultivars

Numerous Australian olive nurseries service the industry. Subject to agricultural and quarantine requirements olive trees are traded interstate. Olives are propagated as self-rooted cuttings and by grafting onto seedlings or clonal root-stock. The latter are used for difficult to root varieties eg Kalamata and Sevillana.

Commonly processed table olive varieties include Kalamata, Verdale, Manzanilla, Sevillana and Hardy’s Mammoth. Common olive varieties from nurseries include:

- large olives - Sevillana, Barouni, Jumbo Kalamata, Hardy’s Mammoth, UC13A6
- medium size olives - Kalamata, Conservolea (Volos), Barnea, Leccino, Manzanilla, Picual, Mission (Californian) and Verdale
- small olives - Frantoio (Paragon, Corregiola, Mediterranean, New Norcia or WA Mission) and Arbequina.

There is scope for the development of new varieties and the introduction of new to industry varieties eg Chalkidiki, Nocellara del Belice and Taggiasca. Most Australian olive orchards have 4 to 6 varieties. With single variety orchards eg Kalamata or Manzanilla, pollinators may improve productivity.

Cultural practices/agronomy

Although the olive is a hardy species it requires a high level of management to yield well. Soils should be assessed for pH, nutrient and organic matter levels and corrections made before planting. The orchard floor is prepared by deep ripping, especially with duplex and heavy soils. Trees are planted in rip lines and supported with stakes at spacings of 8 m x 5 m. Larger olive groves have substantial irrigation installations. Where water is readily available, 2-5 ML of water/ha/yr is distributed at the appropriate times particularly during flowering and fruit set and prolonged dry periods. For mature olive trees, 250 trees/ha, yields should range from around 10 to 20 t/ha depending on water availability. Newly planted olive trees require 10 L/tree/week whereas mature trees require a seasonal average of 500-800 L/tree/week.

Once planted, the olive trees are trained to a maximum height of two metres as a vase shape with a single trunk to facilitate management and hand harvesting. During the establishment period trees must be observed for vigour as well as the presence of any pests or diseases. Once the desired canopy structure is achieved the olive trees should be pruned to maintain canopy shape and to ensure tree health by allowing air circulation and light penetration.

Painting the trunk with latex paint or placing protective paper or foil wrapping around the trunk protects young trees from sunburn or herbicide damage. Competition from weeds, around the trees and in the alleys, a potential problem for young trees, is easily managed by either regular mowing, planting legume cover crops for green mulch, spraying with herbicides or to a lesser extent by tilling.

Because olive trees are often planted as 1 to 1.5 year old trees, most varieties will commence production within 2 to 3 years after planting. The time from planting to first harvest is dependent on variety and management techniques. Most olive varieties will take at least 4-5 years to reach full production.
years to bear commercially useful crops but longer if not cared for properly.

Olives will respond to fertilisers and it is important to take regular soil and/or leaf samples for nutrient analysis especially around December/January to ensure the correct balance of macro and micronutrients.

During establishment, trees need nitrogen additions but once productive, nitrogen, phosphorus and potassium are required. These can be supplied by broadcasting the fertiliser around the trees half in autumn and half in spring or through the irrigation system.

Deficiency of specific elements in the soil eg boron or potassium can also reduce productivity.

**Pests and disease control**

Australia has been considered relatively free of olive pests and diseases. However since the resurgence of the Australian olive industry, several unexpected problems have emerged.

Pests and diseases include black olive-scale, peacock spot and olive-lace bug, curculo-ewevel (beetle), birds and animals and soil pathogens such as phytophthora, nematodes and *Verticillium*. Some growers have also reported olive fruit damage, soft nose, by the fungus anthracnose.

To date, olive fly and olive moth have never been found in Australian olive groves. Some indigenous insects attack young trees and olive fruit. Mediterranean fruit fly is a potential problem for the olive. In drier areas, such as in Western Australia, Rutherglen bug and grasshoppers can attack young trees.

Very few chemicals should be needed for successful olive cultivation. All of these problems can be controlled but they should be positively identified and expert advice on management sought to minimise indiscriminate spraying of broad-spectrum insecticides that will also kill beneficial insects.

Correct pruning to allow adequate airflow through the leaves will help keep many problems under control. Copper sprays applied after harvest and pruning to the tree canopy can be used as a general antifungal treatment. Olive trees are also harmed by some soil-borne pathogens eg. phytophthora and nematodes that damage roots resulting in die-back. If the site has been previously used as an orchard the soil should be tested for these organisms and treated under agricultural agency direction.

Integrated pest management strategies (IPM) using cultural techniques and safe chemical sprays such as *Bacillus thuringiensis* should be adopted. A number of additional pesticides and fungicides have been approved for use with olive trees. Petroleum oil for scale insect pests, Natrasoap for lace bug; copper hydroxide or copper oxychloride for various leaf spots and fruit rots in olives; granular metalaxyl for phytophthora root and crown rot in potted nursery trees; glufosinate-ammonium, fluazipop-p-butyl or pendimethalin for weed control; chloropyriphos for ants (around the tree butt), African black beetle (as a drench around the tree base) and light brown apple moth (foliar spray on non bearing trees); methidathion for scale insects; dimethoate for lace bug, green vegetable bug and Rutherglen bug; fenthion for lace bug, green vegetable bug, Queensland fruit fly and Mediterranean fruit fly; and Alpha-cypermethrin as a but drench for curculio beetle and cutworms.
Harvesting/handling/postharvest treatments/processing requirements

Table olives are mostly picked by hand. Harvesting with hand or mechanised rakes, tree shakers or overhead harvesters bruise olives leading to gas pocket spoilage and soft olives when processed. More serious damage occurs with black olives. Immersing machine harvested green-ripe olives into weak lye solutions within 20 minutes at harvest limits bruising however, this is not widely practised.

With future heavier olive crops serious consideration must be given to selecting varieties with “tough” skin and developing mechanised harvesting technologies that do not damage the olives. Costs for hand harvesting olives are $1.5 - $2/kg depending on the variety, tree shape and height, climate, availability of labour and distance from major community facilities. Machine harvesting estimated at 30 cents/kg would therefore radically reduce table olive production costs.

Olives are processed over three stages of ripeness:
- green-ripe
- semi-ripe or turning colour
- naturally black ripe.

Olive ripening is characterised by increased fruit size and change of skin (green to yellow to reddish - violet to a deep violet) and flesh (green to violet) colour. Harvest time depends on whether green, semi-ripe or ripe olives are required. Small crops of the same variety always ripen quicker than large crops and generally ripen faster in northern areas of Australia than southern areas. Green-ripe olives are ready for harvesting in summer/autumn whereas naturally black-ripe olives are ready in autumn/early winter. Under some growing conditions some olive varieties never fully ripen. When large olives are required the crop is thinned by hand or with chemicals. As yet chemical thinning of olives is not permitted in Australia.

To determine the harvest time for green table olives, the fruit and flesh should be a straw-yellow colour and when squeezed produce a creamy oily juice. Naturally black ripe olives should be picked when the flesh is nearly fully pigmented. Fully pigmented olives when processed produce soft products. Completely black ripe olives are best for dried olives.

Careful post harvest handling of olives is essential for high quality table olive products. Bruised or marked raw olives fetch low prices compared to good quality olives. Harvested olives should be placed into small slotted crates (eg 25 kg) that allow adequate airflow and kept in shade to avoid over-heating and sunburn.

Olives stored in packing sheds or processing facilities should be kept between 5°-10°C under clean and hygienic conditions to minimise the risk of contamination or damage. Transporting olives over long distance should be undertaken at the coolest part of the day or in temperature controlled vehicles. Green-ripe olives generally store better than naturally black ripe olives.

Harvested olives are processed as soon as possible to avoid deterioration by oxidation and fermentation. Olives are washed, graded and placed into tanks where they undergo debittering. Primary processing involves debittering and preserving the olives.

Common primary processing methods include:
- prolonged soaking in water followed by placement in brine (Greek and Kalamata Style)
- brine fermentation - green, turning colour or black ripe
- treating green olives with lye followed by fermentation (Spanish Style) or treating
Large tanks.

green olives with lye without fermentation (Picholine Style)

- treating green olives with lye followed by aeration changing their colour to black (Californian Style)
- drying olives on the tree, by salting or heat (Date olives).

Secondary processing adds value to the olives. Here wine vinegar, vegetable oils (olive, canola, sunflower), herbs and spices are added to enhance flavour. Other forms of secondary processing are pitting and stuffing the olives with fillings such as paprika, peppers, almonds, garlic, anchovy or cheese. Ground primary processed olive flesh is used for olive pastes and tapenade.

Apart from dried olives, most olives are packed in salt brine. Here the final product must meet quantitative, qualitative and health standards before being released for sale.

Processing facilities require careful planning with respect to processing methods and capacity. Facilities and processing procedures must meet occupational health, safety and environmental standards. All equipment must be constructed of food grade material that can be easily cleaned and sanitised. Only potable water and food grade chemicals must be used. Processing barrels or tanks vary in size with some exceeding 15 t. Attention needs to be paid to loading and unloading olives. Fermentations are undertaken between 20°C and 30°C so temperature control is essential. Only a single variety and at a specific maturation state is processed in the same tank. Continuous records should be kept and the process controlled especially pH, salt levels, microbiology and spoilage. All operatives need to be trained in food processing methods, handling chemicals and processing olives. Total quality management and HAACP systems should be in place. A small processing plant with a capacity of 20 t of olives can cost from as little as, $50,000 to $100,000 to establish whereas large scale facilities of 500 t or more will cost between one and two million dollars depending on the level of sophistication. Ancillary equipment and facilities such as waste disposal, pumps, sorting tables, graders, de-pitters, bottling lines and testing laboratory can account for at least $300,000.

In Australia, primary processing of olives is undertaken by boutique, small and medium scale operators see Table 2. Kalamata style olives are very popular with Australian consumers as are stuffed and marinated olives. Tapenade and olive paste production is popular. Current processors are mainly interested in using brine fermentations rather than methods with lye. This view may change as availability of raw olives increases especially for green olive processing. Lye treatments speed up processing but use larger amounts of water and energy than traditional methods involving brine fermentation.

Financial information

Financial information relates to both growing olives and olive processing. Australian olive orchards range from boutique to

### Table 2. Indicative scale of future Australian table olive enterprises*

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<th>Size of Operation</th>
<th>Capacity in Tonnes/Season</th>
<th>Olive Trees Required*</th>
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<td>Boutique</td>
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<td>Less than 200</td>
<td>1 Ha or less</td>
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<td>Small-Scale</td>
<td>5 to less than 100</td>
<td>200 to less than 4000</td>
<td>1 - 16 Ha</td>
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<td>Medium-Scale</td>
<td>100 to less than 500</td>
<td>4000 to less than 20,000</td>
<td>16 - 80 Ha</td>
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<tr>
<td>Large-Scale</td>
<td>Greater than 500</td>
<td>Greater than 20,000</td>
<td>Greater than 80 Ha</td>
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</table>

* based an average seasonal crop of 25kg/tree
large-scale intensive plantings. Boutique and small-scale operations are often associated with vineyards and wineries and have between a few hundred to around 5,000 olive trees. Medium scale orchards range from 16 to 80 ha, whereas large-scale olive operations have more than 20,000 trees. To date most table olive production in Australia ranges from boutique to medium scale. There are no large-scale table olive producers in Australia.

Establishment of new olive groves involves decisions on site selection, planting stock, horticultural management technologies as well as obtaining planning, environmental and water licence approvals from statutory agencies. Establishment costs will vary considerably for each olive orchard depending on the cost of land, irrigation head-works and special soil preparation. Planting stock costs between $5-$10/tree. Irrigation systems vary from $1,000 to $4,000/ha depending on design and installation expenses. With a further $1,000/ha for ripping and soil amendments, establishment costs lie in the order of $3,000 to $7,500/ha for a planting density of 250 trees/ha ie up to $30/tree.

Growers can on-sell their best fruit to table olive processors, undertake primary processing and on-sell the processed olives in bulk quantities, undertake vertical integration - growing, processing and marketing or any combination of these.

Annual gross return for raw olive production is determined by tonnage, variety, size, consumer preference and price. Assuming a planting density of 250 trees/ha and 50 kg of fruit/tree will yield 12.5 t of olives producing around 3,500 jars of table olives.

Using a price of $1.5 to $2/kg for hand picked olives (Kalamata and large olives fetch premium price) would give a gross return of $18,750 to $25,000/ha. Production costs (pesticide, pruning, fertiliser, irrigation, herbicide and picking) are $8,500/ha for hand picked fruit. This gives a gross margin of $10,250 to $16,500 ha/yr.

Little quantitative information is available on the economics of Australian table olive processing such as establishment and processing costs. Currently Australian processed olives wholesale in bulk quantities from around $8 to $10/kg and retail from $6 to $10/jar depending on variety, style, packaging and container size. Imported olives cost around $3/kg. Wholesale mark-up margins for Australian olives are around 40% and retail margins 50%. Value added products such as tapenade and olives in marinade fetch higher prices than plain olives. Excluding the cost of olives processing costs are of the order of 50 cents to $1 depending on the processing method.

The major risks to financial viability being crop losses due to climate variations, international table olive prices and volume of domestic supply. Other threats are competition for resources from other horticultural agencies and the introduction of exotic pests and diseases.

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**Key references**


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Professor Kailis is Professorial Fellow at the School of Plant Biology University of Western Australia and a Fellow of Curtin University of Technology WA. He holds qualifications in Science, Pharmacy and teaching and holds a doctorate in science. His antecedents came from the Greek island, Megisti and he was introduced to table olives by his grandmother Kostantinia. His interests focus on quality aspects of olives. Stan has made presentations on olive growing, olive oil and table olives at national and international forums and to industry groups. He has published numerous research papers in national and international journals. He has conducted many schools and workshops in Australia on olive growing, olive oil and table olive production, organoleptic evaluation of olive products and olive propagation.

Dr David Harris is Principal Chemist at the Chemistry Centre (WA) and is section leader of the Food and Agricultural Chemistry Section. He gained a doctorate degree in chemistry specialising in organic chemistry in 1976 in Canada. His main interest is research into the organic compounds present in legumes and pulses as well as pasture legumes, over the last five years he has become very interested in food safety and quality in Western Australia. Working with Professor Kailis over the last few years has aroused a keen interest in table olives and olive oil with regard to the chemistry associated with their production. David has presented papers at a large number of international forums and has published numerous papers in national and international journals.


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Table olives
Truffles

Duncan Garvey

Introduction

The French black truffle is the fruiting body of the ectomycorrhizal fungus *Tuber melanosporum*. The fungus is an ascomycete of the family Tuberaceae, order Tuberales. It is a native to southern continental Europe, occurring predominantly in the southern regions of France, and northern regions of Italy and Spain.

The truffle is produced when the spores of the fungus attach to the roots of oak and hazel trees to form a symbiotic relationship. The edible portion or fruiting body forms during autumn, and harvesting takes place in the winter once the French black truffle has matured.

The truffles which are formed in the top 20 cm of the soil are harvested manually after using dogs or pigs to detect their presence by the perfume they emit at maturity which occurs in the Northern Hemisphere winter months of December, January and February.

Current estimated annual production ranges from 50 – 80 t/annum from three principal sources being France, Italy and Spain. Typically, 60% of production is consumed fresh.
over the four month season with the remaining 40% of production preserved or used in value adding with other foodstuffs. Truffles produced in Europe are distributed to the finest restaurants in the world.

Towards the end of the last century, France produced up to 1000t of French black truffles from more than 20 departments located in southern France. Since this period, output has fallen continuously, with some slight variations to a level of combined production from France, Spain and Italy of 50-80t annually. The causes of this decline in production are many including; abandonment of land cultivation; wartime destruction of trees; planned deforestation; and acid rain.

As one of the great mysteries of the gourmet food industry, truffles are much sought after by the world's leading chefs and gourmets. When available fresh in the Northern Hemisphere winter prices can exceed $AUD3,000/kg in a season of poor harvest.

Established in 1992, Perigord Truffles of Tasmania (PTT) is a private company owned by directors Duncan Garvey and Peter Cooper. PTT has been established to capitalise on the opportunity to supply French black truffles fresh into the traditional truffle markets of the world, six months out of season.

Focusing on the on the colder agricultural areas in South eastern Australia truffières now have been established in Tasmania, and the colder areas of NSW and Victoria.

Marketing

The truffle markets in France have remained unchanged for centuries and are very much part of French culture. The first point of sale for the truffles is the traditional truffle market, which spread across the main production areas in the Perigord and the Provence. The key markets in the areas are held weekly in the small villages. In the Perigord region the markets are in Lalbenque and St Alvere, in the Provence region where up to 70% of production occurs the market towns are Richerenches, Vaucluse, Carpentras and Vars.

The truffles are presented in plastic bags or small baskets and generally are unwashed and not graded. The quality of the truffles sold at these markets varies considerably from the perfect shaped fresh truffles to broken, badly frosted types.

The traditional market is the first stage in the distribution chain for truffles. The truffles purchased from these markets by the wholesalers and processors are then transported back to premises where they are cleaned and graded.

In France the restaurants either purchase their fresh truffles directly from the markets or through the wholesalers. Due to the limited shelf life of the product the wholesalers distribute the truffles very quickly.

The fresh truffles, which are exported, are distributed through importing agents in the respective countries. The importing agents handle all the importing protocols and distribute to the individual restaurants.

The value added or processed truffles are distributed through fine food outlets in both France and other countries. Similarly to the fresh truffles, the importers handle the distribution in their countries.
PTT’s objective is to be the principal supplier of French truffles in the Southern Hemisphere.

As the industry expands the company will be strategically placed in the Australian domestic market and will capitalise on its market research already undertaken and will have markets firmly established in Europe Asia and the United States of America. Market research and product evaluation has already commenced on developing a range of value added truffle products in association with Chef Tim Pak Poy, Claudes Restaurant, Sydney.

Therefore growers purchasing trees from Perigord Truffles of Tasmania will have the opportunity of having their truffles marketed under the company’s brand name. We firmly believe that a coordinated approach to the harvesting and marketing of the truffles will ensure maximum returns on production.

Production requirements

The major production area in Europe is the Provence region of south east France and the Perigord region the south west of France.

The areas of production in France have warm springs, which is important for the truffle initiation and cold winters with regular below 0°C frosts. The areas regularly have summer droughts and high summer temperatures.

Suitable climatic conditions are important for the production of French truffles. The cold winters are important for the maturation of the truffle. The French truffle matures as the soil temperature decreases through the autumn and winter. So regular frosts and cold periods are very important to produce French truffles of high quality with good perfume.

In France the truffles are produced in the calcareous soils rich in calcium and high soil pH's.

Soils need to be free draining and well structured and ideally with low phosphorus levels.

The key issues with respect to the soils physical characteristics are drainage, structure texture and porosity. Soils with high clay content in the sub soil, which restricts drainage through the soil profile, are deemed not suitable for French truffle production.

Access to a good source of irrigation water is very important, as soil moisture is very important at different stages of the truffle lifecycle.

Host tree varieties

In France the tree species used as host trees in the French truffle industry are a range of oak trees *Quercus* and hazelnuts *Corylus*.

PTT produce hazelnut *Corylus avellana* and two oak species deciduous oaks (*Quercus robur*) and evergreen oaks (*Quercus ilex*).
Based on scientific and anecdotal evidence the hazels will commence truffle production earlier than the oak trees. Typically PTT recommends the truffières be established with all three species.

**Pest and disease control**

There are two issues with respect to truffle production; firstly pests and disease of the host trees and the potential contamination of the truffle fungus.

The oaks and hazels are very much disease and pest free in the truffières established thus far.

PTT try and avoid any use of insecticides and fungicides on the trees unless absolutely necessary.

There is a potential that any applied pesticide could have a detrimental effect on the truffle fungus.

Ectomycorrhizal fungi associated with many Australian trees such as eucalypts, wattles, blackwoods etc and many introduced trees such as willows, poplars and pines can potentially contaminate the inoculated truffle trees. The result is the invading fungi will occupy root space on the inoculated truffle trees and replace the slow growing *Tuber melanosporum* from the root system.

It is very important that the truffières are established well away from other trees, which can host other ectomycorrhizal fungi.

All the truffières are fenced to stop the transfer of competing fungi being introduced by native grazing animals.

**Harvesting**

The traditional method of harvesting in France is to use a trained dog to indicate the presence of a truffle to its handler. The animal is directed along the rows of trees and upon detecting the scent of a mature truffle is taught to indicate its presence by scratching on the soil surface above the truffle, which is then carefully excavated by the handler.

It is usually the case that dogs used by truffle harvesters in France are household pets, but due to the scale of operations and the contractual arrangements of the joint venture, PTT has adopted a strategy of owning, training and housing all dogs used for its harvesting operations.

PTT has contracted Mr. Steve Austin, one of Australia’s leading dog trainers to advise and assist in the selection and training of both dogs and their handlers. His having held the contract to train all AQIS detector dogs and their handlers in recent years evidences Mr. Austin’s expertise.

Handlers are introduced to the principles of handling and are then allocated a dog 2 to 3 months prior to the start of the season in which they reinforce the training procedures required. They are assessed on their ability and relationship with their dog regularly. They then accompany an experienced handler and dogs through the season.

The new team is given first opportunity to search a truffière, followed by the proven team who provides a check on the progress and ability of the new team until the new team is detecting truffles with the same efficiency and reliability as the proven team.

PTT currently has ten trained and proven dogs and will expand the number as required to service truffières, as they become mature enough to begin production. It is anticipated that PTT will require 60 dogs and 30 handlers over a 4-month season from May to September to harvest truffles. All the truffières are inspected weekly over this period.

PTT have developed a mapping extension using a geographical information system (GIS) Arcview 3.2.

Truffle harvesters in Northern Tasmania (Photo: Peter Whyte)
During the truffle harvest details include tree type, date of harvest, truffle weight and quality, distance from tree, depth in the soil and angle from tree.

The development of the program has allowed for the information to be displayed spatially for easy accessibility. The information can now be analysed readily to investigate relationships between truffle yield and other parameters such as tree species, lime treatments, soil types, irrigation regimes etc.

Once harvested, truffles are weighed and transported daily to a central location where they are cleaned and graded ready for dispatch.

The strategy is to have the truffles delivered to the restaurants in Australia within 24 hours of harvest, to ensure maximum freshness.

Financial information

The company has conservatively estimated yield in a well managed trufferie to be 60 kg/ha once the trees reach maturity in year 8-10.

Yield estimates are conservatively based on what is achieved in well managed and irrigated truffières in France and from a limited experience in New Zealand.

PTT have budgeted on truffle production commencing in years 5-6 and yield increasing as the trees reach maturity. In France truffles have been harvested from oak trees over one hundred years and from hazels established in truffières after 25 years.

As with any agricultural pursuit many factors can effect the level production and success of the enterprise. The production of French truffles is no different and there is definitely a risk associated with this venture and the ability to accurately forecast yields and returns.

PTT offer two options for landholders to participate in the production of French truffles.

1. Firstly in a joint venture agreement with PTT supplying an ongoing agronomic advisory service. PTT will be responsible for the harvesting and marketing costs of the truffles, the gross income derived from the sale of truffles will be equally divided between the company and the growers.

2. Non contracted growers, where landholders purchase the trees out right and can utilise the advisory and harvesting services provided by PTT on a fee for service arrangement.

Initial establishment costs are approximately are $21,000/ha. Of this the tree component will range between $8,000 and $12,000 depending on tree density and the ratio of hazels to oaks.

Establishment costs will vary considerably between different sites depending on what infrastructure is already in place with respect to fencing, irrigation and the initial pH of the soil.

Annual maintenance costs are $1,000 - $1,500/ha per annum, which comprises mowing, limited pruning in later years and irrigation.

There is a well established market for truffles in the Northern Hemisphere. The risk in the French truffle industry is one of production rather than of marketing. During the harvests in 2002 and 2003 the truffles produced by PTT have been marketed for $3,000 per kilogram which represents a substantially higher price than the budgeted figure of $1,500.

Key references

Garvey, D.C., Cooper, P.B. 2001 Establishment and production of the French Black Truffle (Tuber melanosporum) in Tasmania. Rural Industries Research and Development Corporation, Kingston, ACT

Garvey, D.C., Cooper, P.B. 2003 Increasing the productivity of truffières in Tasmania. Rural Industries Research and Development Corporation, Kingston, ACT

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Weighing a large truffle
About the author

Duncan Garvey (B Ag Eco, UNE;), Joint Managing Director, Perigord Truffles of Tasmania

Duncan has been working on developing the truffle industry over the past eight years. In this time, he has critically reviewed the literature on truffles, made a number of trips to France to research truffles and conducted market research in Europe, Japan and the United Kingdom.

Duncan Garvey has had extensive experience in Agri-business. After completing studies Duncan was employed as an agronomist. During his time as an agronomist, he developed new cropping opportunities for Tasmanian farmers and was instrumental in extending a number of innovative farm management practices.

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Native foods Overview

Acknowledgement is given to Caroline Graham and Denise Hart, the authors of the chapter on Bushfoods in the first edition of this publication.

Introduction

The native food industry has grown slowly since its inception in the mid 1980’s. Native foods have proven to be difficult to commercialise. They have been difficult to commercialise agronomically, as they are new crops without the benefit of existing established production systems, skills, knowledge and reliable plant material. They have also been difficult to commercialise in the marketplace, as they are innovative products without an established market or general consumer knowledge.

Currently it is estimated that the industry has a gross production value (farm gate and ex-nursery) of between $5 million for native foods (Fletcher, 2003) and $10 million for native food and essential oils from native plants combined (Lester, 2003). It is impossible at this time to extrapolate this to a total “industry” value.

The industry although very small, has four major levels. It is not unusual for individuals or companies to be active in more than one level and may be active in all four:

1. Nursery operators
2. Cultivators and wild harvesters
3. Commodity traders and Value Add-ers (retail and foodservice)
4. Marketers – foodservice, retail – domestic and export

The industry operates within a variety of commercial structures including single-purpose enterprises, networks, co-operatives and vertically integrated supply chains.

Commercial horticultural cultivation of native food species is expanding, however managed wild harvest remains an important and integral part of the commercial supply of native foods.

Table 1 lists, at this stage of the industry’s development, the most commercially utilised native foods. It should be noted that this table represents current industry knowledge but does not take into account plantings that are not yet yielding fruit, leaf or seed product.

The majority of the produce is dried, frozen and/or further processed into value-added products. Native foods are essentially used in the broader food industry as a defining flavour to an existing food product or process; e.g. condiments, sauces, biscuits, ice cream etc.
The main markets for native foods are in the hospitality and tourism foodservice, industrial food manufacturing and retail industries. Within the past two years some native food brands have successfully entered and remained in the mainstream retail market. There has also been significant development in the industrial food manufacturing market both domestically and internationally over the same time frame.

The industry requires an ongoing and targeted focus on the further development of these markets in order to achieve critical mass and anticipated returns.

The native food industry will only succeed commercially in the long term if native food and native food products meet mainstream market needs.

The native food industry continues to face great challenges and must find timely solutions if it is to grow further. These challenges include:

- supply issues – over and under supply – not matched to market demand
- inconsistent and unreliable plant material (yield variability, attrition rates etc)
- establishing efficient and sustainable ways to grow and harvest the crops
- under-capitalisation of the industry in general
- low economic returns to growers through high costs of production and limited markets
- low economic returns to wild harvesters due to climatic and geographic constraints
- low economic returns to processors due to high cost of ingredients and marketing costs in limited markets
- establishing food safety and quality standards
- low levels of co-operation, communication and information sharing within the industry
- identifying appropriate ways to incorporate Aboriginal interests in the native food industry
- increasing homogenisation of food industry which has potential to marginalise niche foods/products
- ongoing product development
- market development and education – native foods are still largely unknown in the domestic and global market place
- establishing a market focus across all levels of the industry.

Some necessary steps towards a sustainable and prosperous growth in the industry are:

- market driven – not production driven
- ongoing research and development in plant selection, sustainable production and post harvest systems (for cultivated and wild harvest)
- uptake across industry of food safety and quality standards
- increasing co-operation, communication and knowledge sharing between all levels of the industry
- product development to meet market needs
- clear and consistent industry marketing messages
- generic marketing initiatives to benefit entire industry.

### Table 1. Commercially utilised native foods - supply status

<table>
<thead>
<tr>
<th>Species</th>
<th>Mainly cultivated</th>
<th>Cultivated/wild harvest</th>
<th>Mainly wild harvest</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aniseed myrtle *</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>under</td>
</tr>
<tr>
<td>Bush tomato</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>under</td>
</tr>
<tr>
<td>Davidson’s plum</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>over</td>
</tr>
<tr>
<td>Kakadu plum</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>over</td>
</tr>
<tr>
<td>Lemon aspen</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>over</td>
</tr>
<tr>
<td>Lemon myrtle</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>over</td>
</tr>
<tr>
<td>Native citrus</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>under</td>
</tr>
<tr>
<td>Native pepper</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>under</td>
</tr>
<tr>
<td>Pepperberries*</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>under</td>
</tr>
<tr>
<td>Native mint *</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>under</td>
</tr>
<tr>
<td>Ribberies</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>under</td>
</tr>
<tr>
<td>Quandong</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>over</td>
</tr>
<tr>
<td>Wattleseed</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>over</td>
</tr>
</tbody>
</table>

* Recent (since last edition) additions to commercial supply
The native food industry offers opportunities at the agricultural level in farm diversification and the development of sustainable and environmentally appropriate agriculture. At the marketing level, native foods offer a unique point of difference to the food industry globally, adding value by product differentiation to potentially every area of food manufacture. There are potential nutritional and functional food benefits and intangible benefits to indigenous and non-indigenous stakeholders.

Dr. Rob Fletcher refers to many of these in his introductory chapter – desire for change, desire for improvement, creating real benefit and an expectation of intrinsic worth in the activity. Aboriginal people who are actively involved in the industry identify social, cultural, economic and health benefits arising from that involvement (Mr John Collyer, Chairperson, Indigenous Australian Foods Ltd). The meaningful involvement of Aboriginal people brings authenticity and integrity to the native foods industry.

**Marketing overview**

**Identifying markets**

All commercially utilised native foods are marketed to the Australian domestic and export markets in four major forms:

- Farm gate commodity product (limited value adding may include drying, freezing, cleaning, grinding etc.)
- Value added into a wide range of industrial food manufacturing flavourings and seasonings
- Value added into a wide range of hospitality foodservice products
- Value added into a wide range of consumer products in mainstream, specialty and tourism markets

There is little or no interest at present in the mainstream market for native foods as fresh fruit or herbs, although this may change as production and post harvest systems are improved.

Table 2 provides some current (2004) indicative farm gate prices for large volume sales. These prices are indicative only and frequently volume users will negotiate a tailored price with suppliers. The pricing may be expressed as a range and may change at any time due to seasonality, shortage of supply, glut of supply etc. The most common forms for each of the native foods are also described in Table 2.

Table 2 illustrates generally high prices for native foods. While these prices may appear attractive to new entrants into the industry, they are based on the high cost of cultivation or wild harvest.

Most food processors and larger scale commodity buyers within the native food industry will usually require tonnage (usually

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**Key messages**

- Market driven – not production driven
- Ongoing R & D in plant selection, sustainable production systems and post harvest systems
- Industry commitment to food safety and quality standards
- Foster co-operation, communication and knowledge sharing between all levels of industry
- Market as an industry as well as individual entities
- Keep commercial reality as focus

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**Table 2. Some indicative farm gate prices (2004)**

<table>
<thead>
<tr>
<th>Product</th>
<th>Form</th>
<th>Current indicative farm gate price/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aniseed myrtle</td>
<td>Dry and milled leaf</td>
<td>$38.00</td>
</tr>
<tr>
<td>Bush tomatoes</td>
<td>Dry whole or ground</td>
<td>$20-24.00</td>
</tr>
<tr>
<td>Davidson's plum</td>
<td>Frozen whole</td>
<td>$2-6.00</td>
</tr>
<tr>
<td></td>
<td>Frozen de-seeded halves</td>
<td>$5-13.00</td>
</tr>
<tr>
<td></td>
<td>Frozen puree</td>
<td>$9-10.00</td>
</tr>
<tr>
<td>Kakadu plum</td>
<td>Frozen whole</td>
<td>$15-20.00</td>
</tr>
<tr>
<td>Lemon aspen</td>
<td>Frozen whole</td>
<td>$8-12.00</td>
</tr>
<tr>
<td>Lemon myrtle</td>
<td>Whole fresh leaf on stem</td>
<td>$2.00-10.00</td>
</tr>
<tr>
<td></td>
<td>Dried and milled</td>
<td>$22-25.00</td>
</tr>
<tr>
<td>Native citrus</td>
<td>Desert lime frozen whole</td>
<td>$5-15.00</td>
</tr>
<tr>
<td></td>
<td>Finger lime whole</td>
<td>$25-80.00</td>
</tr>
<tr>
<td>Native pepper</td>
<td>Dry and milled leaf</td>
<td>$38.00</td>
</tr>
<tr>
<td>Pepperberries</td>
<td>Fresh</td>
<td>$6-20.00</td>
</tr>
<tr>
<td></td>
<td>Dried</td>
<td>$30-70.00</td>
</tr>
<tr>
<td>Native mint</td>
<td>Dried and milled leaf</td>
<td>$35.00-38.00</td>
</tr>
<tr>
<td>Ribberries</td>
<td>Frozen whole, seedless</td>
<td>$13.50</td>
</tr>
<tr>
<td>Quandong</td>
<td>1st grade premium dried</td>
<td>$40-60.00</td>
</tr>
<tr>
<td></td>
<td>Frozen deseeded halves</td>
<td>$25-28.00</td>
</tr>
<tr>
<td>Wattleseed</td>
<td>Raw whole seed</td>
<td>$15.00</td>
</tr>
<tr>
<td></td>
<td>Roasted and milled</td>
<td>$20-24.00</td>
</tr>
</tbody>
</table>
provided over an agreed time frame) and will expect fruit to conform to minimum food safety requirements. With increasing demands within the food industry to provide ever-safer food products, growers (and commodity traders) of native foods will increasingly be expected to provide microbiological data on their products, nutritional information and the provision of specifications and conformation to those specifications. Specifications will describe the product – colour, flavour, typical size etc (including micron for milled product), describe the packaging the product is provided in (which must be food safe) and provide storage instructions for food safety and optimum shelf life. Any known allergens must be identified on the specification sheet.

Smaller quantities can be successfully marketed within local markets and in some sectors of the native food industry this has become the prime market (see quandong chapter).

**Market demand**

Reliable information on market demand is very difficult to obtain, as the industry remains fragmented and unwilling to share information. As Hugh MacIntosh points out in the native citrus chapter there are still “significant amounts of semi or sub-commercial activity ...Further the industry is too small to be considered in the normal horticultural production statistics”. A recent analysis has stated, “claims for sales volumes and market leadership are difficult to substantiate and appear to be exaggerated in a number of cases. However, the native food industry, while small and still fragmented, is nevertheless thriving on a diverse number of fronts and the substantial industry growth predicted in the 1990s is likely to occur in the next several years.

The industry continues to be driven by highly motivated individual “visionaries”, whose ideas for the industry generally vary widely” (Lester, 2003).

One unifying “vision” throughout the industry (see following chapters) is the recognition that without mainstream processors and markets adopting the products, critical mass for the industry will not be achieved.

To encourage uptake by mainstream processors and markets, native foods must become affordable and sustainable to the broader food industry that operates in a highly competitive market place. Consistency of supply must be guaranteed regardless of variations caused by climate, harvest, handling and transport.

Key marketing issues for native food producers include:

- a lack of market awareness about native foods in general and how to use native foods in particular
- developing a clear, industry marketing message that can be heard amongst the cacophony of mainstream food marketing
- how to match the economic viability of native food agriculture with the market’s need for affordable product.

### Species

There has still been little genotype selection of improved plants, but the following species are at present the most commonly used and in demand. The species are listed alphabetically and are not ranked.

**Aniseed myrtle** (*Backhousia anisata*) A relative “newcomer” the aniseed myrtle is typically an eastcoast rainforest tree with dense foliage that has a strong anise flavour. Used primarily as a herb or flavouring.

**Bush tomato** (*Solanum centrale*) A small shrub with grey/green leaves; fruits turn from green through to yellow when ripe and dry on the bush until they reach a reddish ochre colour and resemble a raisin. It is an arid zone plant native to Central and Western Australia and
it grows in lighter soils in areas of extremely variable rainfall. Fruit can be harvested mechanically and it has enormous potential for dry zone cropping (but needs water).

The fruit is intensely flavoured with a piquant, spicy taste balanced by fruit sugars. Used primarily as a spice or flavouring.

**Kakadu plum** (*Terminalia ferdinandiana*) Top end coastal tree from the Kimberley to Darwin. Pale olive green, ovoid fruits with central wooden stone (similar to an immature olive). Fruit is fibrous and difficult to process but has an ongoing market as a value added product.

**Lemon aspen** (*Acronychia acidula and Acronychia oblongifolia*) Eastcoast rainforest tree bearing pale lemon fruits. Can fruit within two years of planting and will grow in a variety of locations. Lemon aspen has a wonderful lemon flavour with secondary flavour of eucalyptus. Used as a processing or culinary fruit.

**Lemon myrtle** (*Backhousia citriodora*) Probably the most intensely cultivated of all native foods, with 150,000 trees in NSW and a further 1 million trees in Queensland. Lemon myrtle prefers nutrient-rich soils of a medium to heavy texture in a well-drained, wind-protected, sunny position. Prefers acidic soils and areas recording more than 800 mm of rainfall per annum. Lemon myrtle has a distinctive lemon/lemon grass flavour due to the extraordinary level of citral in the leaf. Used as a herb or flavouring ingredient.

**Kakadu plum**

**Lemon myrtle**

**Native citrus** (*Citrus glauca, Citrus australasica and other spp.*) Australia has seven native plant species that are true citrus. The wild lime (*C. glauca*) is endemic to the semi-arid regions of south-west Queensland, western New South Wales and South Australia. Finger lime (*C. australasica*) is endemic to rainforest habitats on the east coast. Like all citrus, native citrus prefer a well-drained soil. They will tolerate poor soils, dry conditions and cold (particularly the wild lime). Plantation grown trees have been shown to respond well to both irrigation and fertiliser. The fruits have distinct lime flavour but with that unique difference found in native foods – but so difficult to describe. Extremely versatile and excellent processing and culinary fruits.

**Native pepper and Pepperberries** (*Tasmannia lanceolata and other spp.*) Native or mountain pepper is found naturally in the wet forests and shrublands of southeast Australia and extending, at higher latitudes as far as the Hastings River catchment in mid-north New South Wales. It grows best in cool, sheltered environments free from water stress, on neutral, acidic soil, preferably well drained and fertile. Mountain pepper
Native foods overview

Native pepper berries

Native mint (Prostanthera rotundifolia and other spp) A recent addition to commercialised and cultivated native foods. Native mint predominantly is grown in southern Victoria. The plant is a large bush with dense foliage, which may be harvested three times a year, once established. The leaves have an intriguing minty flavour with a peppery finish. Native mint is used as an herb and flavouring.

Riberry (Syzygium leuhmanii)
With a similar range as Davidson’s plum, the riberry is mainly grown in northern New South Wales, but has potential in many areas. Plants are established easily and there are some selections/hybrids available. The fruit is small and has a striking purple colour that fades to pink when cooked. Ribberries are strongly clove and spice flavoured. Excellent processing and culinary fruit.

Quandong (Santalum acuminatum) Quandongs require a climate with high light intensity, low relative humidity and will grow in a range of soil types including pH variations and high salinity. Soils must be well drained and quandongs will not tolerate waterlogged soils. The fruit is a visually appealing red, tart tasting and dry textured. It is either dried or frozen and is a processing and culinary fruit.

Wattleseed (Acacia victoriae and other spp) Acacia grows throughout the country and many species are suitable for culinary use. The most popular wattleseed in the food industry is Acacia victoriae, which is found extensively throughout the Central Desert region and into South Australia, Western Australia and New South Wales. The seeds can be harvested mechanically. The flavour of wattleseed is nutty with coffee/chocolate overtones. The seed with aril intact is used and it must be roasted and milled before using as a herb/spice or flavouring.

In addition to the above, RIRDC is supporting two projects researching tuberous plants, one based on Adansonia (Boab) tubers, the other based on Platysace tubers which may lead to field crops for fresh produce from native plants. The first project is in conjunction with AgWA and the second with the University of Western Australia. For further information, readers should consult Research In Progress published by RIRDC.

Agronomy

In general, to make a good profit, the producer needs a good knowledge of what management practices will yield good quantities of high quality produce. In the native foods industry producers need more – they need to know they are planting reliable plants with proven yields. Harvest and post-harvest issues need to be identified and addressed with a focus of continual improvement. To gain this knowledge will take time and those entering the industry will need to take a long-term view.

Although commercial production of many native plant foods is still in development stage, sufficient demand for some species is encouraging commercial production (refer Table 1). While basic establishment costs per hectare for most species is unavailable, Table 3 (from Ryder, 2004) encapsulates some of the current limiting constraints and requirements for long-term success for each crop. Dr Ryder has been conducting research of a number of trial plantings of various native foods in South Australian and Victorian locations.

Specific agronomic information for selected species will be found in the following chapters. Species discussed in depth are:

- Bush tomato
- Lemon myrtle
- Quandongs
- Native citrus
- Native pepper
- The Davidson plum.
Table 3. Native food crops: limiting factors and requirements for success.

<table>
<thead>
<tr>
<th>Species</th>
<th>Current constraints</th>
<th>Needed for long-term success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quandong</td>
<td>Not easy to cultivate, market development</td>
<td>Cultivation methods, market and product development</td>
</tr>
<tr>
<td>Acacia</td>
<td>Improved planting material, harvest methods, market development, product awareness</td>
<td>Improved planting material, market development, product awareness and education</td>
</tr>
<tr>
<td>Citrus</td>
<td>Product development, market development, education and awareness</td>
<td>Mechanical harvesting, market and product development, education and awareness</td>
</tr>
<tr>
<td>Mountain pepper</td>
<td>Improved planting material and cultivation methods, market development, education and awareness</td>
<td>Improved planting material, mechanical harvesting, market development, education and awareness</td>
</tr>
<tr>
<td>Lemon myrtle</td>
<td>Education and awareness, market development</td>
<td>Education and awareness, market development</td>
</tr>
<tr>
<td>Lemon aspen</td>
<td>Improved planting material, cultivation methods, market development</td>
<td>Improved planting material, cultivation methods, market development</td>
</tr>
<tr>
<td>Riberry</td>
<td>Improved planting material, cultivation methods, long lead-time to fruit (some locations), market development</td>
<td>Cultivation methods for fruit set and development, market development</td>
</tr>
<tr>
<td>Bush tomato</td>
<td>Improved planting material, cultivation methods, harvest methods, education and awareness</td>
<td>Improved planting material, cultivation and harvest methods, education and awareness, market development</td>
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Key messages

- There are native food species enjoying commercial utilisation and some success
- Focus on those species that have an established demand
- Grow what the market wants
- Be aware of all issues that contribute to or inhibit success
- Be prepared for a long term investment and involvement—native food production is not an overnight success story
Native foods overview

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Juleigh has also authored two native food cookbooks - ‘Wild Lime’ and ‘Wild Classics’ published by Allen & Unwin. Robins Foods was the 2003 Rabobank Agribusiness Award for Excellence Rural Industries Research & Development Corporation Agribusiness Value Adding Award winner. Juleigh was also a Victorian finalist in the 2003 Telstra Business Women’s Awards Westpac Group Business Owner Award.

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Introduction

Bush Tomato is a common name for the arid land species *Solanum centrale* that is found naturally throughout the Central Desert region of Australia. Bush tomatoes are the fruit of the plant and are usually sun dried on the bush before harvesting. Post harvest the dried bush tomato is usually ground into a fine powder or coarse granule depending on application. There are many *Solanum* species in Australia, not all edible. *S. centrale* is by far the most common edible species used in the food industry but further research and product development work is being focused on *Solanum chippendalei* amongst others.

Bush tomatoes are essentially a herb/spice product and a major strength of the bush tomato is its unique and intense flavour that retains its integrity in many applications, and in relatively small ratios to total ingredient mass (refer “Wild Lime- cooking from the bushfood garden” Juleigh Robins (1996) Publisher Allan & Unwin). This characteristic is a double edged sword for the bush tomato “sector” – on the one hand it is an attractive and marketable flavouring ingredient providing a distinctive flavour difference at a relatively economical usage and cost to the manufacturing or hospitality consumer, and on the other a difficult crop for the agricultural sector to commercialise due to the high costs of production combined with the relatively small quantities currently required by the food industry.

The current demand for bush tomato is being met mostly by the wild harvest sector. The wild harvest sector while operating under particular climatic, cultural, geographic and economic constraints is however an important supply chain partner to existing users of bush tomato and provides a valuable income source to its largely Aboriginal members. It is unlikely that wild harvest
can continue to meet the growing demand except in the very short term.

The current uptake of bush tomato into the food manufacturing and food service industry is encouraging and further demand is expected over the short and long term. It is clear however that the professional agricultural sector, while identifying bush tomatoes as a potential alternative crop suited to low rainfall and arid regions, will limit investment in bush tomato production until the demand pull is sufficient to make broad acre production viable. It is also clear that the agricultural sector is seeking reliable plant material with consistent and demonstrable yields. Managed wild harvest activities and small-scale cultivation in particular regions/circumstances will need to fill ongoing and growing demand in the short term.

**Marketing**

Bush tomatoes, particularly *Solanum centrale*, are proving to be one of the most marketable products emerging from the burgeoning Australian native foods industry.

Bush tomato flavoured and seasoned products are now successfully ranged in mainstream categories in supermarkets nationally in Australia.

Chris Mara, Chairperson of the Coles Indigenous Food Fund (a Coles Supermarkets initiative) says bush tomato products are the most popular native foods purchased by consumers and are commercially successful in Coles’ supermarket range of native food products.

Bush tomato based seasonings and flavourings are now available extensively throughout Europe, the UK and Asia and are experiencing growing acceptance in the industrial food sector. Mr. Geoff Gordon, Managing Director of Hela Schwarz Australia, exports high volumes of native food based flavour bases, premixes and seasonings for distribution throughout Europe and Asia and identifies bush tomato as one of the most versatile of all native ingredients currently available. According to Mr. Gordon, bush tomatoes have been successfully incorporated into flavour bases because they “impart a fascinating flavour twist to so many standard herbs and spices”.

The broad supply chain for bush tomatoes is described in the following flow chart.

At present the supply is largely sold direct to the food industry for further on sale or value adding. Bush tomatoes are currently marketed to both the Australian domestic and export markets in three major forms:

- prime ingredient/commodity as a whole dried fruit or ground/powdered dry ingredient;
- value added into a wide variety of industrial food flavourings and seasonings; and
- value added into a wide variety of value added consumer products (sauces, chutneys, herbs and herb blends, breads, biscuits etc).

In some cases companies utilising bush tomatoes in their own value adding production are also acting as commodity warehouses and suppliers to other parts of the food industry. A clear sourcing and warehousing capability has yet to be developed in the bush tomato supply chain. Given the small size of leading companies in the native food industry the overlapping roles may be a major constraint to marketing effectiveness as precious financial and time resources are spent largely on inbound supply chain activities and storage rather than at the outbound marketing activities. Suppliers of bush tomatoes could gain a competitive advantage by developing a warehousing capability. This would fit supply more closely to customer demand by supplying bush tomatoes as required, rather than in bulk seasonally.
As a broad generalisation, the demand for bush tomatoes in the short term is greater than available current supply and future demand is expected to grow significantly. However, it is impossible to provide an exact figure for the total value of bush tomato production (wild harvest and/or cultivation) in Australia today. Recent analysis suggests that annual volumes of bush tomatoes traded are between 8-10 t, of which up to 2 t may be from cultivated sources. The total value of the bush tomato crop per annum is currently fairly modest but expected increases in demand may see the value of the bush tomato crop increase significantly – but of course only if the crop is available to fill demand!

The recent supply of bush tomatoes has been severely affected by drought in the Central Australian region. Prices have moved upward from the range of $15 to $20/kg three years ago. It is now common for wild harvest fruit to fetch around $20.00 to $24.00/kg (depending on fruit supplied as whole or partially value added by grinding etc). Good conditions (rain when the plants need it) in Central Australia may see wild harvest prices ease marginally. Cultivated fruit is similarly priced at approximately $22 to $24/kg and this price is significantly higher than some in the sector had anticipated.

While these prices may sound attractive they clearly reflect the high costs currently involved in either wild harvesting or commercially cultivating these plants. For the bush tomato “sector” to continue to grow it is important that we find ways to make this product economically sustainable in both the cultivated and wild harvest sectors. Barriers to increased cultivation, and therefore large-scale supply, are high initial set up costs, low and inconsistent yields and perceived small market demand. Prices for broad acre cultivated crops are unlikely to reduce until these barriers are removed and bush tomato production must provide commercially acceptable returns to bush tomato suppliers.

It is critical for the future viability of the bush tomato sector that the industry focuses on demand to pull production. However in order to stimulate demand, bush tomatoes need to be more affordable and viable to the food industry that operates in a highly competitive market place. Bush tomato products are expected to compete successfully against mainstream food products using ingredients from supremely well-developed supply chains – perfected over years if not centuries.

Matching and meshing these needs will be essential for long-term bush tomato sector growth.

**Production requirements**

**Climatic**

The bush tomato is an arid zone plant native to central and Western Australia and grows in lighter soils in areas of extremely variable rainfall. The plant will normally grow, flower and fruit after a sufficient rainfall event. Re-growth from below ground is favoured by soil disturbance. Although frosts are common in the natural range of bush tomato, the plant itself and the ripening fruit are susceptible to frost damage. The plant is best grown as a perennial in warm, dry, frost-free or low frost-risk locations, but can be grown successfully in a wider range of conditions.

Bush tomato can also be grown as an annual crop, but must be planted early (in spring) because of the extended ripening period in autumn. Bush tomato fail to thrive or even to establish in colder, wetter areas (eg south east coast of SA).

Most of the current crop of bush tomato comes from wild harvest in central Australia. Note that within the same geographic range there are closely related species that are similar in appearance to *S. centrale* but which produce POISONOUS fruits. Similarly, it is important to note that the fruit of *S. centrale* in the green (immature) state contains the toxins solanine / solasidine (similar to the toxin in green potatoes). Green fruit should not be harvested for human consumption. Yellow / mature dried fruits have very low, acceptable levels of the toxin (Hegarty et al., 2001).

**Soil**

Lighter, well-drained soils are preferred. Mounding (e.g. 0.3 to 0.5 m high) to assist drainage is very likely to be beneficial. In heavier soils, mounding will...
probably be essential. Deep ripping e.g. to 0.5 m, is also likely to aid bush tomato production. There is a view that for large-scale (broad-acre) production in well-drained soil, mounding is unnecessary.

**Water**
A water supply is required, either from natural rainfall or from irrigation. The plant does appear to have a reasonable tolerance of saline water supply.

**Topographic requirements / constraints**
Bush tomatoes have been cultivated with some success at several locations in central Australia and in South Australia (e.g. Reedy Creek Nurseries and associated growers in Indigenous communities, Simarloo Pty Ltd, farmers in the mid-north of SA and Tangentyere Council, Alice Springs). They have also been grown successfully on a small plot trial basis in locations from Ceduna in western SA through to Junee on the western slopes of New South Wales (CSIRO).

**Varieties / cultivars**
When grown from seed, bush tomato plants vary a great deal in morphology (eg leaf colour, presence or absence of spines etc). This indicates that there is a great potential for plant improvement, which has barely begun. Plants are usually supplied in seedling trays and, depending upon the supplier, will consist of highly variable unimproved material or more uniform, improved (selected) planting material. Reedy Creek Nurseries have begun selecting bush tomatoes for increased fruit size and other desirable characteristics.

There are very specific requirements for the good germination of bush tomato. This has been investigated scientifically (Ahmed, 2001) and also by various plant propagators in nurseries. Scarification of the seed, soaking and smoke treatment all promoted germination, but there were also differences in response between seed lots (Ahmed, 2001).

Plant material is available from:
- Australian Native Produce Industries (Paringa, South Australia; Tel 08 8595 8129)
- Steve Ross, AZEC (Broken Hill, Tel 08 8087 8023).

Reedy Creek Nurseries (Kingston SE, South Australia) sells to Indigenous communities (Tel 08 8768 7220). Plants are available from August onwards.

Tangentyere Council Nursery in Alice Springs supplies a variety of native food seedlings including selected bush tomato (10 Brown St, Alice Springs, NT, Tel 08 8952 6644).

**Cultural practices**

**Site preparation**
It is recommended that the soil is ripped and mounded (e.g. to 0.5 m) where possible, to aid drainage, especially on heavier soils and in cooler environments in southern Australia. Where mechanical harvesting is used, the planting layout should be designed to suit the type of harvesting equipment. Some growers practice weed control by use of weed matting.

**Equipment / facility needs**
Equipment is required for ripping the soil along the planting line and for soil mounding where practised.

**Good cultural practices**
Some growers advocate planting rows of other _Solanum_ species every third or fourth row, to attract pollinating insects, since bush tomato is bee-pollinated. Native bees appear to be the preferred pollinators.

Row spacings are commonly in the range 1 to 2 m, with 0.5 - 1 m between plants within the row. At Tangentyere, approx 1/3 ha was
planted with 10,000 seedlings, i.e. a rate of 30,000/ha.

The bush tomato can be grown as a perennial, with the second and later year crops coming either from persistent above-ground growth, or from suckers that re-grow in spring after the plant has died off in winter. The plant grows best as a perennial in warm, dry locations that have a low incidence of frost. In less favourable locations, the crop can re-grow from suckers but will be harvested later because complete regeneration of the shoot is necessary. It is possible to grow the crop as an annual, planting as early as possible in spring and harvesting in autumn.

Mulching can be beneficial but must be combined with good drainage.

**Fertiliser**

Slow release fertiliser has been used on plantings of bush tomato. Not a great deal is known of the specific nutrient requirements of bush tomato, although high potassium fertiliser after flowering, during fruit development is likely to be beneficial. Phosphorus and Nitrogen fertilisers as well as organic manures have been used successfully. However, experience shows that a fertiliser treatment that works at one location will not necessarily be beneficial at other locations.

**Time lines to first harvest**

If planted in early spring at a suitable location, harvest should occur the next autumn. In places where the plant is a perennial, the yield can be expected to rise in the second and third years. Quality can decrease after that time, so Reedy Creek Nursery and associated growers plant the crop on a three-year cycle. Expected yield figures vary from 25 to 100 g of fruit per plant in year one.

Depending on the conditions (and especially where the plant is perennial), this can increase to twice the initial figure in years 2 and 3 (50 to 200 g fruit per plant). However, note that there are examples where yields were similar in years one and two (around 0.7 t/ha) and then decreased dramatically in years three and four. Where unimproved plant material is used, the variation in yield between plants is likely to be very high.

**Pest and disease control**

**Common pests / diseases and controls**

Establishment rates of bush tomato in cultivation can be very variable. It can be excellent, but complete failures have also occurred. The failures were possibly due to soil-borne pests and/or diseases, however no research has been done into the cause and control of these problems. Small trial plantings are therefore recommended for new areas.

Sooty mould on the foliage and fruit has caused problems when grown in moister (especially moist coastal) locations.

**Harvest, post-harvest storage and treatment**

Harvest is by hand or mechanical. The crop should be harvested when the fruit is either dried or at least yellow in colour and ideally when it reaches a rich ochre brown. Green fruit in the harvest should be avoided because these contain higher levels of the toxin solanine. In summer, individual plants very often carry all stages of fruit development from flowering through to ripe fruit. It is therefore more efficient to harvest late in the season when the fruit is more uniformly ripe. When hand-harvesting, protection from the spines of the plant is necessary (gloves). Mechanical harvesting has been achieved by adaptation and modification of grain crop headers.

Fruit that has not dried out to a very dry state or is still yellowish in colour will need to be further dried after harvesting. Fruit must be protected at all times from moth and insect infestation.

**Financial information**

Cultivation of bush tomatoes has only been practiced on a small scale to date. Tangentyere Council in Alice Springs, Northern Territory, pioneered the successful trial of cultivated bush tomatoes on three plots at Tangentyere Town Camps around Alice Springs between 2001-2003. Tangentyere Council generously provided a table of typical set up
costs for a plot of 3,500 m² (Table 1, pp 2). The plot comprised 35 rows of 60 m each, with a 1.5 m spacing between rows.

References
ANPI / PIRSA Online Fact Sheet Bush tomato production [link]

Acknowledgements
The authors acknowledge very helpful discussions with Noel Sims of Simarloo Pty Ltd, Peter Hoffmann (Eudunda SA), Peter Cowham (Tangentyere Council, NT) and Mike Quarmby of Reedy Creek Nurseries. We also acknowledge very helpful discussions regarding the markets for bush tomato with Chris Mara, Chairperson, Coles Indigenous Food Fund, Coles Supermarkets and Geoff Gordon, Managing Director, Hela Schwarz Australia.

Key statistics
- Estimated harvest for value-adding (2002): 4-8 t
- Most of the produce is wild harvested (up to 2 t from cultivated sources)

Key messages
- Industry is currently market-driven (2004) and is in demand because of its flavour profile
- Bush tomato can be grown as a perennial crop yielding up to 0.7 t dried berry per hectare in good conditions
- Cultivation systems are at an early stage of development and yield is highly variable

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Maarten Ryder graduated from the University of Adelaide with Honours in Botany in 1975. He gained a PhD in Agricultural Biochemistry and Plant Pathology from the same university in 1985. He has worked in soil biology research at CSIRO since 1986. More recently (1999) he began working on the cultivation of native food plants and joined the Desert Knowledge Cooperative Research Centre in 2003, where he is working on “bush produce”.

Bush tomato
Sibylla Hess-Buschmann

Introduction

Lemon myrtle (*Backhousia citriodora*) F. Muell. is a medium-sized native tree (3-20m), first discovered by Baron Ferdinand von Müller in 1853. It originates from coastal rainforest areas from 50-800 m above sea level in Queensland Australia, between the latitudes 17˚30’S and 27˚S.

Joseph H. Maiden reported the potential use of lemon myrtle for commercial production in 1889 and a German company, Schimmel & Co., was the first to identify the ingredient, citral. This ingredient, comprising up to 90% in lemon myrtle essential oil, gives it a distinctive lemon fragrance and taste; other lemon flavoured oils have less citral, such as citrus (3-10%), lemon grass (75%) and tropical verbena (74%).

Although lemon myrtle essential oil has been used from early last century for lemon flavouring, it could not compete with the much cheaper essential oils distilled from lemon grass and tropical verbena.

In the early 1990’s, lemon myrtle was rediscovered as a promising culinary herb in the emerging Australian cuisine, fusing native flavours into a variety of dishes. This led growers to view the crop as a potential new enterprise for the Northern Rivers region of the North Coast of New South Wales.

By 1996-7, farmers in New South Wales had planted over 150,000 trees hoping to satisfy a market demand anticipated during the Sydney 2000 Olympics. More than 1 million trees have also been planted in Queensland.
Lemon myrtle prefers nutrient-rich soils of medium to heavy texture in a well drained, wind-protected sunny position. Young trees are particularly frost and drought tender and require irrigation during dry spells.

The tree prefers neutral instead of acid soil and is prone to yellowing in alkaline soils. Once established, the trees are relatively hardy and recover quickly from dry spells.

Although trees have been grown in Victoria and South Australia, most of the crop is located in northern New South Wales and southeast Queensland, in areas recording more than 800 mm rainfall. A well managed mature orchard in northern New South Wales with rich soil and ample water can achieve a yield of 5.5 t/ha dry leaf per annum.

Flat, free draining ground is essential for mechanical harvesting. River flats are not suited, as the trees succumb to waterlogging. The tree is prone to snap off in wind prone areas.

**Market and marketing issues**

Since 1997, the Lemon myrtle industry has been production driven with growers not realising their anticipated returns. Lemon myrtle essential oil is not commercially produced anywhere in the world and the product is largely unknown in the global market place.

Lack of research in growing, processing, storage and product use has severely challenged the industry which faces a glut of raw material and no market. In the past ten years, many more uses of lemon myrtle have been discovered, though lemon myrtle is still only a niche market product, currently oversupplied.

Lemon myrtle product is mainly traded as a specialist culinary ingredient to be added to food for its unique flavour. Some food manufacturers use small amounts of either dried milled leaves or essential oil to flavour pasta, oils, sauces, ice creams or tea. Without mainstream food processors adopting the product, critical mass for the industry will not be achieved.

Lemon myrtle essential oil in vitro has been shown to be superior in antimicrobial and antifungal action to the now popular tea tree essential oil (Ryan, Cavanagh and Wilkinson, 2000). It may have a future as an antiseptic, surface disinfectant or perhaps for inclusion in foods as a natural antimicrobial agent. Although the Therapeutic Goods Administration of Australia (TGA) has listed lemon myrtle essential oil as an active ingredient for external application, no health benefit claims can be made without the appropriate TGA approval.

Key Australian production statistics are unavailable due to the reluctance of key producers to share production information.

Prices for lemon myrtle (as fresh leaf on stem) at the farm gate have recently fallen sharply from $10 to $2/kg, perhaps as a result of the advent of mechanised harvesting.

**Production requirements**

**Varieties/cultivars**

There are two main commercial clones being planted. The line commonly referred to as “Limpinwood” is hard to strike, but shows superior ornamental presentation, high biomass and high oil yield and citral content. The other variety, commonly referred to as Line B or Eudlo clone is relatively easy to strike, vigorous but slightly lower in biomass, oil and citral yield. Most plants have been supplied from contracted specialist nurseries.

**Cultural practices/agronomy**

The decision to cultivate Lemon myrtle as a commercial crop should only be made in...
response to market demand with prearranged prices. The market is very competitive and currently oversupplied.

Lemon myrtle is a perennial tree crop typically planted in rows. Site planning requires that there is easy mechanical access year round. The land preparation required for lemon myrtle is deep ripping, followed by rotary hoeing. It is essential to clear the rows of weeds before planting. Lemon myrtle is most commonly planted in late spring or early autumn. Young trees are transplanted at 30-40 cm tall, placed 1.5 m apart with a 3.5-4 m spacing between the rows. Ample moisture, mulching and weed control are essential for successful crop establishment.

The nutritional requirements for lemon myrtle are not well understood, though the trees grow best in rich fertile soils and need increasing amounts of organic fertilisers as they are maturing. The trees can be cut up to three times each year and as each harvest removes a large amount of biomass it is essential to return nutrients for long term productivity.

In New South Wales, trees are tip-pruned for the first 18 months to encourage leaf production. After 24 months, the trees start to form hedges, which can be mechanically harvested.

Good cultural practises and good manufacturing practises are paramount as the product is a food ingredient. Traceability, HACCP and product specification including microbial or residual counts are now becoming an essential part of virtually any food business. Farmers need to be very diligent about the integrity of their products if they want to sell them.

**Pest and disease control**

Lemon myrtle has not so far been significantly challenged by pests or diseases in northern New South Wales. There is no chemical pesticide approved for the crop.

**Harvest and post-harvest**

Growers of lemon myrtle need to consider economy of scale or critical mass to be cost effective, to be able to assure consistently high quality supply in quantity. This can only be achieved by mechanised production and processing. The capital intensive nature of the production/processing chain, coupled with the high cost of establishing markets poses risks for the grower.

Lemon myrtle mechanical harvest for dried leaf product is done by specially designed and custom-built harvesting machinery cutting the tips of the tree in an angled position. The cut material falls onto a conveyor belt transporting it into a stainless steel bin. Some people in the industry still hand cut and hand strip the leaf from the stem, but this will not be a viable situation for the future.

The leaf-on-stem material is dried as is and is de-stemmed after drying or is mechanically stripped wet, to then be dried in herb drying rooms or custom designed specialised driers.
Due to the high volatility of the citral component, it is imperative to dry lemon myrtle at low temperatures (>35˚C) as quickly as possible. Ideally, the product is placed into the drier within one hour of harvesting to prevent the product heating up, deteriorating and becoming contaminated with a significant microbial load.

After drying, the leaves are ground to customer/product specification and stored in a cool dark environment until dispatch.

For essential oil, specialised machines cut the stems and leaves into smaller particle sizes. This cut material is then fed into a stainless steel bin and placed in a steam distillation unit. The essential oil is very corrosive to plastics and stainless steel containers or glass are commonly used for cool room storage until dispatch.

Financial information

The estimated start up cost per hectare, not including land, machinery, clearing, labour or structures is about $14,000-$16,000 including operating costs for one year. Plants can be obtained from specialised nurseries for $150 - $450 per hundred, depending on size. Weed control, mulching, irrigation and fertilising are the main costs in the two-year establishment phase. While the need for weed control diminishes as the plants mature, harvested trees require application of more fertiliser with age.

Capital outlay for lemon myrtle cultivation needs to include tractors, trailers and mowers. However, the capital outlay for specialised equipment such as custom-built harvesters, stainless steel bins, conveyors, specially designed units to remove leaves from stems, drying units or distillation equipment such as boilers, condensers, separators are very high. Furthermore, suitable structures for processing need to meet the requirements to comply with HACCP.

The size of accessible markets is limited and the marketing cost for a new crop not previously grown commercially anywhere in the world is very expensive. Economic analyses for lemon myrtle, as for all new crops need to be treated with extreme caution. The lemon myrtle industry in Australia is still in the early stage of development and reliable statistical information is unavailable.

Lemon myrtle is one of the most cultivated species of the native food industry, excluding macadamias. It shows wonderful potential as a specialist food ingredient, functional food and cosmetic ingredient. However, its financial viability will depend on mainstream food industries using the product.

Key references


http://www.hort.purdue.edu/newcrop/ncnu02/v5-040.html


About the author

Sibylla Hess-Buschmann is the Managing Director of Australian Rainforest Products Pty. Ltd., a company specialising in growing, processing and marketing Australian native specialised ingredients to food, cosmetic and pharmaceutical industries.
Key messages

- Versatile native herb
- Multiple uses in different categories
- Promising bio-actives present
- Currently in oversupply

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Native citrus

Hugh Macintosh

Introduction

Most Australians would be surprised to learn that there are seven native plant species that are a true citrus. Despite this abundance, the cultivation and use of native citrus was largely ignored until the 1960’s when the CSIRO began investigating the use of some species in their citrus breeding programs.

The application of these native species was primarily in developing new rootstocks, suited to Australian conditions, to support the growth of traditional Citrus species (Sykes, 2000). The native species’ unique characteristics, particularly relating to salt and drought tolerance and disease resistance were of particular interest.

Wild limes have often been cited as one of the native foods with the most potential for commercial development. However, it is only in the last 10 years that researchers have been developing new crop plants based on the native species.

Commercial producers such as Australian Native Produce Industries (ANPI), have seen the potential in these new varieties and secured the right to commercialise them. At the same time, other commercial producers have been developing plantations based on selections taken from better performing wild plants. In some instances these selections are being grafted onto specially selected citrus rootstock.

High quality native limes are now being harvested from orchards, reducing the need to collect limes from the wild, improving the reliability of supply and minimising any detrimental impact on wild populations.

While production issues continue to demand research attention, it is the market that ultimately determines the success of otherwise of a product. Producers, processors and marketers need to continually ask themselves whether the product satisfies a demand in a particular target market.

As with many young industries, the native lime sector suffers from a general lack of understanding of...
existing and potential markets and the forces that drive these markets. This can lead to participants not focussing their energies and scarce resources on the potentially most rewarding sectors of the market.

**Marketing and marketing issues**

Reliable market demand information and statistics are difficult to obtain as the wild lime industry remains fragmented, with a significant amount of semi or sub-commercial activity – e.g. small-scale operations that collect fruit and sell it to local restaurants. Further, the industry is too small to be considered in the normal horticultural production statistics.

The domestic market for native citrus based products is relatively small at present, but there seems to be a significant export market potential for both processed and part-processed product. Until recently, most of the native citrus supplies have come from wild harvest, which has constrained industry expansion as annual yields are highly variable. The emergence of significant plantation grown quantities of limes means that the industry is beginning to establish a base from which to develop a reasonable market presence.

Market development will require a significant capital base from which to develop a range of products and to establish an efficient marketing and distribution chain.

The industry structure includes:

- Wild harvesters
- Commercial growers
- Wholesalers
- Processors
- Marketers
- Retailers
- Nursery operators
- Food service operators.

Native citrus and, indeed, native foods usually comprise only a small part of the business of many of these operations.

Depending on the variety, native citrus are usually sold as either fresh or frozen whole fruit. There are a number of specialist processors currently marketing processed native citrus products. The major companies include:

- ANPI/Red Ochre
- Australian Desert Limes Pty Ltd
- Australian Harvest Fine Foods Pty Ltd
- Byron Bay Native Produce Pty Ltd
- Cherikoff Food Services Pty Ltd
- Kurrajong Australian Native Foods Pty Ltd
- Rainforest Foods Pty Ltd
- Rainforest Liqueurs Pty Ltd
- Robins Australian Foods Pty Ltd
- Taylors Food Pty Ltd
- Tuckombil Native Foods Pty Ltd.

Most of these companies operate at more than one level in the supply chain. The major processor, ANPI, is a grower, wholesaler, processor, retailer and marketer of a range of products. ANPI source most, if not all, of their limes from plantations, predominantly from plantations that they own or control.

Taylors Food is a ‘mainstream’ food processor that also produces a range of native food products under the ‘Wild Taste’ brand.

There is still some product being sold directly from growers/harvesters, in unprocessed form, to restaurants.

The industry is constrained by a lack of critical mass, largely due to a lack of commercial quantities of raw material, and the lack of any real supply chains.

In common with the native food industry generally, the main...
marketing issues (McKinna et al, 2002) affecting native citrus are:

- the large number of brands relative to the size of the industry
- an unclear market position relative to the mainstream food categories
- the relatively small volume of assured supply from plantations
- a general lack of market awareness about how to use the raw product.

Despite the industry’s infancy, there are some significant success stories in achieving export sales of processed products. ANPI and Robins have been successful in penetrating foreign supermarkets/department stores, particularly in the United Kingdom (UK). Export sales have also been established in the United States, Germany and Canada.

Similarly, some of the more established native foods processors have been able to penetrate the domestic supermarket trade with their products. These include Robins Australian Foods and ANPI.

The continued establishment of plantation based production systems is essential to the development of the native citrus industry. As demand increases a reliable supply of high quality produce will be required (Phelps, 1997). In the past, manufacturers have needed to cease production, or reduce promotion of some products due to the unavailability of raw produce. The ‘failure’ of the desert lime wild harvest in 1998 forced food processors to shift to alternative raw materials or to abandon desert lime based products altogether (Cherikoff personal comm., 1999).

Industry sources suggest that the annual use (production) of native limes is around 25 t/yr, with at least 50% of this being from plantation production. This excludes the harvest of hybrid varieties such as those used by ANPI.

Prices can be highly variable due to fluctuations in supply. Indicative price ranges are shown below:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Product</th>
<th>Wholesale price ($/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desert Lime</td>
<td>Frozen whole</td>
<td>$5 - $15</td>
</tr>
<tr>
<td></td>
<td>Whole</td>
<td>$25 - $80</td>
</tr>
</tbody>
</table>

The continued development of commercial plantations will see these prices fall to more reasonable levels, and will assist the market development.

Native limes are an extremely versatile fruit. They may be used in any product or process where ‘normal’ limes are used, the main difference being their size and intense flavour. The typical uses of citrus are shown below.

**Production requirements**

The five rainforest species of native citrus are all endemic to rainforest habitats on the east coast. Their distribution originally extended from Cape York Peninsula to the Clarence River on the north coast of New South Wales. Due to the impact of land clearing and urban encroachment, each species now has a limited distribution, with two of the species endemic to Queensland currently listed as rare in the wild (Birmingham, 1998).

The desert lime is endemic to the semi-arid regions of south-west Queensland, western New South Wales and South Australia.

Like all citrus, native limes prefer a well-drained soil. They will tolerate poor soils, dry conditions (particularly the desert lime) and cold. Plantation grown trees have been shown to respond well to both irrigation and fertiliser.

Research into plantation production is still relatively limited, and commercial growers closely
guard many of the techniques they have learned by trial and error. The CSIRO Division of Land and Water have established trial plantations at a number of sites around Australia to research optimal production strategies.

In the absence of specific detailed research, intending growers should treat native citrus as they would a traditional citrus orchard.

**Varieties and cultivars**

Birmingham (1998) reports that there is a lack of standardisation of common names within the native citrus industries, with the seven different varieties and their hybrids listed as ‘native citrus’ or ‘wild limes’. Botanical names are the only positive method for identifying the true native species.

The Finger Lime and Desert Lime, in particular, hybridise easily with traditional commercial citrus varieties. Cultivated hybrids are generally referred to by their cultivated variety name or origin, e.g. the ‘Australian Blood’ PBR lime is a hybrid between Citrus and Microcitrus.

There are two distinct genera of true native citrus in Australia. These were initially identified as either Microcitrus (the five rainforest varieties) or Eremocitrus (desert lime). More recently there has been a move to re-name all seven varieties as Citrus species, bringing them into line with mainstream citrus varieties.

**Citrus australasica - Finger lime**

The Finger Lime is found wild as an under-storey shrub in the rainforests of southern Queensland and northern New South Wales. Its grows naturally in heavy shade in high rainfall areas, but also appears at the edge of cleared forest where there is more sunlight. In their natural environment trees can reach 6 metres in height.

The fruit is cylindrical, up to 10cms long and can be green, yellow, red, purple or black when ripe. The pulp is usually greenish yellow although there is a variety - Sanguinea - that is red fleshed.

Unlike other citrus the Fingerlime flesh consists of tiny, slightly sticky globules. Flowering generally occurs from February to May, with fruiting from May to September. Production is usually bi-annual.

The finger limes can be used as a fresh fruit for garnish and for processing into a wide range of value-added products. There are a number of commercial plantations in northern New South Wales, producing small quantities of fruit. Wholesale prices can range between $25 - $80/kg, though $8 - $12 is probably a more realistic price.

**Citrus australis - Round lime**

Also called the Gympie lime, this is the most vigorous of the Australian native citrus, growing to a height of up to 18 metres. It is endemic to south-eastern Queensland, in lowland subtropical rainforest.

The fruits are about 2 - 5cms in diameter and have a thick, green to yellow coloured skin and pale green pulp. This species flowers from August to November.

The round lime is suitable for processing into a range of value-
added products. The skin is very thick (up to 7mm) and has potential for culinary use, such as grating into spice pastes, or for candied peel. The species may also have potential for essential oil extraction (Birmingham, 1998). Recent farm gate prices range from $8 - $9/kg (Hele, 2001).

**Citrus inodora - Russell River lime**
A fairly rare species from near coastal areas in far-north Queensland. Plants require shady conditions, plenty of water and organically rich, loamy soil although they will grow in poorer soils. This variety is very slow growing, and only reaches a height of 2 – 4 metres.

Of all the native citrus, *C. inodora* looks the most similar to a traditional citrus. It is somewhat unusual in that there is a distinct lack of fragrance in the flowers.

The fruit are green on maturity, oval (somewhat lemon-shaped) and up to 6.5 x 3.2cm in size. This species is also classified as rare and is protected (Birmingham, 1998). Fruit is not commercially traded.

**Citrus maideniana - Maiden’s Australian wild lime**
Commonly known as Maiden's Australian lime, this species was originally described as a variety or subspecies of *M. inodora*. The two species have a similar distribution, limited to a small area in far-north Queensland. Fruit is not commercially traded.

**Citrus garrawayae - Mt White lime**
This species is endemic to the foothills and upland rainforest of the Cook District on Cape York Peninsula. It grows in deciduous vine thickets as an under-storey shrub and has been recorded at a height of 15m. Due to its limited distribution, this species is now classified as rare and is protected under the Queensland Nature Conservation (Birmingham, 1998).

*M. garrawayae* is similar to *M. australasica*, but has broader leaves (Birmingham, 1998). Fruit forms from April to November. The fruits are also ‘finger-shaped’, with a green skin and greenish-white pulp on maturity. The fruit may be used for processing into a range of value-added products, as for the round lime (Birmingham, 1998).

**Citrus glauca - Desert lime**
Also known as the wild lime or native cumquat, the natural distribution of this species is the semi-arid regions of eastern Australia, from Longreach in western Queensland, south to Dubbo in central New South Wales and west to Quorn, in the Flinders Ranges of South Australia (Alexander, 1983).

The desert lime has blue-grey leaves and prickles along the branches, though above a height of about two metres, there are no more prickles on the branches. Plants are usually found growing on clay or heavy clay soils, often in clumps. They are occasionally found as single large trees to 5-6metres in height.

The desert lime is extremely drought tolerant and able to withstand extremes of hot (45ºC) and cold (-2 – -4ºC) temperatures (Swingle and Reece, 1967).

The flower to fruiting time is the shortest of any citrus species, being from 10–12 weeks (Sykes, 1997). The species flowers mainly in spring and fruits ripen in summer.

Fruit can be picked when still green, and has a pleasantly refreshing and tangy taste. Desert lime fruit is extremely popular and becoming very well known within the native food industry. The fruit has a very thin rind, is often seedless and can be used whole in cooking. Fruit must be frozen within 24 hours after harvest.

Wholesale prices can range from $5 - $15/kg.

**Citrus gracilis**
*C. gracilis* has recently been described and grows wild as a straggling tree in Eucalypt woodland in the Northern Territory. It has a similar growth habit to the desert lime and produces round fruit up to 8cm in diameter (Hele, 2001). Fruit has not been traded commercially. It is also known as the Humpty Doo or Kakadu lime.

There is one known native citrus hybrid – the Sydney hybrid (*C. australis x C. australasica*), which was developed by the US Department of Agriculture. This species is not known to be grown commercially.

In addition, there are four known cultivars (cultivated hybrid) of native citrus currently available.
Rainforest Pearl PBR is a selection of *C. australasica* var. *sanguinea* made by Erika Birmingham from Byron Bay Native Produce in northern NSW. The Outback Lime PBR is a selection of *C. glauca* made by Dr Steve Sykes of the CSIRO. Two cultivars of partly native citrus parentage have also been developed by Dr Sykes, the Blood Lime PBR and the Sunrise Lime PBR.

ANPI have secured the rights to commercialise the three cultivars developed by Dr Sykes.

Plant stock is available from a number of nurseries around Australia (refer to listing at the end of this chapter). The Rainforest Pearl is available from Byron Bay Native Produce, while the three CSIRO bred cultivars are available from ANPI.

### Agronomy

Commercial cultivation of bush foods is a very young industry and the cultivation techniques being used are, to a certain extent, experimental.

Plantations range from those mimicking the standard commercial orchard design to permaculture food forests. These forests have a mixture of species planted in a design that imitates the structure of a natural forest ecosystem. At the other end of the spectrum some growers are planting out using rows in the traditional orchard set up though, until recently, very few were planting mono-cultures.

Generally, orchards have up to 10 species which are either planted in different rows or grouped in a certain part of the orchard to create a mosaic of species. The rows are often inter-planted with a shelter belt of native species which also provides a refuge for insects (Seabrook, 1999).

The food forest structure is often used by growers who are using bush tucker species for revegetation programs. However, this type of orchard poses particular management problems.

Plants may be grown from seed (though the resulting plants may not be true to type), by cuttings which are slow, or by budding onto citrus rootstock. Grafting buds (budding) on to citrus rootstock is the preferred method for most commercial plantation growers.

Budding allows growers to avoid the long juvenile period and enables trees to bear fruit in their second or third year. The selection of the best rootstock will need to be determined, based on soil type and climatic conditions.

Many growers tend to use natural fertilisers and, if herbicides are used, generally this is restricted to Glyphosate (Seabrook, 1999). Weed and grass control around the base of trees or shrubs is important, particularly during the early years of establishment.

Before selecting a species to grow, it is worth examining its natural range and determining whether your area has similar climatic conditions.

While there are a number of research projects under way (e.g. CSIRO) to determine the optimum production systems...
for native citrus in a range of conditions, in the first instance, new growers should treat their native citrus as any other commercial citrus crop. In these early days of commercial production, the application of irrigation, fertiliser and management processes (pruning, etc) will need to be refined and improved based on personal experience.

**Pest and disease control**

Being natives, many of the pests and diseases that afflict traditional commercial citrus orchards may not affect native citrus. That said, there are pests and diseases that will afflict native citrus orchards, particularly those that are planted as a mono-culture.

One notable disease, ‘Sunrise Lime Dieback’, emerged in some orchards during 2000. The disease is similar to diebacks that occasionally occur in other citrus varieties, though it appears that at present the disease is confined to the Sunrise Lime cultivar (Hele, 2001). The disease has been shown to be caused by a *Phoma* sp fungus.

Control is best achieved through good management practices that minimise the incidence of twig death, physical injury or plant stress (e.g. water stress, fertiliser burn, wind abrasion). Dead wood that may have been killed by the fungus or could be harbouring the causal organism should be removed and burnt. All pruning cuts should be painted (Hele, 2001).

Copper sprays, which are often applied to control fungal diseases in citrus are also likely to be a successful in native citrus. As far as is known, no significant pests or diseases have been reported in plantations of the true native varieties.

**Harvest, handling and storage**

Native citrus is harvested by hand, though some of the CSIRO bred varieties, reportedly, may lend themselves to mechanical harvesting. Mechanical harvesting will significantly reduce the labour cost involved in harvesting, and may be suitable for processing fruit but is unlikely to be useful for fruit destined for the retail or food service market where appearance is important.

As with any fruit, it is important to minimise handling so as to reduce labour costs and to minimise the damage done to the product.

Harvesting should take place during the cooler parts of the day so as to reduce the effects of heat on fruit quality. In any event, fruit should be refrigerated as soon as possible after harvest, and/or frozen within 12 - 24 hours of harvest (*C. glauca*).

Whether fruit is being supplied to food service outlets or being used in manufacturing, it will need to be graded and cleaned of dirt, sticks and other foreign matter. In small orchards this task is done by hand, but this method becomes impractical as volumes increase. Though there is no commercial grading equipment available, some of the more innovative growers have developed their own unique grading/cleaning machines.

Fruit is generally packed into 500 g or 1 kg food grade bags or punnets. Occasionally, larger packages may be used for supply to manufacturers. Different manufacturers may have particular packaging requirements depending on the end use of the product. The majority of the native citrus crop is used for processing into a range of value added products, with a small amount being sold direct to restaurants.

**Financial information**

The economics of production will depend on the production system being used. However, the following indicative costs are provided as a guide. These costs assume:

- plantings are in a mono-
**Native citrus**

- Spacings follow "normal" horticultural practice giving a stocking rate of 625 trees/ha.
- The cost of land, water storage, packing shed and plant and equipment is excluded.
- Owner-operator labour is used.

Based on these assumptions, the indicative establishment cost for a one hectare (ha) Desert lime orchard will be in the order of:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site preparation</td>
<td>500</td>
</tr>
<tr>
<td>Plant stock @ $15 per tree</td>
<td>9,375</td>
</tr>
<tr>
<td>Planting</td>
<td>2,000</td>
</tr>
<tr>
<td>Fencing</td>
<td>500</td>
</tr>
<tr>
<td>Irrigation</td>
<td>5,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17,375</strong></td>
</tr>
</tbody>
</table>

Ongoing operating costs will include chemicals, fertiliser, irrigation, harvesting, row maintenance and marketing. Again, on the one hectare example orchard outlined above, the indicative operating costs (excluding labour except in harvesting) will be in the order of:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicide</td>
<td>50</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>550</td>
</tr>
<tr>
<td>Irrigation (excludes water cost)</td>
<td>200</td>
</tr>
<tr>
<td>Orchard maintenance</td>
<td>2000</td>
</tr>
<tr>
<td>Harvest, grading and packing</td>
<td>3500</td>
</tr>
<tr>
<td>Marketing</td>
<td>3700</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10,000</strong></td>
</tr>
</tbody>
</table>

Assuming an average yield from mature trees of 15 kg per tree, and a delivered price of $5/kg, the gross margin on this crop will be in the order of $36,000.

As with most businesses, production is the easy part - marketing is the hard part. The big question is whether the 9.4 tonnes of limes produced from the theoretical orchard can be marketed at an average price of $5/kg. The marketing effort needs to be well planned and should start well before the first fruit is picked.

While native citrus based products are a novelty product, in relatively short supply, they can be expected to attract a premium price. However, in the medium to longer term this premium will be eroded as supply increases and/or competing products emerge. The novelty value will disappear and native citrus based products will have to compete on more or less equal terms with other more conventional product lines.

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**Key statistics**

- Australia has 7 varieties of true native citrus
- The annual use (production) of native limes is around 25 t/yr, with at least 50% of this being from plantation production
About the author

Hugh Macintosh is the Managing Director of IQ Agribusiness, a management advisory firm based in Brisbane. He is a founding partner and Director of Industry Data Online Pty Ltd, a business providing online business benchmarking services to SME’s and industry groups (www.industrydataonline.com).

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Key messages

- Plant breeders have developed a number of new hybrids based on the native varieties
- A number of companies have developed export markets for native citrus based products
- An increase in the area of commercial plantations is reducing the reliance on wild harvest
- CSIRO has established trial plantations at a number of sites around Australia to research optimal production strategies
- Native citrus is usually harvested by hand
- The majority of the native citrus crop is used for processing into a range of value added products, with a small amount being sold direct to restaurants
- Price premiums will be eroded as more plantation grown fruit becomes available

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Red finger lime

C. australisca - finger lime flower (Photo:...
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Native, or mountain pepper products are obtained from the species *Tasmannia lanceolata*, found naturally in the wet forests and shrublands of southeast Australia, and extending, at higher altitudes as far as the Hastings River catchment in mid north NSW.

The commercial appeal of the species derives largely from the presence in both leaf and fruit, of a hot tasting terpene compound, polygodial, for which a wide range of biological activity has been demonstrated, including antibacterial, antifungal and insect antifeedant properties. It is the hot taste to humans which has resulted in the ‘native pepper’ description, thus the potential of both leaf and berries as culinary ingredients.

Most production presently derives from wild harvested stands, mostly on previously disturbed sites where it flourishes as an early coloniser after removal of wet forest or rainforest canopies. Several substantial stands on previously cleared land in Victoria and Tasmania presently supply most of the traded product.

Figures on gross consumption within Australia are difficult to determine since both production operations and the present market...
Native pepper leaves

are small and dispersed. However it would appear likely that total domestic consumption at present would be no more than 3 tonnes of dry leaf, 1 tonne of dry berries and a small amount of fresh or frozen fruit, certainly less than 1 tonne.

**Markets and marketing issues**

Both leaf and berry are traded in the culinary market principally as dried products and leaf is sold mostly in milled or ground form. There is a small market for fresh or frozen berries and fresh leaf, the latter mainly as a garnish.

Food service manufacturers use milled leaf in a range of prepared foods including relishes, sauces, mustards, cheese, meat seasonings and flour mixes.

Most pepper berries are used as an alternative to ‘normal’ pepper, either whole, as a condiment (in grinders) or milled and blended with other spices to produce novel spice mixes and specialty blends. There is a substantial trade in retail gourmet and gift lines and packaged products for the tourist industry.

A proportion of the leaf produced is solvent extracted for the food flavouring market, and some is sold as a raw material in the preparation of health products and nutraceuticals.

All of these markets are small and there is considerable ‘churn’ among the smaller users.

There have been major changes to quality and safety requirements in recent years, and most larger buyers of native pepper products now require some supporting analytical and microbiological data, guarantees of safe and consistent product and avoidance of pesticides in the production systems. While these changes have increased the costs of production and marketing in recent years, they have also helped rid the trade of some unscrupulous operators and led to major increases in efficiency among the more serious producers.

Prices obtained for pepper products vary widely, reflecting the range of producer types – from hobbyists with few overheads and no investment in production systems to a small number of more serious producers. Prices ‘at the farm gate’ can range between $6 and $20/kg for fresh berries, from $30 – $70/kg for dry berries and milled leaf prices range from the low $30’s to over $60/kg, dependent on quantity, quality and the specific requirements of the customer.

From 1994 to the present the average price for 25 kg of milled pepper leaf has fallen from $48/kg to around $38/kg – in real terms
a very large reduction reflecting increased competition for a slowly growing market, and improved efficiency of production.

A major issue for production and marketing is the unreliability of wild fruit production between seasons.

Between 1994 and 2003 almost no fruit survived to harvest in two seasons, while bumper crops occurred twice. The reasons for this are not clear, but from an ecological perspective, the pattern is not unusual, with large crops of fruit or seed often occurring only infrequently, interspersed with small or negligible fruit set in other years. Environmental factors such as late frosts, temperature extremes and drought stress will obviously be important.

**Production requirements**

The species is typically found in higher rainfall regions of southeast Australia (see map), and grows best in cool sheltered environments free from water stress, on neutral to slightly acid soil, preferably well drained and fertile.

Of particular importance is protection from warm winds which can kill plants even if water is being supplied at the time—the plant’s transport system and transpiration regulation appear unable to cope with extreme demand on hot days.

The species is quite frost hardy in the natural situation, although unseasonal late frost has been observed to burn newly emerging shoots in November – December, although the effect is slight and temporary.

**Varieties/cultivars**

In the natural population, the species displays considerable diversity of form, vigour and chemotype, offering plenty of scope for selection of favourable types. Several producers have identified individuals with characteristics suited to their production location or practices, and it is likely that this will continue into the future.

Producers in Victoria, for example, have chosen a ‘Toora form’, and several Tasmanian growers have chosen forms either from nearby local stands, or on the basis of analysis of leaf extract composition for yield of polygodial or presence of undesirable constituents.

Plants are available from most native plant specialist nurseries in southeast Australia, since there is a small market for the plant as an ornamental shrub. Propagation for commercial production may be easily arranged with any competent propagator.
**Cultural practices/agronomy**

Most plantations have been established using rooted cuttings, both for speed and convenience and to enable introduction of uniform material from selected plants. Seed germination is extremely slow (more than 12 months in some reports), and seedlings, once germinated are very small, slow to establish and extremely variable in habit.

Sites should be well prepared, preferably on soils in the neutral to slightly acid range, having good drainage, protection from hot winds and adequate provision for irrigation. In most situations, some protection from browsing animals or rabbits which will dig up newly planted material, is advisable.

In some existing mixed plantations, *Tasmannia lanceolata* is grown as a semi-understorey plant, providing good protection from exposure. This practice reflects the common natural occurrence of the plant as an understorey plant in rainforests.

Weed control during establishment is essential, and mulch mats, hand weeding or careful use of glyphosate products are all effective methods.

Native pepper responds well to the application of side dressings or foliar application of nitrogenous fertiliser, but little is known of the long-term requirement for fertiliser in the situation where substantial quantities of leaf and berry are harvested annually.

Irrigation is required where natural summer rainfall cannot be relied upon, and as mentioned, warm windy weather can cause serious damage to the plant, destroying all the new foliage and shoots or in extreme cases killing the plant.

Symptoms of water stress are not easy to detect until too late – wilting can indicate a complete collapse of the transport system, and shoots may not recover at all, so it is important to monitor soil moisture and to anticipate hot weather with extra watering, shade or shelter.

In ideal situations, vigorous selections will yield fruit and limited quantities of leaf within 2 – 3 years.

**Pest and disease control**

While the hot compound present in the leaves of the plant has been shown to have antifungal and insect antifeeding properties, in the natural situation a variety of insects appear to browse on the species. Leaf miners and leaf rollers consume the leaf, while a tiny grub can be found within the fruit and seed. None of these have been observed in damaging numbers, however, and the plant is typically quite free from severe infestations of any kind in the wild.

No work has been conducted on the ecology of these insects from the point of view of management of commercial pepper production.

**Harvest and post harvest handling**

At present all harvesting of fruit is by hand, while simple mechanical aids are usually used for removing leaves and other foreign matter from berries. Establishment of plantations will enable use of simple mechanical harvest aids, as the fruit is quite robust when ripe, and may be shaken from the bush.

Leaf material is presently either plucked from the plant or gathered using simple trimming equipment after which leaves are dried then separated from the twigs and other woody material. Most producers employ home-made equipment for this purpose, but again, the development of plantation production will enable mechanisation of this process. Most leaf is traded as milled product.

Warm air drying is typically used to achieve better than 93% dry matter, and as with any herb, must be achieved with good air circulation, to prevent 'stewing' of the leaf. In more humid environments it may be necessary to use dehumidification equipment but this has not been the case in Tasmania and Victoria where most leaf and berry is produced at present. The importance of adequate drying must be emphasised, as high residual moisture will allow the development of spoilage bacteria and fungi and may compromise the quality of the product.

When properly dry, a handful of berries should not yield to a firm squeeze.

Product must be stored in a cool, clean, dry, dark and insect-proof environment to maintain the quality, particularly of the leaf, which discolours quickly in sunlight.

**Financial information**

Intending growers should assess the key issues below, and attempt to balance production and marketing issues in their approach to the enterprise.

Key issues for any new producer should be

- to establish a sound marketing strategy
- to address the post harvest and food safety technology
issues for their enterprise

• to devise a plantation system suited to their site and location.

The current market is quite small and marketing could include product development, networking with existing producers or approaching end users for potential partnership arrangements.

At present most producers are employing very simple, low cost harvest and processing equipment in their operations, and any new producer would be well advised to delay major investment in this area until a firm market has been established. A cooperative approach to harvest and drying equipment is to be recommended, especially if the equipment can be used for other herb crops during the year.

The cost of establishing and maintaining a plantation will depend on the approach and resources of the intending producer. A stand-alone plantation on purpose bought land might cost $50,000/ha to bring into production (4 years), while a low key pepper enterprise as part of a broader horticultural operation will be much less capital intensive. The decision on the size of area for production should be made in the context of the identified market and the estimated amount of product demanded.

Indications are that a single tree at five years old should produce (sustainably) at least 3 kg fresh pepper leaf (about 750 g dry leaf) or 1.5 kg fresh berries per year depending on the season. The mature yield will depend greatly on the extent to which the tree is allowed to develop a canopy before harvest of leaf material commences (ie time to first harvest and annual yield).

Key references


Key messages

• Market currently restrains growth
• Pepper prefers sheltered moist site
• Production and marketing networks do work

Key statistics

• Leaf production (dry) <3 t/year
• Berry production
  – fresh <1 t/year
  – dried 1 t/year

About the author

Dr Chris Read owns and operates Diemen Pepper, a small pepper production and marketing business from his mixed horticultural operation in southern Tasmania. He has worked in commercial horticulture as a field officer, consultant, researcher and commercial operator for more than 20 years, specialising in essential oils and cut flower production.

He is presently developing a small farm tourism operation based around a café and essential oil distillery on his property south of Hobart.

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Quandongs

Ben Lethbridge

Introduction

The quandong (*Santalum acuminatum*) is an Australian native shrub or tree that produces a visually appealing yellow to red, tart tasting, dry textured fruit which is a significant component of the native food industry. The flesh is amenable to most culinary purposes including pie filling, liqueurs and preserves. The kernel (nut) is also edible but as yet has attained little commercial significance.

Quandong is closely related to the arid zone Sandalwood and although the good quality timber of the quandong tree is prized as a craft wood, it lacks the fragrant essential oils derived from the heartwood of most *Santalum* species.

The quandong is highly tolerant of saline water and drought but orchard production has been limited by having only a rudimentary understanding of the root semiparasitic nature of the plant (it requires a host plant for best production). This has restricted successful orchard production to those with some horticultural training.

The Australian Quandong Industry Association was formed in 1992 to help guide the development of the industry by organising an annual conference, a regular newsletter and collating relevant industry information.

Markets and marketing issues

The limiting factor to quandong fruit marketing has been a lack of quantity and quality of supply. The dominant market for the quandong is as processed product, usually dried or frozen immediately after being picked. Dried halved fruit can be stored indefinitely in an airtight container. Although the fresh fruit is visually appealing there is virtually no market for the product to be consumed as fresh fruit. Most producers have been able to dispose of all fruit product to local tourist outlets and speciality stores.

Quandong production is currently an entirely Australian industry.

Natural distribution

Ripening Powell No. 1 fruit (prov. PBR)
The quandong industry has been rated conservatively at a $0.7-1.3 million industry (farm gate gross estimates, 2001) with commercial planting of around 26,000 trees which equates to 50 to 100 hectares assuming average planting densities. This constitutes approximately one third of the total production of 25 tonnes (2001) with the remainder wild harvested.

It is unlikely that the high prices obtained for wild harvested fruit in the past will continue, and as orchard production rises, the price is likely to fall to values more consistent with manufacturing grade (mainstream processing) fruit. Quality product will always command higher prices (estimates of $40–60/kg dried fruit).

**Production requirements**

Quandongs require a climate with high light intensity, low relative humidity and will grow in a range of soil types including pH variation and high salinity, but should be well drained and will not tolerate waterlogged soils where susceptibility to root diseases will be more prevalent. Mature quandongs have shallow root systems. The type of host plant chosen will dictate the irrigation requirements of the orchard. Prior to attachment to host plants, young quandongs are very prone to desiccation and will require a regular watering regime, shading and wind protection.

Post-attachment, the irrigation should be matched to the host plant with due consideration to the distribution and depth of the root system and water holding capacity of the host and the quandong tree. the map shows the natural distribution range of the quandong and offers a very rough guide to the types of environments suitable for production.

**Varieties**

Two named varieties, Powells No.1 (provisional PBR) and Frahns Paringa Gem (provisional PBR) are available as grafted scions onto seedling quandong rootstocks. There is limited supply both in quantity and quality. Many new varieties from wild or seedling orchard selections are expected in the coming years, so check with AQIA for latest selections and propagators.

**Agronomy**

The agronomy of quandong production is enhanced by the horticulturally unique semiparasitic nature of the quandong. This parasitism is non-specific and the exact nature of what determines a good host is not completely understood, although drought and salt tolerance are implicated. Because of their semi-parasitic nature, quandongs are able to indirectly adopt many useful adaptive features of the host plant. For example, the nutrient efficiency and atmospheric nitrogen fixing ability of legumes such as Acacias make them good hosts in nutrient starved soils, which are common to many Australian landscapes. Acacia victoriae (bramble wattle) is proving to be highly adaptable to many climates and soil types in orchard situations and is a relatively good host for quandong.

Other useful species include other Acacias, and species from the genus Atriplex, Melaleuca, Myoporum, Allocasuarina etc.,

Many quandong growers have chosen to introduce quandongs into the orchard as potted plants whose root structure has been modified significantly and may retard the attachment to host plants. Young pre-attached quandongs require significant care to prevent desiccation including shade and wind protection. Prior to attachment to a significant host (ie greater than one year old), quandongs require regular supplies of a general purpose, water-soluble fertiliser for good growth. Some small orchards of quandongs have been developed on this host free, simplified plan. Under this system quandong plants usually only attain shrub-like proportions. The pre-attachment phase can be minimised by direct seeding of quandong onto one year old, dripper fed host plants (usually acacia) when soil temperatures permit significant root growth of the quandong.

After attachment of quandongs to significant host plants the management of the orchard should be based on the requirements of the host plant.
Most propagation of selected quandong varieties has been achieved using nursery techniques. Field grafting onto established seedling root-stocks is possible but the technique needs improvement to obtain a commercially satisfactory success rate. This technique offers much potential, for example sandalwood root-stocks (other Santalum species) are compatible with quandong scions, allowing conversion of seedling orchards of Santalum to specified varieties of quandongs, thus combining high value sandalwood and quandong fruit production.

Weeds should be removed manually and frequently from around the plant, with cautious use of herbicides because of the potential for transfer of toxic compounds through the roots of the host plant to the semiparasitic quandong. Check that annual weed roots have not been paratised, by examining a selection of hand pulled roots, before application of herbicides.

Training and pruning of quandong trees should be early and light to improve tree structure and where shading by the host plant could be significant this should also be addressed early in the life of the orchard.

Quandong trees are predominantly cross-pollinated, so planting of at least two varieties of trees in close proximity to each other is recommended.

### Pest control and disease

The major pest affecting quandong fruit is the quandong moth, \textit{(Paraparmenia santiella)}, a native species common in the natural range of the quandong. Quandong moth may be controlled by spraying with a dimethoate based insecticide when eggs are detected in the fruit calyx or if there is obvious fruit damage. Although there can be highly conspicuous damage from leaf feeding insects, this will not greatly affect fruit yield. Scale insects may be damaging to trees and are usually controlled by natural enemies or for heavy infestation, oil based sprays have been found to be useful. Gall forming insects and bud mites (Family Eriophyidae) have been reported to cause damage to some trees.

Root rot diseases such as \textit{Phytophthora} have been implicated in poor establishment rates from nursery-derived plants and inhibiting growth on poorly drained sites.

### Harvest / handling / post harvest treatments

All quandongs are currently harvested by hand. The current scale of production does not yet warrant ‘cool chain’ procedures to be developed. Residual pest infestations may be eliminated by heating the harvested quandong fruit at 60°C for 30 minutes. Most quandong varieties are free stone and fruit are de-stoned and halved on manual or automatic cutting machines based on technology developed from the apricot industry. The fruit is either fresh vacuumed packed and frozen or more commonly sun dried. Quandong fruit has a low moisture content relative to other fruits, so drying is a relatively simple process.

### Financial information

An economic analysis for new crops should be treated with caution due to uncertainties in production and prices of quandong and host plant products. It is recommended that the host plant be established at least one year prior to planting of quandong trees and therefore establishment costs should be based on that of the host plant, plus the additional cost of quandong plants and protection from desiccation.

Most quandong orchards are currently based on seedlings for which yield data is highly variable. For improved grafted varieties estimates of production is predicted to begin in year 4 with increasing yields of 0.5 kg dried fruit per annum to year 15 (dried equivalents, equals approximately 25% of fresh whole weight). Assuming 300 quandong trees/ha, a farm gate price of $40/kg (first quality) of 1.5kg dried...
fruit per tree gives an estimate of $24,800/ha (gross), at year six. This is comparable to returns from other new horticultural pursuits. There exists opportunities to include quandongs in farm revegetation programs. The indirect economic benefits of improved environmental status and seasonally dependant, manufacturing grade quandongs and host plant products (eg. wattle seed) are difficult to calculate.

Key references

Australian Quandong Industry Association Newsletters and Information sheets.


Relevant RIRDC publication Nos. (to May 04) 01/172, 03/110, 03/138, 03/013, 01/28

Key messages

- The economics of this new industry are uncertain but an industry infrastructure is developing according to well-formulated plans
- Research into a better understanding of the semi-parasitic nature and production of quandong is occurring. Acacia victoriae is showing much promise as a host in orchard situations

Key statistics

(estimates)

- 25 tonnes (2001), 33% cultivated, remainder wild harvest
- $0.7 - $1.3 million, farm gate gross estimate (2001)
- 26,000 orchard trees, in various stages of production (predominantly SA)

Key contacts

Australian Quandong Industry Association.
C/- Northern Region Development Board. PO Box 1762 Port Augusta SA 5700 www.aqia.com.au

It is recommended that all prospective quandong growers contact the association for up-to-date status of the industry.

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State Department of Agriculture or equivalents.

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About the author

Dr Ben Lethbridge B.Ag.Sc.(Hons.) Ph.D. is a private consultant and has been a member of The Australian Quandong Industry Association since its inception and committee member since 1994. He has contributed to RIRDC funded research projects on the quandong. For contact details see key contacts.
The Davidson Plum (*Davidsonia* spp) is an ‘un-domesticated’ Australian native rainforest fruit well suited to commercial production. It offers new ingredient value to the global food industry and its versatility of use gives it opportunities in many food market niches. The fruit, whilst versatile, is constrained by market unfamiliarity and thus greater market risk. Present production outweighs demand. There is a need for improved production efficiencies and technologies, as well as improved post harvest processing techniques. Overall, the greatest challenge is better marketing and greater adoption of the fruit in the food-manufacturing sector. Being very sharply acid, the *Davidsonia* does not have access to a fresh food market. The fruit is a processing fruit and must compete on price with processing-grade fruits of other species. These other fruits may be cross-subsidised by fresh produce sales to an extent and hence come onto the processing market at or below cost of production.

Australian production of the *Davidsonia* is very limited but, as long as the market identity of the fruit continues to be ‘Australian Native’, Australian production will be advantaged. At present overseas production seems entirely limited to enthusiasts and researchers. Market demand is perhaps the most significant limitation at present, with many growers over the past 4 years having difficulty selling their crops.

The Davidson Plum is a sour and plum-like fruit used in jams, sauces and preserves, cordials, dairy products, confectionery,
wines and liqueurs. Its tart flavour and intense burgundy colour lend the plum to many uses in food manufacturing industries, particularly those seeking to portray images of Australiana, indigenous Australia, wilderness, nature or rainforest. Current market demand is around 5,000 kg per annum, and buyers estimate growth at 5-20% per annum, though most are relatively young businesses and trends are difficult to assess.

Current production is predominantly in the sub-tropical coastal regions of NSW and tropical NE Queensland.

As with any new crop, a broad range of skills is required to be a successful *Davidsonia* grower. In many cases, due to poor market demand, value adding and marketing skill and commitment are necessary. A strong entrepreneurial ability is advisable. Sound horticultural knowledge and practical abilities are needed. There is a need for technological innovation in the industry and keen improvisational and observational skills. Growers may also need to be in a position to weather financial loss due to market volatility.

Table 1: Marketing chains

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<th>Sold at farm gate</th>
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Markets and marketing issues

Current principal markets are specialty jam and sauce manufacturers, dairy foods, the hospitality and food service industry and wine and liqueur makers. Only a very limited amount of the crop has been exported raw, though value-added products made with *Davidsonia* are exported. The fruit is sold either fresh or frozen as whole fruit, frozen as de-seeded pulp or de-seeded puree. Many growers deseed their crop by hand and freeze to sell as fruit pulp, though the majority prefer to sell whole fruit.

There is a clear and present need for market brokerage and/or grower organisation to ensure quantity and quality of supply in order to access higher volume markets.

Accurate industry estimates are difficult in a dispersed and unorganised industry. Production has been estimated at between 6,000 and 10,000 kg/annum, with many producers not harvesting their crop due to lack of market demand. Some growers have pulled out their orchards in recent years either due to marketing or management problems. Many small orchards (100-1,000 trees, with some to 6,000) were planted in the mid to late 1990s, with very few operating profitably at present. Total plantings may have reached 30,000 trees.

Prices range from $2 to $6 per kg for whole fruit, $5 to $13/kg for hand de-seeded pulp, and around $9 to $10/kg for puree. Organically certified produce attracts a premium in certain markets.

Production requirements

The commercial range of the *Davidsonia* is as yet untested. The tree’s natural range for New South Wales species is from Tintenbar near Ballina to the Tweed Valley in far northern New South Wales, and around 30 km inland from the coast. This suggests the optimum growing area. Young trees do not tolerate frost, but trees more than around three years old can tolerate mild frost to -2°C or -3°C. The natural range of the Queensland species is in rainforest of coastal NE Queensland, however the species is grown commercially in mid-north coastal areas of New South Wales.

No data have been ascertained for *Davidsonia* requirements for optimal photoperiod, chilling hours or diurnal variation to date, and more research in this area would be useful. Good rainfall distribution and volume of around 1,200 to 2,500 mm/annum seems appropriate.

*Davidsonia* do best in deeper, high organic matter, friable soils but naturally occur across a range of soils and climatic conditions.
The Davidson plum or soil types. Soil moisture and therefore water holding capacity is important during flowering and fruit set, though the tree itself can tolerate seasonal dry periods once established. Irrigation is generally thought to be essential for good productivity, particularly at flowering and fruit set during dry springs. During dry periods, competition for water from other tree crops or nurse crops in polycultural orchard plantings has resulted in poor fruit set and size.

*Davidsonia* are able to produce in semi-shaded conditions, and can be appropriate to south-facing slopes. However the most productive orchards appear to be those grown in full sun or east-facing slopes with adequate soil fertility and irrigation. There are problems with losses occurring due to sunburned fruit, which has led to suggestions that south-facing slopes and/or shade tree interplantings are appropriate. Some observations suggest that fruit will burn even in relatively shaded situations, and that fruit burn seems more dependent upon how abruptly high temperatures and sunny conditions follow on from cooler, overcast periods. Orchards should be protected from wind to reduce tree stress.

**Varieties and cultivars**

No recognised cultivars or varieties are available to date. Though some selections have been made by various nurseries for improved performance and manageability, no formal breeding has been carried out on the fruit. Seed-bearing *Davidsonia* spp. are reasonably true to type when grown from seed and are relatively easy to propagate. There are presently three species of *Davidsonia*: *D. pruriens* – the Queensland Davidson Plum, *D. johnsonii* – the Smooth Leaved Davidson Plum. A reported hybrid cross of *D. jerseyana* and *D. pruriens* has fruited for the first time in the last year.

The predominant species grown is *Davidsonia jerseyana*, the New South Wales Davidson Plum. This species is the smallest growing, with trunk-bearing (cauliflorous) characteristics, which lend themselves well to hand harvesting from ground level. The fruit are born in early to mid summer. Selections have been made for larger fruit, a leaf-free trunk and longer flower panicles.

*Davidsonia pruriens* is the predominant crop in Queensland, with much of production in the past coming from the harvesting of naturally occurring trees. This species bears fruit in winter in its natural range, however fruiting period seems less clear in NSW. Crop that is produced in winter has minimal Fruit Fly pressure. Fruit is borne on long flower panicles, generally from upper branches, but often from the tree trunk. Fruit is larger and paler than *D. jerseyana*.

*Davidsonia johnsonii* is very rarely cultivated and is extremely rare in the wild but has been reported to have very high yields. Grafted specimens have been known to bear fruit at year 4 in optimum conditions. This species has significant pest problems from fruit fly (*Dacus* spp) and caterpillars (*Lepidoptera* spp). *D. johnsonii* fruit, though known as ‘seedless’ (seeds are infertile), still...
have a persistent pericarp or seed coat which needs to be removed for most processed products and the flesh of the fruit is paler when compared to *D. jerseyana*.

In the wild, *Davidsonia* are classified by New South Wales NPWS as ‘Endangered’ under the NSW Threatened Species and Conservation Act 1995 and as such a permit is legally required to pick and/or sell material from these plants. Genetic pollution of wild tree populations may be an issue in selecting appropriate planting sites. There are specialist native food nurseries in northern New South Wales selling selected provenance material for fruit production and many rainforest nurseries in both New South Wales and Queensland stock the species or grow to order. One specialist nursery in northern New South Wales offers grafted selections.

### Cultural practices

Site selection should enable adequate safe machinery operation and the ability to irrigate (around 100 l/tree per week during dry periods throughout the flowering and fruiting season may be used as a rough guide). Orchard sward should be established prior to planting if possible, and care should be exercised to avoid any chance of erosion occurring when ripping or exposing soil. Deep ripping will improve the permeability of soil to tree roots, liming materials, fertilisers and water. Liming materials should be applied as early before planting as possible. Soil pH of around 5.2 – 5.5 (CaCl₂) is appropriate for *Davidsonia*. Planting of young trees (less than 300 mm high) will need great attention to weed control, irrigation, sun and frost protection to avoid tree losses and setbacks. Planting of older stock (at least 600 mm high) will improve successful establishment rates, though adequate care will still be needed. Trees from selected seed source or clonally produced will maximise orchard productivity and manageability. Pelleted poultry manure or compost applied at or prior to planting will improve soil organic matter and microbiological health.

Planting models are numerous, ranging from highly diverse plantings to monocultures. Monocultures will provide management efficiencies, though may entail greater pest and disease management inputs. Planting in rows 2.5 – 3.5 m apart will allow for machinery access and plants can be spaced at 1.0 – 1.5 m centres within rows.

Basic equipment relevant to *Davidsonia* production:

- irrigation plant – water storage, licence, pump, controller, mains, laterals and emitters
- tractor with ripper/auger
- mower/offset slasher
- trailer
- brush-cutter or other weed control equipment
- chainsaw/loppers/machine pruner
- picking bags/boxes
- wash and brush system, sorting table/machine
- ripening trays
- ripening room, cool storage, packing room, cold storage (optional)
- commercial grade certified food handling kitchen if value adding
- dispatch, office and warehousing if value adding.

During establishment of young orchards, adequate weed control is essential. As orchards mature, a permanent groundcover should be encouraged. Inter-row sward should be mown or slashed when long and directed under trees as a mulch.

As trees grow taller, canopy must be managed to keep to a harvestable height. Trees beyond this will not be harvested regularly and will become a pest haven. Trees respond to topping at harvestable height by chainsaw every 2-3 years. Alternatively, training the trees to a multiple trunk structure and then periodically trunk stumping.
The Davidson plum on a rotational basis will achieve a similar result.

Harvesting during bearing must be done every 1-3 days, depending on temperature and cloud-cover. Fruit picked just as it is beginning to develop its purple blush will ripen off the tree readily, and this will minimise pest build-up. Other pest control practices should be maintained from flowering to final harvest.

Fertiliser requirements for *Davidsonia* spp. are not well understood or well researched. Current practices are based on individual site observations. Broadly: from year one to three, nutrition aimed at vegetative growth should ensure good tree establishment and bearing structure. Pelleted poultry manure at rates of around 300 g for each site twice a year or 4 litres of composted broiler litter can be applied after harvest, along with 10g per site of K$_2$SO$_4$.

For bearing orchards, at year four onwards, pelleted poultry manure broadcast or banded at rates of around 2,000 kg/ha after harvest or composted broiler litter at 6 m$^3$/ha and 150 kg/ha of K$_2$SO$_4$,

*D. jerseyana* will bear in year three, with commercial production by year four or five. *D. pruriens* will bear in year five or six.

**Pest and disease controls**

Common pests potentially causing large losses:

Native Budworm – *Heliothis sp.* – high populations can occur rapidly and are particularly destructive of flowers and fruit at all stages to maturity.

Light Brown Apple Moth – *Epiphyas postvittana* – larvae grazes on fruit skins and bores into fruit, often grazing on seed. Can cause significant and extensive damage.

Orange Fruit Borer Moth - *Isotenes mierana* - Larvae will eat into fruit and graze on fruit skins.

Fruit Fly – *Dacus* spp. - in heavy Fruit Fly seasons, with poor orchard hygiene, the larvae of this common pest can cause heavy crop losses. Adults may lay eggs in green fruit, not only in ripe fruit, particularly if there are high populations of the pest.

Variegated Hairy Caterpillar – *Anthela varia* – can cause damage to flowers and fruit.

Brown Loopers – *Lophodes sinistraria* - can cause damage to leaves.

Leaf Hoppers and Grasshoppers (unknown spp) can cause damage to leaves and fruit, heavy, deep grazing is often found at all stages of fruit development.

Red Shouldered Leaf Beetle – *Monolepta australis* – often heavily defoliates young leaves of the tree, particularly *Davidsonia pruriens*.

Fruit Spotting Bug – *Amblypelta nitida* – piercing and sucking mouthparts of this common insect superficially damage fruit but do not cause observable losses.

Larvae of Longicorn Beetle – a stem borer, have been known to ringbark and kill off branches and trunks of trees.

Rodents - *Rattus* spp. and *Mus* spp. - Rodents relish the seed of *Davidsonia* spp. but will generally only use fallen or over-ripe fruit, however it has been noted that rodents will forage on fruits in the tree, with the potential to cause substantial damage. Isolated orchards have also lost significant numbers of trees due to rodents chewing the tree bark and root system. Seedbeds in nursery production must be protected from rodents with wire mesh.

King Parrot – *Alisterus scapularis* - will forage on the seed of the fruit and will damage much of the fruit in the process.

Flying Fox – *Pteropus* spp. - have been reported to damage some crops recently. Generally these
native animals have posed a minor problem to *Davidsonia* crops to date.

**Control practices**
There are currently no registered preparations for pest control in *Davidsonia*. Good orchard practice such as maintaining high organic matter, fertile, healthy soils, appropriate canopy management, regular harvest and orchard hygiene are the best measures to minimise the impacts of pest problems.

Integrated Pest and Disease Management practices such as designing orchards to include refuges and corridors for beneficial insects and insectivorous birds will assist in buffering orchards against severe pest problems.

Bait spray or paint yeast autolysate and insecticides (organic or otherwise) subject to compliance with the Pesticides Act and label indications may be a means of controlling fruit fly.

Observations show that where ants are present, generally associated with Mealy Bug (*Planococcus citri*) on fruit stems or calxes, incidence of caterpillar is minimal. Mealy Bug does not observably affect the development or quality of the fruit.

**Harvest and handling, storage, post-**

Harvested fruit should be picked into picking bags or boxes and field heat removed as soon as possible. Food grade approved ripening space at high humidity and low temperature (6-8°C) will be needed for ripening the fruit to full colour. High humidity cool room (2-4°C) storage space for up to a week of harvest during peak bearing period should be planned (around 6m³/ha). Fruit are held cool storage in shallow trays before processing or cold storage. Cold (-18°C) storage facilities may be necessary if fruit is not being sold or processed immediately, or whilst adequate fruit volume is accumulated for processing runs. Around 1m³ will be needed for every 300 kg of whole fruit to be stored. This is often very costly if only seasonally used. Rental of such facilities close to the farm may be practical. Fruit pulp or puree will take less space to store than whole fruit per $ value, and sugar-stabilised puree is able to be stored at more economic temperatures than fresh frozen puree.

Post harvest processing will vary depending on the degree to which a grower value-adds and buyer requirements. Small jam and sauce processors manufacturing boutique or cottage style products generally prefer a hand-deseeded fruit pulp, which has a high ratio of larger fruit and skin pieces in it. There is reasonable demand for hand de-seeded fruit pulp, however the process is very labour-intensive, and growers are often overstretched for labour. Often the hand processing is done in a domestic situation or by junior labour. At award rates and under commercial conditions the costs are such that buyers are often not
Longer panicles occur on some specimens of *D. jerseyana*

prepared to pay realistic amounts for the resulting pulp. Machine pulping to remove the fruit seeds and calyx has been in development by some growers and processors for some years. Getting a balance between removal of the fruit calyx and keeping larger fruit and skin pieces has been difficult, however the resulting puree is well suited to sauces, jams, syrups and beverages and offers commercial scale volume and a more acceptable market price.

**Financial information**

Davidsonia are a high risk crop. It may provide an alternative crop to diversify an existing enterprise, but at this time does not offer a predictable or commercially profitable business opportunity. Enterprises with existing value-adding or tourism operations may be better placed to make a viable income from a Davidsonia growing enterprise through integration with these other businesses.

Broad figures here are based on a monocultural planting on relatively flat and clean, rock-free ground, with water supply, planted at 2000 trees/ha.

**Getting started – establishment costs**

General equipment and infrastructure costs, excluding land, will run to over $100,000. Establishment costs including irrigation, set out, preparation planting and planting stock will run to around $15,000/ha.

**Ongoing costs**

Maintenance costs run to around $3,500/ha/yr including slashing, weed-control, fertiliser, fuel and canopy management. Harvest, grading and packing costs may run to over $8,000/ha.

**Yield**

Given 2,000 trees/ha, a yield of between 1 and 3 kg of fruit/tree is likely – a total of 2,000 to 6,000 kg/ha.

**Value**

Calculating a predicted value in an oversupplied market is fairly academic. Broadly: market prices of between $2 and $6/kg whole fruit give a value range of $4,000 – $36,000/ha. After operating expenses of $11,500 this leaves a profit margin of between $(7,500 loss) and $24,500/ha.

Other costs such as cool or cold storage, finance costs etc. need to be considered. The major risks to the grower lie in the small scale and vulnerability of the buyers’ sector. Only a limited market is established for the fruit, and the market is currently oversupplied. Any further plantings would need significant market development in order to be viable.

**Key references**


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Anthony Hotson operates a wholesale nursery at Tuckombil, near Alstonville in Northern NSW, which specialises in sub-tropical native food plants, rainforest reforestation and macadamia trees. He has been growing and researching Davidsonia since 1995 and runs a 1,500 tree commercial orchard.

Key messages

- Native rainforest species
- Versatile processing fruit
- Clear need for market development
- Need for improved technologies

Key contacts

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Key statistics

- Estimated production 6,000 - 10,000 t/yr
- Estimated plantings - perhaps 30,000 trees
- Estimated current market 5,000 t/yr
Nuts

Cashews 386
Hazelnuts 393
Cashews

Introduction

Cashew (Anacardium occidentale L.; Anacardiaceae) is a tropical evergreen tree from north-east Brazil. Distribution of the species around the world is mainly attributed to the Portuguese who brought the cashew to their colonies in East Africa and India during the 14th and 15th centuries. World production of cashew in 2002 was about 2,100,000 t of nut-in-shell (NIS), produced mainly in India, Brazil, Vietnam, and Africa. Local consumption and demand by importing countries continues to increase, providing opportunities for expansion of the crop worldwide.

Commercial cashew growing has potential in the Australian tropics. Large areas of suitable land with adequate water supply and suitable climate exist in the Northern Territory and far north Queensland. Cultivation in remote locations does not have the risks associated with highly perishable fruits as the nut can be stored for long periods and can tolerate long-distance transport. Australia imported an estimated A$50M (wholesale value) of cashew kernels in 2002. A local industry would provide import replacement and create export.
opportunities for sale of NIS, raw kernel and value-added products.

There are currently two major plantations in Australia, one in north Queensland and the other in the Northern Territory. To be profitable, the Australian industry needs suitable varieties and field management practices to achieve and sustain economic yields. Plantations of at least 500 ha in single or cooperative plantations may be required to establish a brand name in the local/international market and to minimise the unit costs associated with production and the overseas processing. Sound financial, personnel, agronomic and marketing skills are required to manage and operate plantations of this size successfully.

**Markets and marketing issues**

Of the total world production of cashew kernel (estimated at 522,000 t), 241,000 t was traded on international markets in 2002. India (51%), Vietnam (26%) and Brazil (13%) are the major exporters. The major consumers are the USA (46%), the Netherlands (10%), the United Kingdom (5%), and Australia, China and Canada (4%). Australia imported about 8695 t of kernel in 2002. (Data supplied by FAO).

As the major importer of cashew, the USA has a strong influence on the world price which is fixed in US$/pound (1 pound = 0.45 kg) of kernels. The price of W320 grade (320 kernels/pound) over the last 10 years has been quite volatile ranging from US$2.30 in March 1994 to US$3.15 in September 1999 to US$1.75 in July 2003.

Overseas, the nuts are collected from the growers by local traders who in turn sell to large processing companies. After processing, the kernels for export are sold by trading companies to overseas markets through agents or dealers. Several Australian dealers who import from India, Vietnam and Brazil supply the major retailers in Australia with kernel. The major Australian dealers are GB-Commtrade Pty Ltd, Michael Waring Trading and Scalzo Food Industries.

The raw nut produced in Australia is shelled overseas and the kernel returned to the grower and sold raw or as value-added products. Australian production of raw nut in 2002 was 130 t. As the Australian industry expands, it is likely that growers will benefit from pooling their production, producing value-added products, and marketing with an Australian brand name.

**Production requirements**

Commercial cashew production requires a seasonally wet/dry tropical climate, the dry season coinciding with flowering and nut development. The area selected for cashew production should be frost-free. Mean daily temperatures of less than 25°C will limit growth and production. These conditions can also delay flowering resulting in nut maturity during the wet season with potential crop loss. With exceptions, areas south of 16°S latitude are generally considered marginal for cashew in Australia (see map).

Soils should be free draining, as cashew does not tolerate waterlogging. Rocky or stony soils disrupt harvesting and increase post-harvest cleaning costs and should be avoided. Slopes should not exceed 12% to minimise erosion risk and facilitate the operation of heavy machinery.

Cashew is known for its drought tolerance, however it is unlikely that economic yields (above 3t/ha NIS advisable) can be achieved without irrigation. Sufficient water should be available to apply irrigation during flowering and nut development (July to December, depending on location) at weekly intervals at the rate of 500 L/tree/week.
**Varieties/cultivars**

Australian plantings have been established mainly with locally selected or recently imported varieties and generally this material has not been proven under commercial culture in local climatic conditions.

A number of hybrids were selected under a joint government/grower plant improvement program in 2002. Royalties apply to the use of this material and enquiries regarding availability should be directed to CSIRO. Limited genetic material of some local selections is available from DPI&F in Queensland and DBIRD in the Northern Territory. Cashew growth and yield is influenced by environment (climate, soil, culture). Material should therefore be tested on a range of rootstocks in the intended plantation location if the environment of this location is different from the environment from which the material was sourced.

**Cultural practices**

Before developing the property, a farm plan defining the placement of infrastructure (buildings, roads, dams, underground irrigation mains, etc) and a schedule of development tasks should be formulated. Careful site preparation (land clearing, windbreaks, erosion and drainage structures, soil tilth and amelioration, irrigation installation, root and rock removal) will promote healthy tree growth and harvest efficiencies. In areas where giant termite (*Mastotermes darwiniensis*) exists, root removal is also important to reduce the risk of infestation.

Cashews are commonly planted in rows 8 m apart and 6 m apart within the row. Commercial trees are propagated by grafting because trees raised from seed do not grow true-to-type. With good culture, grafted trees will produce sufficient yield by the third year after planting to warrant mechanical harvesting. Nuts with ‘apples’ attached are harvested from the ground, then cleaned, dried, applies removed and the nuts stored. A well managed plantation will require propagation/nursery facilities, an under-tree sprinkler irrigation system with fertigation capability, tractors, slasher/weedicide boom, mist-blower, hedger, sweeper/harvester, nut cleaning, drying and apple removal equipment and storage facilities.

Cultural practices are designed to promote healthy trees while at the same time managing canopy growth, nut yield and quality, and timing of nut drop. In the period from planting to first harvest, a canopy framework is developed which is structurally sound, shaped to facilitate spray coverage and mechanical harvesting, and maximises nut yield in the shortest time from planting.

The main season of vegetative growth (December–April) coincides with the wet season and is followed by flowering (July–September) and nut drop (October–December). The critical aspects of managing growth and nut production are: insect control during vegetative
growth, flowering and early nut development; irrigation during floral and nut development; and adequate nutrition during vegetative growth. Additional operations include pruning immediately after harvest (before vegetative growth season), pre-harvest field preparation, and weed control.

Cashews require all the major nutrients (N, P, K, Ca, Mg and S). They are particularly sensitive to zinc deficiency, and iron deficiency has been observed in trees growing in high pH soil (>8.0). Nitrogen nutrition is very important because it has a major influence on vegetative growth that determines nut yield and timing of nut drop.

**Pest and disease control**

Various insect and animal pests are prevalent in the cashew growing areas in Australia. Only two diseases are of significance, cercospora blotch (*Pseudocercospora anacardii*) in north Queensland and anthracnose (*Colletotrichum gloeosporioides*) in areas where rainfall occurs throughout the year.

Some insects are confined to the wet season, e.g. mango shoot caterpillar (*Penicillaria jocosatrix*), leaf miner (*Acrocercops spp.*) and leaf roller (*Anigraea ochrobasis*). Others can attack trees at any time during the year, e.g. giant termite (*Mastotermes darwiniensis*), tea mosquito bug (*Helopeltis spp.*), fruit spotting bug (*Amblypelta lutescens*), red-banded thrips (*Selenothrips rubrocinctus*) and pink wax scale (*Ceroplastes rubens*). Insects (*Ephestia spp.*) can also infest nuts in storage.

Most of the insect pests attack tender growth causing defoliation, death of flowers and premature nut drop. Control during mid to late vegetative growth, panicle emergence and early nut development is essential as damage during these periods can result in the greatest reduction of nut yield.

An integrated pest management approach involving regular monitoring, biological control, and strategic sprays during critical times should be taken. Green ants (*Oecophylla smaragdina*) attack a number of insect pests of cashew and the wasp, *Anicetus beneficus*, is a parasite of pink wax scale.

**Harvesting, post-harvest handling and processing**

Cashew fruit (nut with apple attached) fall to the ground when mature. The fruit is swept to the centre of the inter-row and then picked up by a harvester. Tree canopy obstruction and ground surface condition influence the speed of harvest, the quantity of nuts harvested and the amount of extraneous material mixed with harvested nuts.

A pre-harvest cleanup is necessary to remove low branches, level the

Giant termite, only a problem in the Northern Territory and Western Australia, burrows within the tree, gaining entry through the roots from subterranean canals. Infestations can exist unnoticed until death of the tree. Control requires constant surveillance and baiting. Fruit bats and rats can also cause economic loss. Fruit bats feed on the apple and can remove significant quantities of nut from the plantation boundaries. Windbreaks planted within the plantation have been effective in encouraging bats to feed on the cashew apples and drop the nuts within the plantation. Rats can destroy polyethylene irrigation pipes and fittings. Damage can be minimised by baiting and plantation hygiene (grass control).

Currently there is only one insecticide registered with the Australian Pesticides and Veterinary Medicines Authority for use in cashew. This chemical does not control the full range of insect pests and will burn some cashew varieties. Effective management of insects in cashew will require the registration of additional chemicals.

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Sweeping nuts into the inter-row during harvesting

Financial information

Since 1987, a number of economic analyses of the profitability of commercial cashew growing in Australia have been undertaken that conclude various yields up to 5 t/ha NIS are needed to attract investment. The most recent analysis, completed in 1998, investigated the profitability of growing cashew in the Mareeba–Dimbulah Irrigation Area (MDIA) of far north Queensland.

Growing cashews in the MDIA was profitable based on an analysis of a 200 ha farm. The analysis used a farm-gate price of A$1.63/kg NIS and a most likely yield of 14 kg NIS/tree from Year 6 onwards. All nuts were processed in China and the raw kernels were sold in Brisbane. The estimated equivalent annual return (net of all operating, labour and capital outflows) was $144,000 or $0.34/kg NIS. The internal rate of return and discounted payback period were 14% and 11 years, respectively.

To establish the farm it was estimated that an investor would outlay $1,607,000. This included cash outlays for land, capital equipment, water allocation and establishing the plantation.

determine the yield of kernel to the processor. Kernel price is influenced by kernel quality (e.g. kernel size, whether whole or broken), and quality specifications are defined by the International Organization for Standardisation (ISO).

Australian nuts to date have been sold mainly as processed value-added products. Such sales reap higher returns compared with NIS and raw kernel sale.

In addition, broken kernel, which would otherwise be downgraded under ISO standards, and so draw a lower price, can be marketed at the same price as premium grade kernel.

ground surface and remove trash and old nut.

While the harvester aspirates light extraneous material, further cleaning may be required before the nuts are dried and the apples removed.

Nuts must be stored at less than 9% moisture content to prevent rancidity.

There are no shelling facilities in Australia. The process of kernel extraction is complicated and laborious and involves removal of the shell’s caustic oil, shell cracking and testa removal.

Australian nuts are currently sent overseas (e.g. China) for kernel extraction. Overseas processors are reluctant to accept small quantities of raw nut (less than 100 t).

Growers with less than 100 t can sell to a local large producer or combine their raw nut crop with other small producers to meet processors requirements.

Nuts may be sold as NIS, raw kernel or as processed value-added products (roasted, chocolate coated). The price paid for NIS is influenced by the nut’s size and kernel recovery that together

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Sweeping nuts into the inter-row during harvesting

Ground surface and remove trash and old nut.

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About the authors

Pat O’Farrell is a Senior Experimentalist with the Department of Primary Industries and Fisheries based in Mareeba in north Queensland. Mr O’Farrell has worked in horticulture research for over 30 years, mainly in banana, cashew and macadamia agronomy.

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Key statistics

Quality and value of cashew kernel imported into Australia and estimated Australian production of kernel in 2002.

- Kernel imports (t) – 8695
- Import value (A$m) – 50
- Australian production (t) – 35

Key messages

- Domestic and export market opportunities
- Tropical Australia suited to cashew
- High NIS yields (>3 t/ha) advisable
- Efficient in-field production systems necessary
- Limited chemical registration
- Overseas processing required
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Hazelnuts

Basil Baldwin

Introduction

Although hazelnuts (*Corylus avellana* L.) were introduced into Australia over 100 years ago, to date they have only been grown on a relatively small scale. Current annual production is estimated to be approximately 50 tonnes of in-shell nuts. However, there appears to be an opportunity for considerable expansion of the local industry, as more than 1600 tonnes of nuts and kernels, valued at over $12 million, are imported into Australia annually.

It is considered that the establishment of a local industry could complement overseas production through the provision of fresh, locally grown nuts that could be stored, in-shell, at a relatively low cost and cracked as required to supply fresh kernels for local processors and consumers. Major users of hazelnuts in Europe are also interested in obtaining product from Australia, provided the nuts or kernels are of appropriate quality and are available in sufficient quantities.

In addition to the freshness of the Australian product for local users, it has the potential to capitalise on a ‘clean and green’ image, as few of the major pests and diseases of hazelnuts have been introduced.
into Australia. In order to capitalise on these market opportunities, there is a need for research to evaluate appropriate varieties and develop efficient production systems. To be competitive and gain labour efficiencies, growers need to mechanise harvesting, storage, and processing of nuts. Although opportunities exist for growers to market their own produce, as production expands and smaller market niches are satisfied there will be a need for growers to develop strategic alliances with major buyers.

**Markets and marketing issues**

Hazelnuts are marketed as two products, nuts in-shell and kernels. Nuts in-shell, marketed mainly for home or table consumption, account for less than 10% of the total market. Most hazelnuts are cracked and sold as kernels, which can be eaten fresh, but the vast majority are either blanched or roasted and then used in confectionery products, cakes and biscuits. Hazelnuts are highly nutritious and can be used for a wide range of purposes, such as in muesli, salads and as a complement to many food dishes. Other products include hazelnut spreads, nougat, hazelnut oil and liqueurs.

The major centre of hazelnut production in the world is in northern Turkey, on the Black Sea coast. There are other important production areas in Italy, Spain and Oregon, USA. The nuts produced by the Turkish growers are commonly stored on farm and then sold during the year to operators of cracking plants. The cracked kernels are size-graded and placed in plastic vacuum packs, which are kept in cool storage to prevent rancidity. The volume and value of nuts and kernels imported into Australia in recent years are given in Table 1. The quantity of imported kernels has generally risen over the last decade, as has the average price. The unit value is the landed price in Australia.

There are many variations of the market chain from production to processing and consumption (Figure 1).

**Table 1: Quantities and values of hazelnut imports into Australia**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazelnut kernels (Shelled nuts)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total tonnes</td>
<td>1713</td>
<td>1811</td>
<td>1764</td>
<td>1648</td>
<td>1990</td>
</tr>
<tr>
<td>Total customs value (A$ '000's)</td>
<td>9734</td>
<td>12317</td>
<td>10936</td>
<td>8613</td>
<td>12583</td>
</tr>
<tr>
<td>Unit value (A$/kg)</td>
<td>5.68</td>
<td>6.80</td>
<td>6.20</td>
<td>5.23</td>
<td>6.32</td>
</tr>
<tr>
<td>Hazelnuts in-shell</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tonnes</td>
<td>28</td>
<td>125</td>
<td>111</td>
<td>42</td>
<td>43</td>
</tr>
<tr>
<td>Total customs value (A$'000's)</td>
<td>66</td>
<td>590</td>
<td>476</td>
<td>221</td>
<td>149</td>
</tr>
<tr>
<td>Unit value (A$/kg)</td>
<td>2.33</td>
<td>4.71</td>
<td>4.28</td>
<td>5.27</td>
<td>3.45</td>
</tr>
</tbody>
</table>

*Source: Australian Bureau of Statistics*
To date, one of the major constraints to the development of the local industry has been the lack of knowledge on the performance and appropriate management of introduced varieties which might be grown to complement imported nuts.

Production requirements

Hazelnut production is favoured by a climate with a cool winter and mild summer (Allen A. 1986) such as is found in the coastal and upland areas of southern Australia.

Hazelnut trees have a poor tolerance to heat, wind and moisture stress. The trees are deciduous and, when dormant, can tolerate temperatures as low as -15°C. At the time of pollination, June - August, the pollen and stigmas can be harmed by temperatures below -8°C and above 20°C. In Australia, spring frosts at the time of leafing in September and October do not seem to be a problem.

The main production areas in the Northern Hemisphere have a Mediterranean-type climate and are in the latitude range 37° to 47°. The climate of locations in Australia where hazelnut groves have been successfully established compares favourably with major Northern Hemisphere production areas (Table 2).

The growth of hazelnut trees is favoured by well-drained, fertile loam soils with a pH range of 6.5 to 7.5. Overseas, where annual rainfall exceeds 900mm, the crop is generally grown without irrigation, particularly where soils are deep. In Australia, it is considered highly desirable to irrigate orchards in the establishment phase. Where annual rainfall is less than 850-900mm and soils are not deep, irrigation is recommended for mature orchards, particularly during the phase of nut development and kernel fill, which is from late November to early February. Water requirements are estimated to be about 1-1.5 megalitres for every 150mm of rainfall less than 900mm. Dry weather during the harvest period is advantageous. This is generally during March in Australia.

Hazelnut trees do not tolerate strong winds and therefore the selection of sheltered sites, or the planting of wind breaks before establishing the grove, is very important. Flat or gently sloping sites are preferred to facilitate operations within the grove, particularly mechanical harvesting.

Varieties

Selecting the most appropriate hazelnut varieties for planting

Table 2: The climate of hazelnut production areas overseas compared with Australian localities where hazelnut groves have been successfully established

<table>
<thead>
<tr>
<th>Climatic Data</th>
<th>Location</th>
<th>Australia</th>
<th>Myrtleford Vic</th>
<th>Orange NSW</th>
<th>Kettering Tas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Key production areas</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ordu Northern Turkey</td>
<td>Nola Campania Italy</td>
<td>Corvallis Oregon USA</td>
<td>Bega, NSW</td>
<td></td>
</tr>
<tr>
<td>Latitude (°N)</td>
<td>410</td>
<td>410</td>
<td>450</td>
<td>370S</td>
<td>370S</td>
</tr>
<tr>
<td>Mean annual rainfall (mm)</td>
<td>990</td>
<td>1010</td>
<td>1050</td>
<td>870</td>
<td>910</td>
</tr>
<tr>
<td>Hottest month Mean max (°C)</td>
<td>25</td>
<td>30</td>
<td>27</td>
<td>27</td>
<td>28</td>
</tr>
<tr>
<td>Mean min (°C)</td>
<td>18</td>
<td>18</td>
<td>11</td>
<td>14</td>
<td>12</td>
</tr>
<tr>
<td>Mean rain (mm)</td>
<td>68</td>
<td>29</td>
<td>14</td>
<td>89</td>
<td>45</td>
</tr>
<tr>
<td>Rain days</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Coldest month Mean max (°C)</td>
<td>10</td>
<td>12</td>
<td>7</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Mean min (°C)</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Mean rain (mm)</td>
<td>95</td>
<td>111</td>
<td>173</td>
<td>53</td>
<td>106</td>
</tr>
<tr>
<td>Rain days</td>
<td>10</td>
<td>11</td>
<td>19</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Harvest month Mean rain (mm)</td>
<td>72</td>
<td>79</td>
<td>38</td>
<td>98</td>
<td>60</td>
</tr>
<tr>
<td>Rain days</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>8</td>
<td>6</td>
</tr>
</tbody>
</table>

Source: Climatic Averages, Australia, Bureau of Meteorology, www.bom.gov.au
is a very important decision. The University of Sydney is undertaking research on this matter with funding provided by RIRDC. A report of research to-date is available at http://www.rirdc.gov.au/reports/NPP/03-141sum.html

There are two main aspects that have to be considered when selecting varieties; these are the productivity of the variety for the particular conditions of the site and the marketability of the nuts. Ideally the varieties planted should be both productive and of a type for which there is a market demand.

Although a wide range of varieties can be sold in-shell, there is a customer preference for nuts that are large with a clean, shiny appearance and even size. Varieties that meet these requirements include Ennis from the USA and Wanliss Pride, an old Australian selection (Table 3). A large proportion of the imported in-shell nuts are of the variety Oregon Barcelona, which has relatively large attractive nuts. However, imports of this variety are being superseded by the larger sized Ennis.

Those growers who plan to sell into the kernel market need to talk to buyers or potential buyers to ascertain whether any particular variety or varietal characteristics are sought such as kernel size, shape, texture, taste, oil content and blanching or roasting characteristics. Some processors have very specific requirements for their products. Small round kernels (13-15mm diameter) are generally preferred in confectionery products, such as from the variety Tonda di Giffoni. A few buyers have specific varietal preferences, such as Bristowe Farm Hazels who prefer the variety Tokolyi/Brownfield Cosford (TBC), see http://www.hazelnuts.net.au/

Wanliss Pride is a variety that was widely grown in the past. It has a large nut and produces a sweet tasting kernel. However, it is prone to rancidity when insufficient care has been taken to thoroughly dry the nuts at harvest time.

Hazelnut kernels are covered with a skin or pellicle, which varies in thickness and appearance between varieties. The pellicle can be readily removed from most varieties by a process known as blanching, which involves heating kernels for 10-15 minutes at 140°C, followed by brushing off the loose pellicle to leave a clean white kernel. Examples of varieties that blanch well are Tonda di Giffoni, and the Australian selections Tokolyi/Brownfield Cosford (TBC) and Wanliss Pride. Roasting, which involves heating for a longer period of time increases the flavour and crunchiness of kernels. General descriptions of nut and kernel characteristics are given in Table 3.

Many of the early hazelnut introductions into Australia were in the form of nuts. As the species is cross-pollinated, the seedlings grown from these nuts were not true to varietal type. Local selections have been made from these seedling types, some of these have been found to be useful, such as Wanliss Pride, Tokolyi/ or Brownfield Cosford (TBC) and Tonollo. Unfortunately, the word Cosford as applied to Tokolyi Cosford is a misnomer as the selection is a round nut, rather than the typical, elongated Cosford shape.
Table 3: Key characteristics of some important overseas and Australian hazelnut varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Country of Origin</th>
<th>Av. nut wt (g)</th>
<th>Yield attributes</th>
<th>Characteristics of nuts &amp; their uses</th>
<th>Principal pollinisers (Early (e), mid (m) and late (l) female bloom)</th>
</tr>
</thead>
<tbody>
<tr>
<td>** Introduced cultivars **</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barcelona</td>
<td>USA</td>
<td>3.3</td>
<td>Good, wide adaptation</td>
<td>Moderate blanching, kernel and in-shell</td>
<td>Butler (e), Casina/Lewis/TBC (m) and Halls Giant (l)</td>
</tr>
<tr>
<td>Butler</td>
<td>USA</td>
<td>3.3</td>
<td>Good, wide adaptation</td>
<td>Mainly a polliniser, but suited to the in-shell market. Poor blanching</td>
<td>Barcelona (e), Ennis (m) and Hall's Giant (l)</td>
</tr>
<tr>
<td>Casina</td>
<td>Spain</td>
<td>1.6</td>
<td>Moderate yield, mainly used as a polliniser</td>
<td>Little pellicle, poor blanching</td>
<td>Hall's Giant (m)</td>
</tr>
<tr>
<td>Ennis</td>
<td>USA</td>
<td>4.0</td>
<td>Moderate to good yield</td>
<td>Large nut for in-shell market</td>
<td>Butler/Casina (e), Hall's Giant (m) and Jemtaegaard#5 (l)</td>
</tr>
<tr>
<td>Hall's Giant or Merville de Bollwiller</td>
<td>Germany</td>
<td>3.4</td>
<td>Very low yield.</td>
<td>Large nut, principally a late pollinator for many varieties</td>
<td>Ennis and Casina (e)</td>
</tr>
<tr>
<td>Tonda di Giffoni</td>
<td>Central Italy</td>
<td>2.7</td>
<td>Early variety, high yield</td>
<td>Excellent blanching, used in confectionery</td>
<td>Barcelona (e), Lewis (m) and Halls Giant (l)</td>
</tr>
<tr>
<td>Lewis</td>
<td>USA</td>
<td>2.8</td>
<td>Promising new cultivar</td>
<td>Blanches well</td>
<td>Tonda di Giffoni/Banana (e) and Hall's Giant (l)</td>
</tr>
<tr>
<td>** Australian selections **</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBC</td>
<td>Aus</td>
<td>3.0</td>
<td>Appears to be productive over a wide range of environments</td>
<td>Kernel blanches well, very crunchy</td>
<td>Barcelona/Ennis (e), Casina/Willamette/Turkish Cosford (m) and Daviana/Woodnut (l)</td>
</tr>
<tr>
<td>Tonollo</td>
<td>Aus</td>
<td>3.2</td>
<td>High yields on basalt soils</td>
<td>Sweet kernel, blanches well</td>
<td>Butler (e), Casina/Lewis (m) and Halls Giant (l)</td>
</tr>
<tr>
<td>Wanliss Pride</td>
<td>Aus</td>
<td>3.3</td>
<td>Poor growth on red basaltic soils, Spreading habit of growth</td>
<td>Large nut, sweet kernel for in-shell and kernel markets</td>
<td>Suggest TBC (e), Woodnut (m) and Kentish Cob (l)</td>
</tr>
</tbody>
</table>

During the last ten years, many individual growers and propagators have imported varieties from the USA and Europe. These are currently being evaluated at sites in New South Wales, Victoria and Tasmania. The yield attributes, under Australian conditions, of the local selections and promising overseas varieties are given in Table 3.
**Cultural practices**

It is important to select a sheltered planting site, as hazelnut trees are very sensitive to wind damage, particularly in the establishment years. It is advisable to plant shelter belts around a proposed site, two or three years ahead of planting the grove.

It is generally advisable to apply lime to sites that are acid, one year before planting, to bring the soil pH up to a reading of about 6.5. Ripping the planting rows in the autumn of the planting year may be beneficial on soils that are prone to compaction. Cultivating the planting row in autumn will loosen soil in preparation for planting in winter and provide an environment that favours root growth.

Groves are commonly planted at a density of 400 - 500 trees/ha, with a spacing of 5-6m between the rows and 3-4m between trees within the rows. The more vigorous varieties are planted at the wider spacing. It is essential to keep new plantings free of weeds and highly advisable to mulch around the base of young trees to favour moisture retention and lower the soil temperatures in summer. It is very important that young trees receive adequate water. Supplementary irrigation will be required if rainfall is insufficient.

Hazelnut varieties produce suckers to varying degrees. These suckers grow vigorously and must be removed several times each year, in order to restrict growth to the main productive part of the tree. Suckers are either removed by hand or by chemical spraying. The removal of sucker buds before planting can reduce subsequent sucker production.

Hazelnut trees are cross-pollinated. The male catkins, formed during late summer and autumn, elongate in winter and shed pollen, which is carried on the wind to the small female flowers. When receptive, these female flowers appear as small buds with reddish filaments (stigmas) at their tips. Although catkins and female flowers are borne on the same plant hazelnuts are not self-fertile. Pollination occurs in the winter, but fertilisation does not take place until early summer when the seed (kernel) develops within the shell. The mature nuts ripen in late summer with most varieties falling free from their husks to the ground during March.

For pollination to be effective, the two varieties involved need to be genetically compatible and their period of pollen shed and stigma receptivity must be synchronous. The genetic compatibility of overseas varieties is known and can be used by growers to select appropriate varieties for effective pollination. The variety Barcelona, for example, which is grown for its high nut yield, is pollinated by the varieties TBC and Halls Giant. TBC sheds its pollen earlier than Halls Giant. These two varieties cover the main period when the female flowers of Barcelona are receptive. Both TBC and Halls Giant produce many catkins and copious quantities of pollen.

The selection of appropriate pollinisers is a critical aspect of hazelnut production. A ratio of one polliniser tree to nine main crop trees is generally recommended to ensure sufficient pollen is spread through the grove. Some main crop varieties such as Barcelona and TBC are cross compatible, with TBC giving good pollination of Barcelona. Unfortunately Barcelona only pollinates the early flowers of TBC; thus additional pollinisers are required for TBC.
Hazelnuts

Pests and diseases

Hazelnut producers overseas have to contend with many pests and diseases but, as a result of strict quarantine regulations, most of these have so far been excluded from Australia. Hazelnut blight (Xanthomonas corylina), an important bacterial disease of hazelnuts world-wide, does occur in Australia. It was first detected in Victoria in 1980. Blight mainly affects young trees, causing dieback of new shoots and reddish brown lesions (1 - 3mm diam.) on the leaves. The husks of infected nuts also have reddish-brown lesions on them and some staining or discoloration of the actual nuts can occur. The disease is favoured by wet weather in spring and seems to be more prevalent at sites where trees are exposed to strong winds. The rubbing of leaves under windy conditions causes damage to the leaf surface, which allows bacteria to enter and blight to develop.

The principal method of blight control is through the application of protective copper-based sprays. Cupric hydroxide is the most commonly used chemical.

Aphids are often found on the underside of hazelnut leaves. These small, greenish insects suck out the sap of the plant and can affect development when aphid populations are high. Sooty mould develops on the honeydew excreted by the aphids, causing an unsightly black discoloration of the leaves, nuts and wood.

Flocks of sulphur-crested cockatoos have caused losses of mature nuts in some Australian groves. This pest is a major threat in some areas. Foxes can also be a pest at harvest time, as they eat the fallen, ripe nuts.

Harvesting and postharvest handling

In most commercial varieties, nuts fall freely to the ground, falling free from their husks. In small groves, nuts are often picked up by hand but as this is a relatively slow process mechanised or partly mechanised systems are usually employed. There are three types of mechanical harvesters - sweep and pick-up, vacuum and finger wheel harvesters. The sweep and pick-up method is fast and best suited to larger orchards. Flory Industries in the USA manufacture a range of sweeping and pick up machines for hazelnuts, see under Products on their web site [http://www.floryindustries.com/](http://www.floryindustries.com/).

Vacuum harvesters are of intermediate price. They have hand held hoses which operators use to suck up the fallen nuts. Most of these harvesters use wind to separate the nuts from the leaves and have dehuskers and rotary screens for cleaning nuts. A tractor driver and two operators on the suction hoses can pick up 5kg of nuts per minute in productive orchards. Leading Australian growers Brian and Glenice Horner of Glenbri Farm near Eden, use a small suction harvester for their crop. This can be seen on the RIRDC Thirty Australian Champions web site [http://www.rirdc.gov.au/champions/GlenbriFarmHazelnuts.html](http://www.rirdc.gov.au/champions/GlenbriFarmHazelnuts.html).

It is essential to have a level, smooth, firm soil surface in the grove at harvest.

Nuts that are dirty should be washed. All nuts should be dried to a moisture content of 5%, as soon as possible after harvest. Nuts at this moisture content will keep satisfactorily for 12 months.

Nuts for the in-shell market should be size graded. The five size grades used in the USA are recommended for Australian grown nuts, ranging from Small, (less than 13 mm) to Giant or Jumbo (over 22 mm). The maximum moisture tolerance is 5%, as is the maximum tolerance for blanks.

For the kernel market, nuts are cracked and size graded. Kernels produced by the major exporting...
countries are subject to stringent quality specifications. There is a zero tolerance of foreign material and uncracked nuts as well as kernels that are rancid and mouldy. Those planning to crack nuts and sell kernels must develop quality control systems to similar standards.

**Financial information**

The economics of production is strongly influenced by crop yield, the price obtained for the kernels or nuts and the scale of operations. The cost of land will have a major influence on the establishment costs. Assuming that an intending grower already has the land and a water supply, the main costs incurred in establishing a hazelnut grove are land preparation, purchase of young plants (whips) and the installation of an irrigation system. Typical establishment costs are:

<table>
<thead>
<tr>
<th>Costs</th>
<th>$/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime application 5t/ha @ $60/t</td>
<td>300</td>
</tr>
<tr>
<td>Land preparation, fertilisers and weed control</td>
<td>250</td>
</tr>
<tr>
<td>400 trees @ $11/tree</td>
<td>4400</td>
</tr>
<tr>
<td>Irrigation system (1)</td>
<td>2000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6950</td>
</tr>
</tbody>
</table>

Note (1) - Assumes water supply to the site

Little production occurs before the fifth year, with nut yields rising steadily over the next five years. Assuming a yield of 2t of nuts/ha per annum by the tenth year from planting, the following annual gross margin could then be achieved:

<table>
<thead>
<tr>
<th>Income</th>
<th>$/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazelnuts (in-shell) 2 t/ha</td>
<td>6000</td>
</tr>
<tr>
<td>Variable production costs</td>
<td></td>
</tr>
<tr>
<td>Fertilisers</td>
<td>150</td>
</tr>
<tr>
<td>Sucker removal (4 times/yr)</td>
<td>100</td>
</tr>
<tr>
<td>Mowing (5 times/yr @ $20)</td>
<td>100</td>
</tr>
<tr>
<td>Weed control</td>
<td>100</td>
</tr>
<tr>
<td>Irrigation (Application costs)</td>
<td>150</td>
</tr>
<tr>
<td>Harvesting (Machine @30c/kg)</td>
<td>600</td>
</tr>
<tr>
<td><strong>Total costs</strong></td>
<td>1200</td>
</tr>
<tr>
<td>Gross margin ($/ha)</td>
<td>4800</td>
</tr>
</tbody>
</table>

Notes:

(1) Yields equivalent to 3t/ha have been achieved at the Myrtleford research site. Commercial yields of 2t/ha are common in Oregon, USA.

(2) Estimated cost of mechanical harvesting using a contractor.

The overall economic viability of the enterprise can be improved through value adding, such as cracking nuts, roasting the kernels or using them to make some special products such as biscuits, or hazelnut chocolate.

At Glenbri Farm, Brian and Glenice Horner have equipment to crack nuts and value add to their kernels, which are all sold locally, see: http://www.rirdc.gov.au/champions/GlenbriFarmHazelnuts.html. Brian and Glenice have no difficulty in selling all they produce locally, indicating the potential for Australian grown, fresh hazelnuts.

**Key references**


**Source of planting materials**

Bristowe Farm Hazelnuts (Nursery), Mudgee, NSW. http://www.hazelnuts.net


Milan Paskas, 24 Olsen Road, Nar Nar Goon North, Victoria. Phone 03 5942 8381

Mountain Greenery Nurseries Richard Salt, Daylesford, Victoria. Phone 03 5348 7818 rsalt@bigpond.com

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Industry Association
Hazelnut Growers of Australia Ltd
http://www.hazelnuts.org.au/

Key statistics

- Imports of hazelnut kernels 1997 -2001
  - Total quantity       nearly 2000 t
  - Total customs value     $12 million
  - Unit value of imported kernels  $5-6/kg

Key messages

- Hazelnuts are a cool climate crop
- Hazelnuts valued at more than $12 million are imported annually into Australia
- Current Australian production of hazelnuts is small
- Hazelnuts have great potential as a crop, but careful selection of sites and varieties is important
- Long term potential exists for organic production and export to Northern Hemisphere countries
Wildflowers

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Boronia 420
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Flannel flower 434
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NSW Christmas bush 450
Smokebush 458
Thryptomene 463
Tropical rainforest foliages 469
Waxflower 476
Banksia and other proteaceae
Including Telopea (Waratah) and South African species

Christine Horsman

Acknowledgement is given to Margaret Sedgley, the author of this chapter in the first edition of this publication.

Introduction

In the last few years, there has been a resurgence of interest in the use of Australian wildflowers in floristry, largely due to the exposure received during the Sydney Olympics in 2000. In a flow-on effect, South African Proteaceae species (such as Protea, Leucadendron, Leucospermum and Serruria) have also become more popular. Demand has increased on both the domestic and export markets, but buyers have also become much more discerning. Since these species are no longer considered exotic, they must now compete against more traditional products in a marketplace where price is always a major issue.

There are several major constraints to the on-going success of the industry. Firstly, it remains fragmented.

There is still no truly representative national body, funds committed to research are minimal, the marketing chain is competitive rather than cooperative and coordinated promotion is almost non-existent.
Secondly, climate change has meant that many areas that once had reliable rainfall are either getting much less, or, precipitation patterns have changed so there is now insufficient run-off into storage dams. Increased UV radiation is also having a detrimental effect on flower quality in some regions. In other areas, urban development close to plantations has increased the potential for conflict arising from farming practices.

Thirdly, increased government regulations relating to environmental and income tax issues act as disincentives to many who consider entering the industry.

Significant quantities of Proteaceae are grown in South Africa, Hawaii and California, all of which have labour and/or freight advantages over Australia. New Zealand, while having a similar cost structure to Australia, has the advantage of an efficient and integrated export chain.

In spite of these constraints, there is still potential for growers to be successful, provided they: research the market properly before planting; choose a suitable site with reliable, good quality (low salinity) water, that is also relatively near transport facilities; make a commitment to grow and supply only quality blooms; and maintain close contact with other industry stakeholders.

### Markets and marketing issues

Flowers are fashion items, and as such, the popularity of particular colours and types of flowers will wax and wane. These trends are set—often several years ahead—by overseas designers. This can make product selection difficult for growers of Proteaceae species that take several years to mature. On the positive side, trends do tend to be cyclical, so what is ‘out’ one year may be ‘all the rage’ the next.

Within Australia, the main market for Proteaceae is in Sydney, where growers from all over the country sell to wholesalers at the Sydney Flower Market. The wholesalers on-sell to florists, makers of bunch lines and sometimes to exporters. While some suppliers of top grade blooms receive an agreed price for their product, much is sold on consignment and, in periods of oversupply, prices can be significantly reduced. At times, the product may not be sold at all, especially if it is of poor quality.

There are smaller flower markets in Brisbane and Melbourne that also move significant quantities of product. Some growers sell directly to florists or through local produce markets, but these are generally not volume producers.

Overall, domestic market prices have not increased for many years. Although quality has improved, more than adequate supplies of many lines have kept prices down. The exceptions are new and attractive cultivars that have great appeal for florists.

Elizabeth Fraser preparing Leucadendrons for export, at Protea Pride, Western Australia
While export markets remain the area of greatest potential for the industry, exporters have experienced severe setbacks in the last three years. The attack on the World Trade Centre, followed by the wars in Afghanistan and Iraq and then the SARS outbreak, all affected both the overall demand for flowers and the availability and cost of freight space. Proteaceae tend to be bulky flowers that occupy a large volume of space relative to their weight. This increases the freight cost per bunch compared to smaller flowers. Australia is a long way from its main markets (Japan, USA and Europe), so this increase adds significantly to the final cost to the consumer. The strength of the Australian dollar in 2003 has almost been the final 'nail in the coffin' for some exporters and per stem returns to growers have correspondingly decreased.

The challenge for the export side of the industry is to 'work smarter', with more large-scale growers producing high volumes of quality blooms that can be sold at lower margins. Unless they are able to supply very high-end niche export markets, small-scale growers generally achieve better returns on the domestic markets—provided that they grow top quality flowers and avoid species that glut in peak season.

**Production requirements**

All Proteaceae require well-drained, slightly acid soil, that is low in phosphorus, but there is variation between the species in their preference for sand or heavier loam. When selecting a site, it is advisable to research the history of the property with regard to past fertiliser and chemical use (high phosphorus levels in particular are detrimental to Proteaceae).

It should be confirmed that the land is allowed to be used for flower field crops and that a dam or bore can be constructed if required. Ample, low salinity water should be available all year round and particularly in times of drought. To grow the top quality product that is demanded by today’s markets, irrigation of the plantation is a necessity in most areas of Australia. Growers need to assess very long term climatic averages, especially rainfall and temperature, because factors like frost and drought can cause severe setbacks in production.

Some states require that the grower hold a licence to produce Australian native species, so check this before making any planting decisions. There are also environmental issues that must be taken into consideration, such as irrigation and fertiliser run-off and spray drift.

Most commercially grown banksias are native to Western Australia and are adapted to sandy soils, lacking in nutrition. They grow best in a Mediterranean climate with high light intensity, long hours of sunshine, low relative humidity and absence of frosts. In Australia, that means the coastal areas of south-western Western Australia and the sandier parts of South Australia, Victoria and New South Wales.

Serrurias likewise prefer winter rainfall and sandy soil, tending to have high death rates and very short productive life in heavier ground. Some success has been achieved using gro-bags in areas where the climate is satisfactory but the soil is not.

Proteas, leucospermums and leucadendrons will thrive in a wider range of soils and climates, but prefer winter rainfall. In regions where there is summer rainfall, these species are prone to suffer from fungal leaf diseases and Phytophthora root rot. Leucadendrons in particular grow extremely well in richer soils, with high rainfall, provided that there is excellent drainage.

Waratahs are adapted to summer rainfall, but also grow well in the cooler, wetter parts of South Australia, Victoria and Tasmania. They are less vulnerable to phosphorus toxicity than other species, but the soil must be very deep and well-drained.
**Varieties/cultivars**

Many of the most commonly grown cultivars, such as *Protea* ‘Pink Ice’, *Leucadendron* ‘Silvan Red’ and *Banksia spectosa* have periods of severe glut during peak season, which results in extremely poor farm gate prices—if indeed a market can be found at all. There is presently unfulfilled demand for the banksia species *B. praemorsa*, *B. menziesii* and *B. plagiocarpa*. *B. plagiocarpa* is unusual in that it thrives in the high humidity, high rainfall conditions of the east coast and produces both flowers and foliage that are saleable.

Variegated leucadendrons such as *Katie’s Blush* and ‘Corringle Gold’ are popular on both domestic and export markets, but tend to be harder to grow successfully than more common species. There is demand for *L. Safari Sunset* with large heads, good colour and long, strong stems, at either end of the season, but mid-season is well-supplied; *L. gandogerii* sells well, providing heads are large and the yellow colour is bright; *L. argenteum* is popular, but only grows well in cooler areas with deep, well-drained loamy soil. The new leucadendrons developed in Western Australia with RIRDC support show great promise and should give growers some interesting choices when they are released.

*Serruria florida* and white varieties and cultivars of species such as *P. cynaroides*, *P. neriifolia* and *Telopea* are all popular, particularly for the wedding market. Red flowers, like *B. coccinea* and *Telopea* species are in great demand if they can be supplied late in the season at Christmas time. Selected leucospermums in yellows and oranges, such as *L. Red Ribbon* and *L. Veldfire* are still in demand, particularly late in the year.

The hybrid *P. Grandicolor* has been one of the most sought-after proteas in the domestic Sydney market for the last couple of years, mainly because of its unusual apricot colouring. *P. compacta* cultivars like ‘Christine’, ‘Trish’ and ‘Thomas’, which have large heads and bright colour, are also popular.

There are specialist *Proteaceae* nurseries in most states that are the best source of the latest hybrids and cultivars. It is no longer a sensible business decision to plant seedling-grown stock.
Banksia speciosa (Showy Banksia)

Leucadendron salignum (Salignum/Yellow)

Protea magnifica (Queen Protea)

Leucadendron coniferum (Sabulosum)

Leucospermum reflexum (Cape Gold)

Protea

Leucadendron "Safari Sunset" (Safari Sunset)

Leucospermum reflexum (Cape Gold)

Telopea speciosissima (Red Waratah)
Cultural practices/agronomy

It is vital that intending growers research both the market they intend to supply, and the ideal growing conditions for the products they would like to grow. For example, trying to grow most banksias in heavy soil, where there is high rainfall, is futile. The plants will probably not thrive and the quality of blooms will be inferior to those grown in ideal conditions. Grow what grows well in the area, provided that there is demand for it. It is advisable to plant a number of species that flower at different times, to spread the risk of losses due to weather or gluts and, to maximise use of labour and equipment resources. A trial planting will allow assessment of the viability of selected plants.

The ideal plantation has an easterly, north-easterly or northerly aspect, with a convex slope mild enough to allow safe tractor access to every point. On windy sites, windbreaks should be established, but the presence of some air movement is beneficial in reducing the incidence of fungal diseases.

Many growers these days have found that there are major benefits to adjusting the pH and soil nutrient levels, based on extensive soil analysis, before laying out the plantation. This gives plants the optimum start in life and ensures that the nutrients they require are available in a useable form.

To avoid root rot, the soil should preferably be deep-ripped, then shaped into parallel, mounded rows, far enough apart to allow machinery access when bushes are fully grown. Depending on the species and the machinery, this is usually 3–6 m. To minimise the time spent on weed control, the mounds are often covered with weedmat. The disadvantage is that on very hot days, it causes the soil to heat up, resulting in damage to roots that are near the soil surface. Using gravel or organic material as mulch is also an option.

Drip irrigation should be laid along the mounds, with drippers at spacings appropriate for the species:

- 1–1.5 m for leucadendrons
- 1.5–2.5 m for proteas and leucospermums
- 2.5–3.5 m for waratahs
- 2–3.5 m for banksias
- 1 m for serrurias.

It is advisable to get professional advice about ideal watering times and flow rates, which will vary significantly according to the soil type and depending on the weather. As a guide for assessing availability of sufficient water, many growers use 4 l/hr drippers for 2–3 hours, at least twice a week.

Planting can be done in autumn (unless there is the likelihood of frost damage) or spring (provided that there is ample water to supply the young plant over the summer months). Soil should be mounded away from the base of the plant, to allow best possible drainage and, if mulch is applied, it should be kept clear of the stem to avoid collar rot.

Fertiliser rates used on Australian flower farms vary enormously, but it is generally agreed that ‘fertigation’—applying fertiliser through the irrigation system—is the best method. Nitrogen, potassium and iron are all important nutrients, but actual requirements should be assessed based on skilled analysis of soil and leaves.

Training and pruning of bushes should be commenced early and continued throughout the life of the plant. Pruning aids weed and disease control, encourages good stem length and extends the useable life of the plant. It is usually done in winter or early spring until the plant begins to flower and thereafter, either during picking or after the plant has finished its flowering season.

The other major maintenance jobs are spraying (to control weeds, insects and diseases), and other methods of weed control, such as slashing and brushcutting. As a guide, about 2 ha of intensive planting is about as much as one person can properly attend to on their own.

In general, Leucadendron and Serruria will flower in their second year and Protea, Leucospermum, Telopea and Banksia in their third year, but another year is required for a commercial crop. The useful life of the plants varies with the species and the care they receive, but generally, it is about 10 years from maturity. Serrurias seem to be the exception, and only live about 5 years in most plantations. Waratahs and some proteas, such as *P. magnifica*, will live much longer, but as new hybrids are released, old varieties may become so unpopular.
that a commercial decision must be made to remove them.

**Pest and disease management**

*Phytophthora cinnamomi* is the nemesis of *Proteaceae* growers everywhere. This soil-borne fungal disease causes root rot, collar rot and dieback and can result in widespread losses. Control of *Phytophthora* is extremely difficult, and prevention is the best option. Related species like *Pythium* and *Rhizoctonia* can also cause problems and again, prevention is better than cure. Buy plants only from accredited nurseries, make sure the plantation has effective drainage and keep plants well nourished and watered. Just like people, plants are more resistant to infection if they are in peak condition. To avoid spreading diseases during harvesting, it is best to disinfect secateurs when moving from one bush to another.

Most states now have a requirement that those using chemicals must have undertaken a course in the proper use and disposal of these potentially dangerous compounds. It is important to always read and follow label instructions carefully and get specific, professional advice about the best and most effective time to spray for a particular pest. Flowers grown for export may need to be sprayed every few weeks to meet quarantine requirements.

Scale is a very common and difficult pest to eradicate, but can be controlled with applications of white oil when the larvae are at the crawler stage (early and late summer).

Waratahs are attacked by leaf miners, mealy bugs, chewing caterpillars and bud-tip borers. These need to be managed by strategic spraying, especially from December to March, when the buds set. *Protea, Leucadendron* and *Leucospermum* may require fungicide applications to combat diseases such as *Elsinoe, Drechslera* and *Colletotrichum*, especially in summer rainfall areas.

*Bankia* species may suffer from *Phytophthora, Elsinoe* and *Diplodena*, an aerial canker. Tunnelling moth larvae (*Arotrophora* spp.) feed on the soft tissue in the centre of the flower, thus killing the bloom. As is the case with all diseased material, removal and destruction is essential.

**Harvest/postharvest**

For maximum postharvest life, flowers need to be picked daily, preferably in the cool of the morning, at the earliest stage that will allow them to mature. Over-mature flowers are often damaged by bees and drip nectar that can ruin other more saleable blooms. Ideally, flowers should be placed in water out in the field, but if this is not possible, keep them in a shaded area and return them to the packing shed no more than an hour after picking. Care must be taken to avoid bruising and damage to the blooms.

In the packing shed, flowers and leaves are checked for damage, colour and general quality, leaves are stripped from the bottom 10 cm (approximately) of stem, avoiding damage to the stem itself. The stems are recut, then blooms are graded and bunched according to stem length and species. Larger flowers like waratahs, King proteas and most banksias are sold as singles; average-sized proteas and leucospermums are bunched in 5s and leucadendrons in 10s, using rubber bands. Multi-headed leucadendrons and those with heavy cones are often sold in 5s. Different markets may have particular requirements, so ‘the customer is always right’!

The blooms should be put into buckets of clean water at room temperature, to which chlorine (1 g/10 l water) has been added, then placed on trolleys in a coolroom operating at 1–4°C and 98% humidity, which is lit by fluorescent gro-lights. A coolroom is an essential piece of equipment in today’s demanding market, because maintenance of the cool chain from farm to market is vital to maximise flower vase life for the consumer.

Duncan Wood picking Protea White Pride, a Protea pride hybrid
Flowers for export may need to be dipped in fungicide or fumigated. More detailed postharvest information can be found in the RIRDC Publication No. 02/021, which is a comprehensive postharvest handbook (see key references).

After cooling and hydration, flowers are usually packed in sturdy cardboard cartons and then either taken directly to market (local) or delivered to a freight-forwarder, who transports the produce in refrigerated trucks or by air (interstate and overseas).

Waratahs benefit from the use of a plastic liner in the cartons. This prevents drying out and the resultant browning of bracts. Plastic liners are not recommended for other Proteaceae, especially proteas, where excess humidity will accelerate leaf-blackening.

**Financial information**

Growing Proteaceae for profit is more likely to be successful if undertaken as an extension of some other agricultural activity on land already owned that has adequate water, otherwise, the capital costs of purchasing land, facilities and equipment could be prohibitive.

Main establishment costs are: preparation of the land; building windbreaks (if required); purchase and laying down of weedmat or other mulch (if used); irrigation mains and dripper lines; pump and filters (if not using mains water); packing shed and coolroom. Total expense will vary depending on the area planted out and the size of facilities, but expect to spend at least $50-60,000.

The plants themselves are a major expense, particularly if more advanced stock is chosen. Cutting grown plants in 75 mm pots cost about $3.50 (ex GST), while for those in 140 mm pots, the cost increases to around $7-8.50. At 1,500 to 2,000 plants/ha, depending upon the species, a minimum cost is still over $5000/ha. Although the larger plants cost more initially, they will begin producing sooner, so a cost/benefit analysis needs to be undertaken.

The number of saleable stems per bush will depend both on the species and the pruning strategy. When assessing the potential returns for a species, consider not only the number of stems, but also the work required to get that stem to market. For example, most leucadendrons do not return a great deal per stem, but there are many stems on a bush, they are easy to process and the picking can be done over an extended period. A stem of summer-flowering *P. repens* may sell for more than twice as much, but there are fewer stems on a bush. They need to be picked every day during the flowering period to avoid significant losses due to overblown flowers and, because of the extra labour required to trim off bypass shoots,

| Table 1. Sample gross margin (per ha) figures for Banksia (mature plants) |
|-----------------------------|-----------------------------|-----------------------------|
| **Income**                  | **Grade 1 (60 cm)**         | 20,000 stems                |
| Grade 1 (60 cm)             | $0.50                       | $10,000                     |
| Grade 2 (Dry)              | $0.30                       | $6,000                      |
| **Total**                   |                             | $16,000                     |
| **Cost**                    | **Supplies**                | **Labour**                  |
| Replace plant               | $500                        | $200                        |
| Pruning                     | $200                        | $200                        |
| Pest Control                | $400                        | $200                        |
| Fertiliser                  | $300                        | $300                        |
| Irrigation/fuel             | $500                        | $500                        |
| Harvest pack                | $1,000                      | $5,000                      |
| Transport etc               | $500                        | $500                        |
| **Total cost**              |                             | $9,600                      |
| **Gross margin/ha**         |                             | **$6,400**                  |

Chart published in Floriculture News December 2003. Used with permission of Gerry Parlevliet, Dept. Agriculture WA. Figures collected as part of a benchmarking project funded by Agwest, Flowerswest and RIRDC.

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White Protea neriifolia
Chris Horsman has been growing South African Proteaceae commercially in the Adelaide Hills since 1982. She has written many informative articles about the production of proteas and was closely involved in the making of several training videos for protea growers. Chris was National President of the Australian Flora and Protea Growers Association (now called Wildflowers Australia) for five years, so has an intimate knowledge of the wider industry and of the challenges and satisfaction that come from growing wildflowers. She is currently a member of the RIRDC Wildflower Advisory Committee.

**Disclaimer**

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**Key messages**

- Research markets before planting anything
- Proteaceae production is labour intensive
- Ample fresh water is vital
- Consider cost of transport to market
- Quality, quality, quality

the return per hectare of plantation could actually be less than for the leucadendrons.

“Costs are forever going up and are still one of the areas growers can look at to significantly improve the profit margin. The largest cost in growing banksias is the cost of labour at about 60-70%. Most other costs are relatively small. However, knowing the cost of your operation and the costs of producing and preparing the flowers for sale is critical for long-term sustainability of the business.” *(Floriculture News December 2003)*


All these figures are *a guide only*. Actual prices achieved will depend upon the season, the markets, the quality of the flowers and how well they are presented. Ongoing costs will vary according to the efficiency and scale of the operation.

**Key references**


RIRDC has funded a number of other projects that may provide useful information to growers of proteaceae. Visit the RIRDC website [www.rirdc.gov.au](http://www.rirdc.gov.au) click on ‘Publications’ and then on ‘Wildflowers and Native Plants’ for further details.
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Key statistics

Collection of industry statistics is fragmented and sometimes inaccurate. Quoted figures are therefore a guide only.

• Nearly 50% of Australian fresh flower exports are to Japan
• Fresh flowers constituted 87% of flowers exported in 2001
• Total export sales of all wildflowers amounted to 4,500 t in 00/01
• Over 380 t of proteas, valued at nearly $3 million were exported in 2002
• Total domestic sales of all wildflowers amounted to $96 million in 2000
**Blandfordia**

**Introduction**

The suitability for cultivation of *Blandfordia* (Christmas bells) was recognised as early as 1803 (Australian National Botanic Gardens, 1987), when *B. nobilis* entered cultivation as a glasshouse plant in England. In Australia, the genus has been exploited as a bush-picked seasonal cut flower crop for many years on the domestic market. For the export markets however, cultivated flowers must be provided to meet the high quality standards of the international markets.

From 1989 there were investigations conducted on *Blandfordia* at various institutions in New South Wales. The Australian Rural Research Fund (now RIRDC) funded a 3 year study of the biology and development of *Blandfordia* species as a new native ornamental crop and that study was conducted by the author at UTS (Johnson, 1994). At the same time Dr Peter Goodwin at Sydney University was granted funds to develop...

**Key messages**

- *Blandfordia* is a unique Australian flower
- Its habitat is under pressure
- Its potential as a cut flower is only minimally utilised
- It is popular with the world markets
- Its cultivation, postharvest and marketing have been researched
- *Blandfordia* requires reasonable establishment time
production and export technology for *Blandfordia*. In 1993, the Department of Agriculture was funded by RIRDC to investigate postharvest disinestation and management of *Blandfordia* (Worall & Wade, 1996).

The formation of a group of growers, researchers, advisers and other interested parties, in 1989, known as Blandfordia Research and Extension Group (BREG), has consolidated its efforts to develop and market *Blandfordia* as a commercial cut flower. This has proved an innovative way of encouraging communication and cooperation aimed at developing a new crop. There has been a lot of enthusiasm, energy and willingness in this group that has endeavoured to put this beautiful plant on the international map. At the time of writing, *B. grandiflora* is grown as a commercial cut flower crop by a few growers in New South Wales (Port Macquarie and the Central Coast of NSW).

The natural habitat of the genus has been disappearing since the time of European settlement, and it would seem that the whole genus may be under threat in the wild, since its distribution, along the eastern coast of Australia includes some of the most heavily populated and rapidly developing areas of the continent. Because of its protected native plant status a licence is required to grow *Blandfordia* for commercial purposes (http://www.austlii.edu.au/au/legis/nsw/consol_act/). Licences are available from the New South Wales National Parks and Wildlife Service on application to the local NPWS area office. The licence conditions are described in *Protected and Threatened Plants in the Cut-flower Industry—Management Plan 2002-2005*, and apply to all commercial growers and harvesters from the wild. The objective of this new management plan, is to phase out wild harvesting of the genus altogether by 2005 (NSW NPWS, 2002).

*Blandfordia* is considered the ‘best bet’ for cultivation of all native flower crops (pers, com.). It has very attractive flowers with long vase life and high value to freight volume. The biggest constraints however, in establishing commercial production of *Blandfordia* are the lack of uniform planting materials, selections or cultivars that would satisfy the fundamental requirements of the industry: predictability of flowering, colour, size, number of florets in the inflorescence and vigour of the planting material. These traits however, so important to the industry have not been fully investigated to date.

**Market and marketing issues**

None of the species were cultivated until 1989, when commercial cultivation for cut flowers of *Blandfordia* has commenced. This species is a relatively new cut flower crop with a very attractive focal flower, wide range of colours, an attractive shape and a long vase life. Eleven types of the flower colour (from red to yellow) and eight different shapes were identified (Johnson 1996). *Blandfordia grandiflora* is a very slow growing crop taking at least three years to produce its flowers. It has quite specific requirements for soils, water and nutrients. It is also subjected to weed infestation, and requires close husbandry. A good understanding of horticultural practices and postharvest handling is required to grow the crop successfully.

Other species in the genus also present horticultural potential, but there have not been investigated in detail so far. *B. nobilis*, for example, with petite bells has great potential as a pot plant. *B. cunninghamii* presents qualities other species do not possess. Its beautiful long gracefully drooping leaves and spectacular bells suggests this would also make a very good cut flower or a pot specimen. *B. punicea*, that is endemic to Tasmania has usually scarlet red flowers finished off with brilliant yellow wings. This species also has cut flower potential.

At present the growers from Eastern Australia (Port Macquarie area, see map) are the only world suppliers of this novel cut flower variety. It is understood however, that attempts are being made by other countries such as Zimbabwe, Israel and Japan to investigate *Blandfordia* as a commercial cut flower crop. A knowledge of the plant’s specific needs, diligence and harvesting practices will be required for successful growing.

*Blandfordia* flowers October-January (early summer, Christmas). Remembering the scarcity of flowers during the Northern hemisphere winter this product meets a ready market. The contribution of income from this genus to the Australian economy, could be substantial if the number of growers increased.

*Blandfordias* are grown and packed for market on the farm. Those destined for the domestic market are forwarded directly to agents at the metropolitan flower markets or to local retailers. Flowers destined for export must be carefully checked for quality and freedom of pests and diseases. They are graded and dipped prior to packing on the farm, and kept in cool storage until transported to the exporter. They are again checked by Australian Quarantine...
Inspection Services before being dispatched to overseas destinations. On arrival, flowers are checked again by the importers’ Quarantine Services before being auctioned and distributed to the customers.

In recent years *Blandfordia* has been shipped to USA and Canada as well as small quantities to Belgium, Switzerland, The Netherlands and Germany, but the main market remains Japan. The quantities being exported are much smaller than the markets could absorb. The average price in recent years has been AU$1.00 net return (per stem for a grower (pers. com.).

**Production requirements**

The natural habitat of *B. grandiflora* is the moist areas of coastal heathland with an annual rainfall of 1000–1600 mm, and a temperature range of 0°C–35°C.

The preferred growing medium for *Blandfordia* is a mixture of equal quantities of peat and coarse clean sand. The pH should be in a range of 4.0 - 5.5. For young plants the proportion of peat can be reduced to 25%. Pine bark ‘fines’ and/or composted hardwood sawdust can be used to replace the peat in the growing medium.

The amount of water required by *Blandfordia* plants of different ages has not been determined, but it has been suggested that the older plants require less frequent watering. A considerable need for water has been observed especially during budding and flowering. Through the summer daily watering is required. In winter plants are watered less frequently (Gollnow et al. 2003).

**Varieties/cultivars**

The need for consistent and improved cultivars of *Blandfordia* has been recognised, therefore a very systematic approach to selection and breeding was required to achieve the desired results. The initial micropropagated material using vegetative buds did not perform to expectations. More success has been achieved in recent attempts using floral buds for micropropagation. The Australian domestic market looks for red flowers, but in Japan yellow and orange colours are very marketable. Good selections have been made by the leading growers, and at present, there is adequate clonal material available for planting.

*Cultural practices/ agronomy*

*Blandfordia* can be propagated from seed, however seed propagated plants give a wide range of characteristics that are often undesirable in the cut flower production. However, to get started seeds can be used as they are easy to germinate. The seed material however, should be obtained from recognised sources. Germination usually takes three weeks, but it can be faster in warm, humid weather and much slower in winter. Seeds do not require germination pre-treatment and should be planted in a mixture of 50% peat and 50% sand with the pH adjusted to a round 5. The main dangers in the germination stage are fungal attacks, hence regulation of watering is critical. Excessive water and shade can also encourage moss growth, which can retard and choke the seedlings. Growth in the seedling stage is slow and takes 4 –5 months for seedlings to reach a height of 5–6 cm. Complete fertiliser solution (half the normal rate at fortnightly intervals) may be used when the first true leaf appears. Plants take 2–4 years to produce flowers from germination.

For cut flower production, the preferred strategy should be vegetative propagation from the underground rhizomatous corm (with highly impressed internodes). The central growing point is located at the centre of the crown, and becomes active when flowering occurs. At the sides and around the crown of the corm lateral side buds may arise. These may produce young shoots
that give rise to a new clone, but this method of propagation is very slow. Clumps of Blandfordia can be subdivided into single plants every 2-3 years giving 2-3 new plants that take about 2 years to regain the flower production stage.

It seems clear that plant tissue culture will become the essential propagation technology as the demand for new improved cultivars increases (Johnson 1998, Johnson and Burchett 1996). Micropropagation has become a useful tool enabling the rapid build up of stock of selected clones showing desired attributes. Moreover, the need for the development of new hybrids resulting in plants bred for qualities such as vigour, yield, and consistency of performance makes micropropagation a desired technology for the cultivation of the genus.

From the commercial perspective, the need for supply of not only the quantity but also the quality of propagation material is of prime importance at this stage of Blandfordia crop development. The development of this genus, for both domestic and overseas markets, as cut flowers, pot-plants or garden specimens, and its conservation, which will involve both ex situ and in situ cultivation, all require speedier approaches than those of conventional propagation methods alone. Vegetative meristems or flower buds can be used for micropropagation of Blandfordia. The appropriate media for multiplication and rooting have been selected from a very wide range of media used in the micropropagation experiments (Johnson 1994, Bunn and Dixon 1996). Long term investigations however, indicate that the flower bud material of selected hybrids or cultivars is favoured as the starting material.

Blandfordia has been grown commercially in 5-7 litre plastic planter bags with 3 plants per bag, but root-binding and crowding is apparent after 4 years of growth. This has not changed the frequency of flowering however, and the number of flowering stems has not decreased. An alternative is to plant into beds at density 35 x 40/m².

Blandfordia grow in nature in the understory of heathlands rarely exposed to full sunlight. Hence provision of shade is recommended. Thirty percent shade cloth is being used by a number of growers who have felt that 50% was too heavy, and flowers produced under it tended to be pale. Shade cloth also provides physical protection against birds and insects, and reduces wind damage.

Although Blandfordia grows naturally in poor soils it does much better with a suitable fertiliser regime. If plants do not receive appropriate nutrient the growth becomes retarded. A range of slow releasing fertilisers may be incorporated into the mixture. To maintain good growth, a two-part soluble fertiliser is applied regularly. This regular application of fertiliser at fairly low concentrations together with slow release fertiliser is giving excellent results. Fairly light fertiliser use has been the rule, however, the optimum nutrient regime for Blandfordia is still to be established. Dick (2004) has reported boron and calcium deficiencies in cultivated Blandfordia plants, however, the optimum doses are yet to be established.

Present applications of water by Blandfordia growers are based on personal judgement, rather than sound scientific studies (Dick et al., 1996). Studies on B. grandiflora flowering response to temperature conducted by Goodwin and Watt in 1994, concluded that it requires a chilling period of six weeks with temperatures below 10°C. It has been observed that plants flower after three years from planting, however there have been few cases observed that plants flowered after two years from planting. The number of stems/plant increases with plant maturity and later tillering. The capacity for increased stem production has a considerable significance for future commercialisation and profitability of this crop.

Pests and diseases

Blandfordia grandiflora appears to be susceptible to soil borne pathogens namely Pythium sp. and Phytophthora species (Stovold, pers. comm., 1995). Wet conditions and poor drainage must be avoided in the cultivation of Blandfordia. Botrytis flower rot has been observed in storage or shipment. It may be caused by hot humid periods, the preharvest fungicidal sprays or too low storage temperatures.

Helicoverpa armigera (corn earworm) Epiphyas postvittana (light-brown apple moth),
Pseudococcus longispinosus (long-tailed mealy bug), and thrips have been identified as the principal insect pest of Blandfordia. The mealy bug (Pseudococcus longispinosus) has proven to be the most intractable pest problem to date. Others are scale, aphids and rats which can attack corms, especially in pots and planter bags. Use of oil spray and insecticides gives good protection.

Blandfordia does not compete well with other vegetation and can be choked out especially by stoloniferous invaders. Liverworts and mosses can be harmful, especially for young plants. Recommendations as to the use of herbicides in future production are required, as well as to cultivation and use of mulches.

Harvest and handling

At present, Blandfordia flowers are harvested when one flower per cluster is splitting. The use of floral preservatives; 8-hydroxyquinoline sulphate (HQS), sucrose and silver thiosulphate does not improve the keeping quality of Blandfordia stems (Worrall & Wade, 1996). Blandfordia stems respond well to cool storage and appear not to be sensitive to ethylene. Flowers can be stored at 1°C for up to at least 30 days. At 1°C there is no bud opening at 2 weeks, however, when flowers open they are of paler colour. It is recommended that stems are stored at 4°C and the cold chain is maintained through to markets. This will assure vase life of 12 or more days (Dick, pers. com.). Progress has been made in packaging Blandfordia. To prevent the movement of the blooms within the box, five graded stems are clamped together to form self-supporting bunch. The stems are secured with rubber bands just below the florets and again, near the stem bases. Use of sleeves is recommended on each bunch to keep the florets securely together. Bubble plastic liners are used on the bottom and top of each box to insulate from temperature extremes, provide shock resistance and retain humidity in the box. For harvesting, a cold room and packing shed are requirements.

Financial information

The following points must be observed at present when exporting Blandfordia flowers:

Flower colour

From a range of eleven colours 1-11, from light yellow to dark red with various patterns of these colours on a perianth. Most are accepted for sale, as the present production comes from the seedling material. However, four basic types have been identified as most popular by the industry for export markets; yellow, orange, yellow-red and red types (Fig.3-6). When clonal material is available, flowers will be graded by variety, which, by definition, will include standardised colour combinations.

Flower stem

Must be free from natural or induced deformities, with good proportions between flower head size and stem length.

Stems for export are graded according to stem length and the number of florets per stem.

(a) Stem length:

- 30cm-100 cm long have been exported

(b) The number of florets per stem:

- 30 cm stem - minimum 3 florets
- 40 cm stem – minimum 4 florets
- 50 cm stem - minimum 5 florets
- 60 cm stem – minimum 6 florets
- 70 cm stem – minimum 7 florets

(c) Grades:

- only boxes with stems of 60 cm or more are labelled as ‘AAA’ class, or stems with more than 11 florets are labelled ‘Super’

About the author

Dr Krystyna Johnson is the editor of major text Native Australian Plants, Horticulture and Uses published by the University of NSW Press. Author and co-author of many research papers in area of plant tissue culture, conservation and horticulture of Australian plants. Her work includes species such as Blandfordia, Ceratopetalum gummiferum, Doryanthes excelsa. She is currently a Senior Lecturer and Supervisor of Honours, Masters and PhD students at UTS.
Optimal harvesting stage

- when the first bud tip is starting to split.

To get started a new grower will require:

- a suitable area of land with good water
- a system of irrigation (dripper lines are suitable for in-ground plantings, but overhead sprays may be used, especially with pots or poly bags)
- initial 50,000 plants which can be purchased from reputable nurseries
- selected clonal plants are also available.
- 50,000 (1 year - 18 months old) seedlings or de-flasked, rooted plantlets will cost around $20,000-$25,000
- a simple shade house design will cost around $15.00/m².
- a packing house (about 40 m²) can be built for about $10,000
- Power and water need to be connected
- a cold room (about 2.4 m²) will also cost about $6,000
- tables, benches, stools and sink are also required.

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Key references


Boronia

Jonathan Lidbetter and Julie Plummer

**Introduction**

Boronias belong to the citrus family, Rutaceae and are known for their floral displays and scent. Like so many wildflowers boronias were originally bush picked. Today *Boronia heterophylla*, and to a lesser extent *B. megastigma*, *B. serrulata*, *B. clavata* and *B. muelleri* are cultivated for fresh, cut flowers. *Boronia megastigma* is also cultivated for the essential oils in its blossom. Boronias are very popular although often unreliable garden plants.

*Boronia heterophylla* can produce long stems of vibrant pink flowers. Bushes are commercially productive for three to five years. Postharvest life is adequate and there is strong export demand. The main limitations for expanding boronia production are the restricted flowering period, colour range in cultivation and susceptibility to root diseases. *Boronia heterophylla* is the dominant crop both domestically and for export. Unfortunately in most areas the harvest is over within a few weeks.

Some varieties of *B. megastigma* are cultivated but the market is much smaller as the postharvest life is short and the perfume is unattractive in Asia, making it...
unsuitable for export. Production of other species is quite limited. Until recently \( B. \ megastigma \) was the only species that had been surveyed for superior varieties.

Boronias are currently grown for cut flowers on the east and west coasts of Australia; New Zealand, California, Israel and to a lesser extent in South Africa and Europe with trials commencing in South America. They are susceptible to root rots and rust and require good site selection and careful management.

**Markets and marketing issues**

Fresh cut flowering stems of \( B. \ heterophylla \) have been exported to Japan for over 15 years and markets are growing in Singapore, Hong Kong, Taiwan, Europe and Canada. An import ban on Rutaceous species prevents boronia from entering the United States of America. An import ban on Rutaceous species prevents boronia from entering the United States of America. Western Australian sales are dramatically down from an apparent peak of 408,000 stems in 1999 (AQIS export figures) and eastern states production has steadily grown from less than half the current figure in the corresponding period. Growers and exporters alike have suggested 2003 production was a significant drop on previous years.

**Production requirements**

Boronias require a period of cool conditions (winter nights less than 10°C) to initiate flowers. Warm conditions can lead to the failure of flower development or flower abortion at certain stages of flower development. Inadequate chilling is often seen as vegetative growth at the tips of stems and this reduces stem value. Boronias have been successfully cultivated across a range of latitudes from the hot dry conditions of Coorow, WA (30°S) to the cool temperate conditions of Tasmania (42°S) and even the South Island of New Zealand. Many species are frost tolerant but areas with regular moderate to severe frosts should be avoided. Strong winds will damage shoots and weaken roots and so windy sites should be avoided or wind breaks constructed or planted.

Although some boronias naturally grow in wet areas, in cultivation they prefer well-drained, slightly acidic soils. Soils with a very high residual phosphorus level should be avoided. Sites should be tested for the presence of \( Phytophthora \) and nematodes. Three \( Phytophthora \) species; \( P. \ cinnamomi \), \( P. \ cryptogea \) and \( P. \ dreschleri \); were regularly identified in association with severe plant losses in plantings of \( B. \ heterophylla \) and related hybrids, with \( P. \ cryptogea \) the most regularly isolated species. Greenhouse assays have confirmed the pathogenicity of all three species. Also avoid sites with root attacking nematodes, such as \( Meloidogyne \) or \( Pratylenchus \), or treat the area with a suitable soil fumigant or nematocide.

**Varieties/ cultivars**

The genus \( B. \ heterophylla \) (Rutaceae) is represented throughout Australia and species are found in a wide range of soil and climatic conditions. A range of flower colours and flowering periods exist but only a few species have been commercially exploited.
Consult with your exporters, local nurserymen and experienced growers to determine the best varieties for your area.

*Boronia heterophylla* is an upright shrub 2–3 m tall from Western Australia. It bears a profusion of vibrant, pink, bell-shaped flowers about 1 cm long which provide a spectacular floral display. This species is the most widely grown for cut flowers. The flowering period for individual plants is usually less than two weeks in late August/early October and flowers fade if left on the bush. Older flower colour selections have been registered including, ‘Moonglow’ (white), ‘Cameo’ (pale pink), and ‘Lipstick’ (mid-pink) and ‘Morandy Candy’ (deep pink), which may be hybrids. New selections continue to become available with several released over the last few years including Stella®, Cascade® and Purple Rain®. These varieties offer a greater range of colour and flowering time. A breeding program examining a wider genetic base within the genus *Boronia* is in progress and has already resulted in promising new hybrid varieties including the *B. heterophylla x B. megastigma* hybrid Purple Jared®.

*Boronia heterophylla* is fast growing and responds well to pruning. It can withstand moderate to heavy frosts. Plants prefer dappled shade or partial sun but will grow well in full sun if roots are kept moist and cool. Plants are also susceptible to stem twisting or breakage in strong winds and need protection.

*Boronia megastigma* is an upright, dense shrub 1–3 m tall. It is found in wet or seasonally wet sites in Western Australia. Individual plants flower from late July to October. The bell-like flowers are usually dark to reddish brown on the outside and yellow on the inside and are not showy. Flowers are very fragrant. *Boronia megastigma* used to be extensively grown as a cut flower in Victoria but rust (*Puccinia boroniae*) wiped out the industry. Selections, based on morphological characters desirable for cut flowers, include forms where the outside of the petals are red, such as ‘John Maguire’s Red’, ‘Arch Chandler’s Red’ and its sport ‘Harlequin’ which has vertical reddish-brown and yellow stripes, and ‘Lutea’ a yellow-green form. Unfortunately these selections have poor vase-life and do not transport well. The perfume, which is the main attraction in Australia, is less desirable in Asia. Much variation exists in flowering time, flower colour, fragrance, oil content and growth habit.
**Boronia muelleri** is from the southern coast of New South Wales and Victoria. Flowers are 1.5 cm across and vary from white to pale pink. Flowers are borne on terminal clusters from August to November. At present production is limited.

**Boronia purdieana** is a small shrub from the coastal sandplain north of Perth and it probably requires well-drained soils and will grow in hotter/drier areas than *B. heterophylla*. It bears a profusion of perfumed, greenish-yellow flowers from July to August. This early flowering species has short stems (30–40 cm) but it is sought after as a cut flower. Cultivation is still limited by cutting propagation difficulties although grafting is an option. Low yields may also limit the transition of this crop from wild harvested to cultivated crop.

**Boronia pinnata** is a small shrub from New South Wales. It bears pink clusters of flowers from August to November and is in demand from florists. It has 5–8 days of vase life.

**Boronia serrulata** is a small shrub 1.5 m tall from New South Wales which produces abundant rose pink flowers. Individual plants produce flowers for 4–8 weeks but flowering in natural habitats occurs from late July to November. A short vegetative flush occurs from December to January and this can be extended in cultivation with irrigation. Plants produce cut flower stems up to 40 cm in length.

**Cultural practices/ agronomy**

For cut flower production, boronia should be propagated vegetatively. Clonal propagation will provide uniformity in flower quality, stem length and harvest date. Propagation is primarily by cuttings, but grafting is opening up opportunities for difficult to strike varieties and in areas where plant losses to root diseases are unacceptably high. For cuttings, choose a reputable nursery and allow at least four months between ordering and delivery. Grafted plants may take a little longer. Tip cuttings are most successful when taken from new shoots in summer and autumn. High concentrations of auxins, basal heat and misting improve rooting. Losses through damping off can be reduced with good hygiene and by avoiding root damage. Grafting may be done at any time of year under the right conditions depending on the availability of suitable rootstocks or the ability of cutting grafts to strike roots.

The ground should be prepared and weeds controlled before planting. Good planning at this stage is critical. Remove any large tree roots and cross rip. Remove soil from machinery before use to reduce the risk of introducing *Phytophthora* to the site. Plants should be ready to plant in winter to capitalise on the growth flush over spring/summer. Plants should be disease free, 10 cm high with well formed roots. Ensure plants are not root bound. Remove plants carefully and do not disturb the roots when planting.

Plants produce cut flower stems up to 40 cm in length. Irrigation or reliable rainfall throughout the year is essential for successful production. Boronias are shallow rooted and *B. heterophylla*, for example, produces a mat of roots in the top 30 cm of soil. The soil therefore needs to be kept moist. Roots are susceptible to root rot and collar rot fungi and so should be grown in free
draining and not waterlogged soils. Mature boronia plants require 2–10 litres of water/day depending on conditions. Micro-irrigation supplied several times a day is preferable in very sandy soils but a full root zone soaking every couple of days is more appropriate for heavier soils.

Mulching is highly recommended due to its beneficial effects on water use, soil temperature, and disease and weed control. Artificial mulches include plastic mulch, weed mat and organic mulches such as wood chips or straw. Organic mulches can substantially reduce water loss from evaporation. They also keep the roots cool which reduces plant losses from water stress and slows the growth of root rots. Composted straw and other organic mulches give some control of diseases, such as Phytophthora, by encouraging organisms antagonistic to these pathogens. Organic mulches however may run the risk of introducing weeds especially if of poor quality. In California plastic has been used with a covering of straw to obtain the benefits of each type of mulch.

Mulching generally gives good weed control. This is particularly important in boronia as root disturbance often leads to plant death. Grasses can be controlled with selective herbicides. Broad-leaved weeds are more difficult but may be controlled with a hooded wand using a non-selective herbicide. There are no selective broadleaved weedicides registered for use on boronias.

Boronia require fertiliser application, especially nitrogen. For spring flowering species, vegetative growth occurs from mid-spring to autumn with a peak over summer. Stem length is critical for profitable cut flower growing and fertilising during the growth phase is essential. However late application of fertiliser, particularly nitrogen, can reduce flowering especially of shoot tips, and should be avoided. Fertiliser can be applied as a solid or in liquid form through fertigation. Greater control of fertiliser application is possible with fertigation and split applications are recommended for solid fertiliser to avoid plant death or nutrient loss through leaching by heavy rain. The NPK requirement will vary depending on soil type but applications of N:P:K::90:10:130 kg/ha/year have been used for B. heterophylla in Western Australia and N:P:K::50:79:100 kg/ha/year for B. megastigma in Tasmania. Trace elements should be applied in areas deficient in micronutrients. Plants should be analysed to determine any nutrient deficiencies.

**Pests and disease control**

A number of pests attack cultivated boronias including nematodes, black beetle, stem borers, grasshoppers, Rutherglen bug, scale and psyllids. Mealybugs and two-spotted mite are pests primarily of boronias grown under cover. Nematodes and black beetle are best controlled by a pre-plant pesticide application. Other insect control measures should be applied when required. Even insects which do not cause damage to flowers are a major problem in export shipments and will lead to rejection in most importing countries. Therefore field control of insects is essential. Depending on export requirements, cut flowers may still have to be treated for pests and diseases with disinfection fumigations or dips. Consult your exporter.

Boronia is susceptible to root diseases, especially Phytophthora and Pythium. Boronia often suddenly die and this is probably due to infection from these pathogens after wounding from insects, wind damage or water stress. Phosphorous acid and other fungicides can be used to help control both Phytophthora and Pythium but will rarely eliminate the disease. Rust (Puccinia boroniae) causes brown pustular growths on boronia and may cause leaf drop. Contact your local horticulturist for suitable methods of control. Boronias are also susceptible to Botrytis and require fortnightly treatment from
bud initiation to harvest, especially during wet conditions with a fungicide rotation to prevent fungicide resistance developing.

Harvest, handling and postharvest treatments

Vegetatively propagated *B. heterophylla* will flower within 15 months of planting but because the plants are small, this initial harvest will only yield 8–12 stems/plant. By the second year 20–30 stems can be harvested, then 30–60 stems annually. Commercial plant life is usually 5–6 years on sandy soils but even with the best management an annual loss rate of 5% is not uncommon. Commercial plant life for cutting grown plants is heavily reduced and loss rates increased on heavier soils and in warmer climates.

Grafted plants have yet to be commercially tested but greenhouse tests have proven the benefits of *Phytophthora* tolerance in extending plant life.

Immature floral buds do not open after harvest and so stems are harvested when most flowers are at least partially open. Practices vary, but most boronias are pruned to a height of 25–35 cm at harvest with some horizontal laterals left intact. One-year-old plants can be pruned harder. The main concern is to leave enough vegetative material to reduce the risk of disease development and providing an adequate base for the future year’s stem production.

Cut stems should have abundant flowers for most of their length. At least 50% of flowers need to be open at harvest. Clean straight stems of *B. heterophylla* 60–70 cm, with 50–70% of blooms open and no wilting are regarded as first grade cut flowers by the Flower Export Council of Australia. Second grade stems are less than 60 cm but should have a minimum length of 50 cm, 50–70% of flowers open, no wilting and clean stems with no more than 5% curve. A premium is paid for >80 cm stems. Stems are bunched in fives or tens for Japan, while most other markets require the product to be sold by weight.

Without treatment, vase life is short. Standard postharvest care, including placement in clean water, removing field heat as soon as possible and storage at 1–5°C, greatly improves quality and longevity. Delays in cooling greatly reduce flower quality. Pulsing with a biocide, such as 8-hydroxyquinoline citrate (HQC, 800 mg/L) overnight (8 hours) increases vase life.

Flowers are usually provided bunched to the exporter, who handles packaging and consignment to domestic and export markets. Check requirements for handling with your exporter.
Financial information

Establishment costs although significant are a minor cost of total production costs with picking, grading, packaging and disinfection the major on-farm costs. Returns to growers are dependent on stem length, branching and flower number, stem straightness; uniformity of stems within bunches and postharvest handling including pulsing, cool storage, disinfection treatment and packaging. Choice of packaging and presentation can have a major influence on both market price and return to grower.

Growers in the eastern states usually disinfect and pack their own product before delivery to the exporter ready for sale. In the west, exporters may pay for the domestic transport of bulk packed material which they disinfect and pack in their cartons.

Timing of your crop will greatly affect your returns as the price varies significantly. For example New South Wales and Victorian ‘Red’ B. heterophylla is usually harvested well before Western Australian product, and the variety ‘Lipstick’ is generally earlier still. Product which appears on the market earlier usually obtains a better price. Grower returns depend on many factors beyond supply and demand including quality, presentation, freight availability and the exchange rate. Who bears the responsibility for risk will also affect prices. This includes quality claims against the product and quarantine claims. Whether this is the grower’s or the exporter’s risk will depend on the agreement you have with your exporter and will affect potential return and associated risk. A summary of prices paid by exporters to growers is presented for 2003.

<table>
<thead>
<tr>
<th>Product</th>
<th>East Coast $</th>
<th>West Coast $</th>
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</thead>
<tbody>
<tr>
<td>B. heterophylla</td>
<td>21-34c</td>
<td>NA</td>
</tr>
<tr>
<td>‘Red’ 50cm</td>
<td></td>
<td>($2.00-2.20/400g bunch)</td>
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<tr>
<td>60cm</td>
<td>30-63c</td>
<td>30-38c</td>
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<td>70cm</td>
<td>38-85c</td>
<td>38c</td>
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<tr>
<td>80cm</td>
<td>57-90c</td>
<td>50-80c</td>
</tr>
<tr>
<td>100cm</td>
<td>60c-$1.00</td>
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</tr>
<tr>
<td>‘Lipstick’</td>
<td>≤10% discount</td>
<td>≤10% discount</td>
</tr>
<tr>
<td>‘Purple JaredA’</td>
<td>≤10% premium</td>
<td>≤10% premium</td>
</tr>
<tr>
<td>‘Moonglow’</td>
<td>≥10% premium</td>
<td>≥10% premium</td>
</tr>
</tbody>
</table>

Key references


Growing Boronia Agriculture WA Farmnote No. 47/96 (Agdex 282/220).


Table 1. Range of average returns to grower per stem of boronia from exporters produced on the east and west coasts of Australia in 2003

# Returns to growers vary depending on date of harvest, quality, postharvest treatment, packaging and domestic and export freight charges. These values were kindly supplied by a number of exporters from WA, NSW and Victoria.

$ Discounts and premiums quoted are in relation to B. heterophylla ‘Red’ prices for corresponding lengths
About the authors

Jonathan Lidbetter is a Research Horticulturist for NSW Agriculture. He has investigated the role of *Phytophthora* spp. in sudden death of Boronia and the development of grafting combinations to overcome this problem.

Dr Julie Plummer is a Senior Lecturer in Plant Sciences at the University of Western Australia. She has selected boronias which are currently being tried out and is breeding boronias using a range of species.

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Austwinds International
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Fax: (03) 9379 8514

Collina Exports
Tel: (03) 9329 3322
Fax: (03) 9329 3366

IHM Australia
Tel: (02) 9311 7600
Fax: (02) 9311 7800

Longford Flowers
Tel: (03) 9598 5151
Fax: (03) 9598 5151

Muchea Gold
Tel: (08) 9571 4189
Fax: (08) 9571 4295

Sunglow Flowers
Tel: (08) 9525 1800
Fax: (08) 9525 1607

The Australian Flower Company
Tel: (02) 9667 2766
Fax: (02) 9667 2773

Total Flower Exports
Tel: (08) 9451 5744
Fax: (08) 9351 8019

Westralian Flora Exports
Tel: (08) 9250 2431, (03) 9312 2121
Fax: (08) 9250 2592, (03) 9312 0765

Floratrade
Tel: (03) 9338 0444
Fax: (03) 9338 4455

Key statistics

- Virtually all *Boronia heterophylla* in Australia are currently harvested in a few short weeks
- Most production of cut flowers occurs in Western Australia, Victoria and New South Wales
- Most Boronia grown for essential oils are grown in Tasmania and Western Australia

Key messages

- Choose your site and varieties carefully
- Talk with your wholesaler/exporter
- Know the demand for your product before you plant

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Eucalypts
for cut bud, flower and foliage production

Introduction
Eucalypts are cultivated for cut stems with foliage, buds, flowers or gumnuts, but the various products require different species and management. Eucalypt foliage has been cultivated for many years in southern France, Italy, the USA and more recently in Australia. The market is based upon the attractive juvenile growth of species with crowded, round or oval waxy leaves which have a silvery sheen. Once the tree attains the adult state, the foliage assumes the green, elongated leaf form and its value for foliage stems is decreased. Hence the trees must be heavily pruned to maintain juvenile growth. In contrast, mature material is required for flowering stems, and the priority is attractive buds, flowers or gumnuts which contrast with the foliage. Precocious species with these attributes have formed the basis of a more lucrative cut floral stem trade.

With over 500 species the Eucalyptus genus has wide adaptation to temperate, subtropical and tropical climates. Eucalypts are tolerant of most soil types and have a range of uses. In addition to cut flowers and foliage, they are used for amenity horticulture, revegetation, timber, pulpwood, fuelwood, shelter belts, soil amelioration, honey production, salinity alleviation and water table lowering.

The main constraint to industry development is lack of cohesion in the cut flower and foliage industry, and reluctance to communicate and cooperate. A further constraint is the lack of superior cultivars in Australia, which results in low uniformity in yield and
quality of product. Export of fresh cut flowers and foliage is the area with most potential for expansion.

The most important personal skill requirement for the eucalypt flower and foliage industry is recognition of the intensive nature of production. Plant care is essential for quality production and hence for success.

Markets and marketing issues

Stems are sold on both domestic and export markets. High quality and long stem length are important for the export market, and Australian exporters generally deal direct with overseas importers.

Stems are packed into florist size boxes for direct sales as well as through the auction system.

Key statistics

- Total Australian flower exports were over 5,000 tonne in 1999/2000 (Fresh 4,000 t, dried 1,000 t).
- Destinations in 1999/2000 were Japan 2,000 t, USA 1,000 t, Netherlands 500 t, Canada and Germany <100 t.

Key messages

- Export potential to Asia, Europe and USA
- The Japanese market is undersupplied
- Wide climate and soil tolerance
- Peak industry body is Wildflowers Australia (formerly AFPGA)
- Supply northern hemisphere off season

Niche markets for Australian product have been identified in Asia, Europe, USA and Canada. Both buds and foliage are handled through these channels.

The best period for sending product to Japan is from October to April when supply from northern hemisphere countries is in short supply.

Common names have been developed for some of the species to aid in market identification.

Production requirements

Current production is mainly in coastal areas (see map). Most species require a minimum of 200 mm rainfall per year, and many growers supply drip irrigation to ensure reliable production levels.

Regular watering is especially important during spring and summer in regions with a Mediterranean climate.

Soil type, salinity and pH tolerance vary widely across the genus, with species adapted to most areas across Australia.

Varieties

As yet, there are no superior eucalypt varieties for flower or foliage production available in Australia. A breeding programme for ornamental eucalypts has been underway at the University of Adelaide since 1989, and many superior selections are currently under evaluation (Sedgley and Delaporte 2003).

The main species grown for foliage production are E. gunnii, E. pulverulenta and E. cinerea. Many others have potential for foliage production including E. albida, E. bridgesiana, E. cordata, E. crenulata, E. crucis, E. gillii, E. globulus, E. kruseana, E. perriniana and E. tetragona.

Eucalypt buds and flowers fit into three main categories: filler bud, feature bud/flower and focal bud/flower. Filler buds have small, brightly coloured buds and are used as a background to accentuate the focal flowers. Generally, production is high per tree but the product has low value. Feature bud/flower species have medium sized, coloured buds and flowers and are used as a focus of an arrangement. They produce a reasonable number of stems per...
tree, and can be sold in a bunch or as single stems, with a higher value than that of filler buds. Focal buds and flowers are large and dramatic, and are the central focus of the arrangement. The number of stems per tree is low, but each stem achieves a high price.

Filler bud species include *E. leptophylla*, *E. fraseri*/*E. lesouefii*, *E. gillii*, *E. hypochlamydea*, *E. transcontinentalis*, *E. uncinata*, *E. yalatensis*, *E. pterocarpa*, *E. crucis*, *E. georgei* and *E. torquata*. Feature bud/flower species include *E. caesia*, *E. erythrocorys*, *E. forrestiana*, *E. stoatei*, *E. tetragona* and some larger forms of *E. pterocarpa* and *E. torquata*. Focal bud/flower species include *E. pyriformis*, *E. macrocarpa* and *E. youngiana*, and larger forms of *E. caesia* and *E. erythrocorys*. Other attractive species with potential include the filler bud species *E. aniceps*, feature bud/flower species *E. conveniens*. *E. ficifolia*, *E. miniata*, *E. pachyphylla*, *E. phoenicea*, *E. preissiana*, *E. globulus* and *E. macrandra*, and the focal bud/flower species *E. ptyocarpa* and some larger forms of *E. ficifolia*, *E. miniata*, *E. pachyphylla*, *E. phoenicea* and *E. preissiana*.

The most popular eucalypt currently grown is *E. tetragona*, which can be sold as foliage or with capsules (nuts). Prices remain consistent during the season, an indication of a good balance between supply and demand. Production time varies with climate. The Australian cut flower best bets program places eucalypt buds (reds, yellows, gold), and *E. tetragona* in the top 12 best crops (Slater and Carson 2003).

**Agronomy**

Plantings are established using seedling material, although vegetative propagation via rooted cuttings and grafting is possible for some species. Seedlings are planted out when they are 30 cm high. Planting is done in spring or autumn, and the land should be deep ripped to 30 - 50 cm a few months before planting when the soil is moist and friable. Plant spacing is dependant on machinery, topography, climate, species and end use, with spacing ranging from 1.5 to 5 m within rows, and 1.5 to 10 m between rows. The currently recommended spacing for bud and flower species is 5 m x 10 m. Wide spacing avoids reduction of flower initiation for floral stems, whereas 30 cm within row spacings are sometimes used for intensive foliage production. Some growers use mounded beds to increase aeration of the root zone, drainage and salt leaching, or contour banks to avoid erosion on slopes. Weed mat can be used, and black plastic also increases root zone temperature. Tree guards are advisable in areas where rabbits are a problem. Dolomite or lime improves establishment in acid soils, and sulphur serves the same purpose in alkaline soils.

Fertiliser is often applied via the irrigation system, although top dressing is advisable on sandy soils to avoid leaching. In frost prone areas, nitrogen should be avoided after mid summer, as the new growth may burn before it hardens off. Eucalypts benefit from regular applications of complete fertiliser, including trace elements, and this can be applied via organic or inorganic preparations. Nutrient deficiencies are common if harvesting is regular and fertiliser application is inadequate, and common symptoms include chlorosis, leaf spot and purpling.

Pruning is essential for optimum production, but differs depending on the end use of the crop. For foliage production the tree must be heavily pruned to maintain juvenile leaves and encourage long stem length. At 18 months of age, the main stem is pruned to one metre and major lateral branches

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**Eucalypts for cut bud, flower and foliage production**

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are removed flush with the trunk. Stems for harvest derive from buds under the bark of the trunk or of the basal swelling or lignotuber. In temperate climates, pruning in late winter stimulates stems for harvest in late summer, and trees are pruned annually. More flexibility is possible in frost free and tropical climates, where irrigation can be used to control production and vary harvest time. High foliage yields are produced by *E. globulus* and *E. bridgesiana*. Average yields for most species are ten bunches per tree, of 10 - 12 stems 65 - 70 cm in length, at three years of age.

For bud, flower or gumnut production, the plant must attain the adult state, so pruning is less severe. The tree should be pruned prior to one year old to stimulate branching and create maximum shoots for flower initiation. At harvest, some leaves should be left below the cut to provide further branches for flower production.

Response to pruning varies with species and type of tree (mallee/multi-trunk or single trunk). Tips of new seedlings should be picked out to encourage branching once the tree is about one metre tall. Mallee types may not require any tip pruning as they are naturally bushy. Some species must attain a certain height and maturity before flowering (eg *E. pterocarpa*), so tipping should be done with care, with leaders that are 30 cm long left to grow. As the trees get older, low growing and/or diseased branches should be removed regularly, as well as any diseased or poor performing trees. Mallee types respond well to hard pruning (to one metre), producing numerous long stems that flower two years after pruning. Tall, bud-producing species should be pruned after harvest, by one third of their height, for yearly stem production. Hard pruning will produce better quality product, however there is a two year delay to flowering.

**Pest and disease control**

Many insect pests attack eucalypts, including sawfly larvae (*Perga*), leaf miners (*Perthida, Phylacteophaga*), sucking insects (*Creis, Eriococcus, Cercopidae*) borers (*Cerambycidae, Phoracantha*), gall forming insects (*Apionomorphiinae, Strongylorrhinus*), mites, caterpillars (*Uraba, Mnesampela, Doratjeta, Oenochroma*), beetles (*Catascus, Liparetrus, Chrysomelidae, Paropsis*) and grasshoppers. The leaf-eating beetle *Paropsis* can defoliate plants within a short space of time. Pests can be controlled with a range of standard insecticides.

The most devastating disease of eucalypts is *Phytophthora cinnamomi*, which causes root rot. Care must be taken to avoid introduction of the disease, as eradication is impossible. If a property is infected, then tolerant species should be grown, such as *E. cinerea, E. cordata, E. crenulata, E. globulus, E. gunnii, E. perriniana* and *E. pulverulenta*. *Phytophthora* sensitive species, such as *E. caesia, E. crucis, E. erythrocorys, E. forrestiana, E. kruseana* and *E. tetragona* should be avoided.

Leaf spot and shoot blight fungi can cause problems in eucalypt plantings, particularly in humid climates. Fungi involved include *Phoma, Microsphaeropsis, Mycosphaerella, Colletotrichum, Botrytis, Stemphylium* and *Alternaria*. They can be controlled using standard fungicides.

Careful consideration of plantation layout and good hygiene practices...
will reduce the need for excessive pesticide applications. There are no chemicals registered for eucalypt cut stem production.

**Harvest, handling, packaging, storage, post-harvest treatments and processing**

Foliage stems should be harvested into water during the coolest part of the day, and the stems recut under water. The leaves are carefully stripped from the basal 15 cm of the stem. Stems may be dipped into anti-transpirants to reduce water loss. Holding solutions of 2% sucrose with germicide are beneficial in extending vase life, but pulsing has no effect. Stems have a vase life of two weeks when kept in holding solution, or one week following dry transport. Stems should be dry before packing, and box liners are often used.

*Eucalyptus* foliage is sometimes preserved using glycerine. This gives an attractive sheen combined with supple texture. One part of glycerine is mixed with two parts of water, and stems will take up the mixture over a period of up to a week, or they can be immersed in a more concentrated solution. Dyes can be used to colour the foliage. The stems are then hung to dry.

Stems with buds, flowers and nuts vary in their postharvest requirements. Small bud species can be picked straight into water, whilst larger bud species benefit from short periods of cool dry storage. Different species also vary in their response to sucrose and glucose: generally low levels of sucrose result in faster flower opening, higher levels may result in detrimental bud and leaf blackening. Cold storage (2ºC) is beneficial for all types.

Stems for export must be free of pests, and stems with gumnuts are generally sold on the domestic market as seed predators are difficult to eradicate.

**Financial information**

Economic analyses for new crops should be treated with caution, especially as so many eucalypt growers produce other crops as well.

Upfront expenses per ha for a eucalypt foliage farm are estimated at $1,800 for plants, $1,500 irrigation, $1,500 weedmat, $750 soil preparation, $2,250 labour, and $150 contingencies (Carson, 2000). Approximate annual expenses include fertiliser $400, chemicals and spraying $450, harvesting and packing $7,500, packaging $3,000, freight $1,250, pruning $650 and contingencies $300. Gross return at Year 5 is $16,000 (Carson, 2000). Based on noted annual expenses, this equates to a net return of $2,450 per ha.

Upfront expenses per ha for a eucalypt bud or flower farm are estimated at $480 for plants, $400 irrigation, $600 weedmat and guards, $250 soil preparation, $600 labour, and $150 contingencies (Carson, 2000). Approximate annual expenses include fertiliser $100, chemicals and spraying $120, harvesting and packing $2,300, packaging $1,600, freight $500, pruning $700 and contingencies $300. Gross return at Year 5 is $15,440 (Carson 2000). Based on above mentioned annual expenses, this equates to a net return of $9,820 per ha.

**Key references**


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Eucalypts for cut bud, flower and foliage production
Flannel flower

Ross Worrall, Catherine Offord and Lotte von Richter

Introduction

Flannel flower (Actinotus helianthi) is a cut flower crop whose potential is beginning to be realised. The Australian Best Bets Program (Slater and Carson 2003) assessed it as a clear leader from 77 other cut flower crops studied in terms market potential and economic return. Until recently the majority of flannel flowers sold as cut flowers were bush-harvested. However the percentage of the total bush picked is falling rapidly with greater restrictions being placed on their harvest and declining natural populations. Cultivated product is also more reliable in terms of quality and supply. In addition there are a number of short stemmed, bushy flannel flower selections that have considerable potential for the pot plant or bedding market.

Considerable progress has been made in recent years in the production of flannel flower, both as a field crop and in protected cultivation. This is due to a greater understanding of its cultural requirements and its interaction with root diseases combined with the introduction of new, high yielding varieties, especially one that flowers continuously. High yields and better quality flowers have made the production of...
flannel flower under protected cultivation economically viable. Both horticultural (growing, harvesting and packaging) and marketing skills are very important in the successful culture of flannel flower. There have been a number of significant failures where the importance of these skills was not appreciated. Currently, flannel flowers are mainly produced commercially in coastal New South Wales, the region of origin. The main constraints to production appear to be varietal availability, root diseases, and lack of knowledge of nutritional requirements and postharvest treatments.

### Markets and marketing issues

Flannel flower is in demand as a cut flower, both on the domestic market and overseas, especially in Japan where the highest returns have been obtained. Other Asian markets have shown interest as well as Europe, Canada and the west coast of the USA. The season for both bush picked and field production in New South Wales is August to February with the greatest yield and highest returns in October. Previously bush harvesting produced about 1 to 2 million stems per year (of variable quality), depending on seasonal conditions, and as a consequence presented a threat to cultivated material by reducing the ‘base’ price. In 1996, less than 2% of the flowers produced were cultivated. However bush picking has recently been curtailed both by increasing legal restrictions and declining natural populations. In 2002 over 0.5 million stems were produced in field cultivation.

Production in protected (green house) cultivation is also increasing rapidly. In early 2004 about 0.25 million stems pa were being produced in protected cultivation, by 2005 it is anticipated that over 1 million pa will be produced. The flowers produced in protected cultivation have the added advantages of out of season production and high quality—commanding a premium price for most of the year.

Best sale prices (per stem) have been achieved by long-stemmed flannel flowers (> 80 cm) with some prices as high as $A2.70/stem—although the average is much lower. However, test shipments have demonstrated that good export prices can be obtained for material as short as 20 cm. The return to the grower per box was actually much higher than longer material due to the greater number of flowers in the box. The average return to the grower in 2003 was between $0.01 and $0.02 per cm of stem (ie $0.50 and $1.0 for a 50 cm stem)—varying with the time of year and flower quality. Prices on the domestic market are $A3.50–7.00/bunch (of 10) depending on stem length and time of year. The quantity of flowers sold on the domestic market is not known as many are sold directly to florists. However with year round availability sales are expected to increase. There is also much less risk in marketing the flowers locally.

Although bush harvesting is decreasing it is still a threat to the development of flannel flower markets. Most of the bush-harvested flowers are exported, the perception of them is poor and makes high prices for quality product difficult to achieve. This, and the export markets expectation of quality, are good reasons to develop economical systems for cultivation of this species.
Flowers may be directly exported by larger growers, through grower groups or through agents. In Japan, flowers may be sold at auction or directly by arrangement through importing agents. Remember different markets may have different preferences so do your home work.

**Production requirements**

Flannel flowers (*A. helianthi*) grow naturally on sandstone areas along the NSW coast from Tura Beach in the south to south-eastern Queensland in the north. The species also occurs in isolated pockets inland. The climate in these regions varies considerably from high rainfall on the coast to low precipitation further inland. The number and severity of frosts also varies across these areas, and the humidity ranges from high to low. The species is not uniform across this area. For example inland types are more resistant to frosts. However even coastal types will withstand 0°C under protected cultivation i.e. heating is usually not necessary.

Flannel flowers require a very well-drained, slightly acid growing medium, whether using amended natural soils or artificial medium.

Use of artificial media means that the crop can be grown in areas with unsuitable native soils. Despite having a reputation as being sensitive to fertilisers, especially those containing phosphorous, in practice they have a high fertiliser requirement, especially when grown in artificial media. Use of fertigation to supply nutrients on a regular basis has been very successful in commercial practice. Trickle or microject irrigation is preferred. The foliage should be kept as dry as possible. In most cases irrigation will also be required for field grown material. Although plants will grow in the full sun, better quality flowers and longer stems will be achieved with light shade, which can also provide wind protection.

Proximity to appropriate transport and cool storage facilities is also essential for production of a premium product.

**Varieties**

Selection of suitable seed lines or clonal material is extremely important to the success of the venture. Prospective growers must ensure that the source of their stock material is suitable for cut flower production, i.e. long stemmed forms. Currently most material available is grown from selected seed forms. However a number of nurseries are beginning to vegetatively produce flannel...
Flannel flowers by cuttings and tissue culture. Mt Annan Botanic Gardens has produced a number of varieties suitable for cut flower production that are multiplied by tissue culture eg ‘Starbright’. As yet it is not clear which method of propagation will produce the greater economic returns although currently all methods appear to give reasonable returns. However seed germination of flannel flowers is notoriously unreliable and they produce the most variable plants. Further work is required to improve the reliability of germination.

Currently year round production of flannel flowers largely relies on one selected seed line. Although all seedlings of this selection flower continuously there is considerable variation between plants with some producing flowers too short to be economically viable. Growers intend replacing the seedlings with selected clones propagated by cutting for this reason.

It is clear that there is a need for new varieties that have better flowers and yields, out of season production and resistance to root diseases. Although the colour is currently limited to white or cream, pink occurs in a closely related species and may be added as the result of future breeding programs.

**Cultural practices/ agronomy**

*Field cultivation.* Cultivation site preparation is similar to other Australian native plants; that is, soil is cultivated and generally raised into beds 1 m wide and 20–30 cm high. Weed matting and mulching with wood chip or straw can control weeds and maintain soil moisture. Irrigation should be drip or trickle and is necessary in most areas, particularly during dry and/or hot periods. Flannel flowers are best planted out into the field while still small, approximately 3–5 cm high. Root systems are easily damaged and so avoid unnecessary disturbance at all stages including planting out. Planting in spring or autumn is best for active growth, although summer planting may be satisfactory if the plants are irrigated. For maximum production per unit area, plants should be planted in two rows with 30 cm between rows and plants. This spacing also provides maximum interplant support against wind, which may easily blow over this shallow rooted species. Flannel flowers are considered a short-lived perennial and should be treated as a biennial. Under some circumstances, flannel flowers may be productive into their third and fourth years, but rarely beyond.

While still young, the growing shoot of flannel flowers should be pinched out to encourage low branching in the plant and thus increase flower yield. This pinching (or pruning in older plants) should be carried out in autumn, but it should be noted that if this operation is carried out too late then stem length will be reduced in the following spring.

*Protected cultivation.* Plants are currently grown in containers of 4-10 litre capacity and generally raised off the ground onto benches for disease control. It is important that the growing medium be very well aerated. Media, mostly composed of pine bark less than 12 mm with added coarse sand, lime and other fertilisers, i.e. one that is usually used in potting mixes seems to be satisfactory. The growing structure should be very well ventilated. Plastic appears to be a satisfactory cover. Since, with the clones used, plants flower year round they can be planted at most times of the year, except during very hot periods. Plants are usually spaced at 10 per m² in rows of four to allow sufficient space for walkways. String or stakes may be required to support plants.

Although from areas of low natural fertility, flannel flowers in cultivation respond well to added
fertiliser. Trials using slow-release fertilisers in pot plants (Nutricote® Total N13:P5.7:K10.8 and N18: P2.6:K6.6) indicate that increased stem number and earlier flowering are achieved at higher nutrient levels (5–10 kg/m³ potting media). Low to medium levels of available phosphorus (0–82.5 mg/kg) can be tolerated by flannel flowers and toxicities have only been seen at very high levels (290 mg/kg found at one grower site).

**Pest and disease control**

The most serious diseases of flannel flower are root rots. These are the most common cause of plant death in cultivation and losses can be serious or even total. Death can occur within a week. The two most serious pathogens causing root rot are *Pythium* and *Fusarium*, although other fungi have been implicated (eg *Rhizoctonia* and *Phytophthora*). It is thought that several species/strains of the fungi genera are implicated and they have differing effects on the plants, however further research is required to clarify the situation. The most effective control is hygiene and cultural practices. It is essential the growing medium is very well aerated and that the plants are not overwatered. If the growing conditions are good the root rots will normally only have a small effect on plant growth. No effective fungicides have yet been found to control the rots, however research is continuing. During the propagation of flannel flowers, grey mould caused by *Botrytis* sp. is common and may be controlled by reducing humidity, avoiding overcrowding, regular removal of dead material, use of fungicides and keeping temperatures in the range 20–25°C.

A number of pests attack flannel flower. However they are usually relatively easy to control and cause little damage if detected early. Some recorded pests are mealy bug, aphid, thrips, mites and caterpillars. It is important that the number of insects be kept low because of the need for disinfestation for export. Even spiders may be a problem.

**Harvest, handling and postharvest treatments**

Seasonally flowering flannel flowers will produce saleable blooms in the first spring season if planted at least by mid summer of the previous year (approximately 8 months) They may produce a second crop in late summer although stems lengths will be reduced. Production will generally be higher in the second flowering season. Depending on the size of transplant continuously flowering clones will produce flowers in 2–4 months after transplanting.

Flowering heads are ready for harvest when approximately 15–20 individual florets are open in the centre of the disc of the main flowering head. The exception is the continuously flowering clone that may be harvested when the head is fully formed, without any individual flowers being open, to all of them being open without a reduction in vase life. Harvesting should be done in the morning and the stems placed directly into cool water. Stems should be cut as long as possible but never cut into
the oldest part of the stem as this may kill the plant. Blooms can be stored in a cool room (2-4°C) either dry or standing in water, for several weeks although maximum vase life (7-35 days depending on variety) is achieved if they are transported (in water) immediately or overnight.

The use of chemical treatments such as citric acid and bleach may assist in prolonging vase life and controlling fungal diseases. Addition of sucrose, as a pulse or to vase solutions has not been found to extend vase life (see Faragher et al 2002 for further information). Further work is required on postharvest treatments to maximise shelf life. Flannel flowers are graded according to stem length: 40 cm is the shortest marketable length for field grown material; the export markets prefer stems 60–80 cm and longer if available. Flowers as short as 20 cm produced under protected cultivation are also saleable due to their out of season production and higher quality. Stems are bundled in groups of 10 and placed in cartons containing, depending on length, up to 200 stems. More stems can be put in a box using bunches of different stem length but importers may have their own preference. Bunches in microperforated sleeves and a plastic box liner present well and suffer less damage during transport.

Skin irritation may occur in some people when handling flannel flowers due to the fine hairs on the stem. Due care should be taken during handling and especially harvesting when gloves, long sleeves and a mask should be worn, especially during very dry conditions. The potential for skin irritation is greatly reduced after the flowers are dipped.

**Financial information**

One person can manage about 1 ha of field production with additional labour for harvest processing and packaging. However, normally the crop will be grown in association with others to spread labour and risk. Without previous experience in the growing and marketing of flannel flower the planting of large areas is inadvisable due to the risks involved.

For flowers grown in protected cultivation one person can manage about 1,500 m² of greenhouse space. In this area, the year round flowering clone is capable of producing over one million stems per annum, thus the need for additional labour for harvest processing and packaging is obvious.

Since the production of flannel flowers under protected cultivation is still in the development stage, a gross margin is presented for field production.

A number of assumptions have been made. The average return to growers for product exported to Japan in 2003 was between about $0.01 and $0.02 per cm of stem. It is assumed that an average return for a 50 cm stem was $0.75. Prices could be much higher or lower than this. Also prices of the individual components will vary greatly between enterprises. The crop was assumed to last for 2 years. Capital costs are not included.

**Table 1: Flannel flower gross margin analysis – 2 year average**

<table>
<thead>
<tr>
<th>Summary</th>
<th>$/stem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm gate price</td>
<td>0.75</td>
</tr>
<tr>
<td>Harvesting</td>
<td>0.06</td>
</tr>
<tr>
<td>Growing costs</td>
<td>0.08</td>
</tr>
<tr>
<td>Plant cost</td>
<td>0.04</td>
</tr>
<tr>
<td>Packaging</td>
<td>0.03</td>
</tr>
<tr>
<td>Processing</td>
<td>0.10</td>
</tr>
<tr>
<td>Cost / stem</td>
<td>0.31</td>
</tr>
<tr>
<td>Gross margin/ stem</td>
<td>0.44</td>
</tr>
<tr>
<td>Stems/plant</td>
<td>19</td>
</tr>
<tr>
<td>Stems/ha</td>
<td>330,671</td>
</tr>
<tr>
<td>Gross margin/ha</td>
<td>145,495</td>
</tr>
</tbody>
</table>

A number of assumptions have been made. The average return to growers for product exported to Japan in 2003 was between about $0.01 and $0.02 per cm of stem. It is assumed that an average return for a 50 cm stem was $0.75. Prices could be much higher or lower than this. Also prices of the individual components will vary greatly between enterprises. The crop was assumed to last for 2 years. Capital costs are not included.

**Key messages**

- A key focal filler
- Expanding industry with good growth potential
- Production shifting from bush picking to both field and protected cultivation
- Root diseases are the major constraint to cultivation
- A seasonal crop but year round production now expanding

**Key statistics**

- Production largely in coastal New South Wales, Victoria and Queensland
- One to two million stems exported annually
- Production of cultivated product approaching one million stems p.a.
About the authors

Ross Worrall (Ph D) is a senior research horticulturist with NSW Agriculture. Since 1972 he has been involved in the breeding and development of Australian native flowers for both cut flowers and pot plants.

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Flannel flower

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Kangaroo paw

Ross Worrall and Ken Young

Introduction

Kangaroo paw (*Anigozanthos* and *Macropidia* species) is Australia’s second largest export cut flower. However it is facing increasing competition from overseas producers, especially from central America and southern Africa. The appreciating Australian dollar is also placing pressure on financial returns. Exact production figures are not known, however it is thought that growers are exiting the industry due to poor financial returns. Australia has been the major source of new varieties, although Israel is now also producing them. There is a need for higher yielding, more disease resistant clones, especially of the brighter colours, particularly yellow, and to extend the flowering season. Few successful new varieties have been developed in recent years.

Any potential for the expansion of the industry in the short term mostly lies in expanding the domestic market through promotion and expanding availability throughout the year. To compete more effectively on the overseas markets, new and novel varieties, out of season production (especially earlier), a reduction in costs and a relatively lower Australian dollar are required. Both horticultural (growing and harvesting–packaging) and marketing skills are very important in the production of kangaroo paws. They are not considered a difficult crop to grow compared with many other cut flowers, especially the *flavidus* hybrids. However, proper

*Anigozanthos pulcherrimus* flower. Yellow (left) is the most popular colour. Cultivar ‘Big Red’ (right) is also a popular cut flower (Photos: NSW Agriculture)

Approximate limits

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Kangaroo paw

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scheduling of harvesting and marketing is quite important.

**Markets and marketing issues**

The farm gate price has been decreasing in recent years with the average price per stem in 2001-2003: $0.50, 2002- $0.38 and 2003-$0.32 for red and yellow 50-110 cm flowers to Japan. There is also a large price differential between early and late flowers. For example red flowers marketed in 2003 before mid October averaged $0.45/ stem, those later averaged $0.25/stem. However the price can also be very volatile; very low or negative returns are also possible. Rapid feedback from overseas markets is very important to determine if flowers are to be harvested and exported without incurring a loss. For example if prices are a week out of date two or three additional shipments may have been sent after a price crash.

The declining price is largely due to the appreciating Australian dollar, especially against the Yen and keen competition for the overseas markets from other large producers. Major competition for the European market is from Israel. Whilst Israeli production is ‘off-season’ to ours, Israel’s closeness to Europe and relatively low freight rates means it can sell at a lower price than us and achieve a satisfactory return. This tends to ‘stabilise’ returns from Europe to that for a generic commodity. In the Southern Hemisphere countries directly competing with Australia for the Japanese market are Zimbabwe and other southern African countries. Production is also expanding in central America, especially under protected cultivation. The USA and Canada

*Greenhouse production of kangaroo paw (Photo: NSW Agriculture)*

**Key messages**

- Increasing competition from overseas countries
- Declining production and returns except for niche products with significant numbers of growers ceasing production
- Relatively easy to grow crop
- High labour input in processing
- Need for new varieties to expand industry

**Key statistics**

- Second largest cut flower export crop
- Over 4 million stems produced in 2000 but no reliable recent statistics available
- Significant domestic market
- Large losses due to frost and drought in 2003- over one million stems
- Many flowers not harvested later in the season due to declining prices
take only small volumes of flowers in the 60–90 cm stem-length range.

Flowers may be directly exported by larger growers, or through agents. In Japan, flowers may be sold at auction or directly by arrangement through importing agents. Different markets may have different preferences. For example Japan prefers longer stems (up to 150 cm) and flowers with ‘clean’ vibrant colours, especially yellow. The strongest market is in September to October. In contrast there is a niche market in Europe at Christmas time, mainly for red kangaroo paws 70 - 100 cm long, with smaller volumes in the New Year. Colour preference changes frequently.

Production requirements

Soils must be well drained, with slightly acidic sandy loams preferred. Some varieties are particularly sensitive to phosphorus, which is exacerbated by nutrient imbalances. A soil test is recommended, especially for previously cultivated areas. Sites should be frost free. Although the foliage may not be damaged, flowers may be severely degraded by a light frost (i.e. –0.5°C), even in the bud stage. There were wide spread losses in 2002 and 2003 due to heavy frosts. Plants may be grown in well-ventilated greenhouses for earlier flowering and to protect them from weather damage. However, high temperatures and/or lower light levels may result in severe flower fading, especially of the red varieties. High summer temperatures limit production areas to approximately south-eastern Queensland and south in the eastern states and the south-west of Western Australia.

*A. flavidus* and its hybrids are generally much hardier.

The approximate limits of commercial production are given in the accompanying map. However, many microclimates in this area may not be suitable for the reasons outlined above. Similarly, it may be possible to grow plants in other areas. This can be determined only by trial plantings before starting full-scale production.

Adequate irrigation using high quality water is usually necessary for maximum production and to extend the flowering season, although production areas with high summer rainfall on the east coast may have little need for irrigation. Extended periods of wet weather will also exacerbate disease problems. Provided that
the area is well drained, and
flood and frost free, flatter areas
are preferred for ease of cultural
operations and harvesting.
Availability and cost of transport
to market or export airports should
also be considered.

Varieties
Most plants cultivated today are
hybrids or selected clones, usually
produced by tissue culture. \(A.\)
\textit{flavidus} hybrids are especially
popular, especially in the more
humid areas of the eastern states
due to their resistance to most of
the common pests and diseases.
There are at least 40 varieties
exported with well over 100
cultivars available. Many of the
cut flower varieties have also been
grown for many years and there
is a need for hardy new varieties,
especially of \textit{Macropidia}, early
yellows and perhaps late flowering
reds.

Taller (approximately 1 m)
varieties with clear bright colours,
especially yellow, are favoured for
cut-flower production. However,
smaller varieties may have a place
in the mixed bouquet market.
Some of the varieties grown as cut
flowers include Autumn Harmony,
Big Red, Bush Dawn, Bush Gem,
Bush Glow, Bush Emerald, Bush
Harmony, Bush Haze, Bush Noon,
Bush Ranger, Bush Ruby, Bush
Sunset, Copper Charm, Crisp
Pink, Gold Fever, Golden gem,
Orange Cross, Regal Claw, Royal
Cheer, Ruby Delight, Yellow
Dawn, Yellow Gem, Yellow Mist
and Yellow Sunrise. Some species
that are grown include \textit{Macropidia},
\textit{A. manglesii} and \textit{A. bicolor}, and \textit{A. pulcherrimus} (orange and yellow
forms).

Cultural practices/
agronomy
After a suitable site is selected and
drainage installed, if necessary,
a basal dressing of fertiliser or
chicken manure is incorporated
into the beds, especially in poor
sandy soils. In the field, the
distance between beds (usually 3–4
m) will depend on the equipment
to be used for cultivation and
transport of flowers. Failure to
allow for free movement will
greatly increase production and
picking costs.

Within beds, there may be up to
three rows 1 m apart, and plants
are usually spaced 1 m apart
within rows. Break rows every
50 m or so to allow for efficient
vehicle movement. Beds are often
raised to provide better drainage,
especially in the eastern states,
where the use of weed mats and
mulches is also common. Planting
in spring/autumn to avoid very
hot weather is preferred, especially
on black weed mat. Applying
fertiliser through the irrigation
system is the most satisfactory
method of fertilising kangaroo
paw, especially if weed mats or
mulches are used.

Fertilising should be carried
out during the growing season,
especially from mid autumn to
mid spring.

Plants will first flower about 6
months after planting, then at
their normal time each year. Full
production will be achieved in the
second to third year. The number
of flowers will increase beyond this
but the quality will be reduced,
necessitating severe pruning
(slashing).

Some species, such as \textit{A. manglesii},
are best treated as annual or
biennial crops. The most time
and labour-critical operation
is harvesting. Flowers must be
harvested at the right stage for
maximum quality, and processed,
packed, cooled and transported to
market promptly. Most varieties
have flushes; therefore a mixture
will help to even out production
over a greater period.

Basic equipment and facilities
required are a processing shed
with facilities to treat flowers
with fungicide/insecticide and
to grade, bunch and box flowers,
forced air cool room, buckets,
chemicals, good quality water,
tractor/transport vehicles for site
preparation and movement of
flowers, slasher, spray equipment
for pest and disease control, an
irrigation system and access to
refrigerated transport.

Dwarf kangaroo paws can also make excellent flowering pot plants (Photo: NSW Agriculture)
Pest and disease control

Ink disease of kangaroo paws (blackening of the leaves and flowers) is a widespread problem, especially in the more humid areas (e.g. coastal New South Wales) and under protected cultivation. Some varieties are much more susceptible than others. Ink spot is a response to a wide range of stresses e.g. insect damage, nutrient imbalance and pathogens (esp. *Alternaria*).

Rust (*Puccinia haemodora*) is also a serious disease which causes typical rust pustules (blisters) on the leaves. Development of rust is favoured by hot, wet conditions, as are a range of crown and root rots caused by a variety of fungi (e.g. *Pythium, Fusarium, Phytophthora, Sclerotinia, and Rhizoctonia*). Young plants in poorly drained soils are especially at risk. Petal blight or grey mould (*Botrytis cineria*) may also be a problem, especially in cool damp conditions. Severity of infection of these diseases can be minimised by the use of resistant clones (usually *flavidus* hybrids), avoidance of environmental stresses, good air circulation and trickle irrigation to avoid wetting of foliage, and use of fungicides. An annual slash or slash and burn may be effective in removing infected material. Disease-free planting material is also essential, especially since Tomato Spotted Wilt Virus has been detected in kangaroo paws. How wide spread this problem is, however, not known.

Compared with many exotic flower crops kangaroo paws are relatively free of pests. However, for the production of high-quality blooms a pest-control program may be necessary, especially if flowers are to be exported. It is essential to reduce insect populations to low levels before harvesting because most disinfection treatments are only partly effective at levels that do not damage the flowers. Some problem insects are aphids, leaf miners, bud worm, thrips and small, leaf-chewing caterpillars. Most of these pests are relatively easily controlled by the application of an appropriate insecticide. Slugs and snails may also be a serious pest, especially of young plants in the greenhouse and in cooler areas. Susceptibility of species/clones to slugs and snails varies widely, with *A. flavidus* and hybrids generally being more resistant. Control is by good hygiene and spray or pellet application of a molluscicide.

Birds may cause extensive damage to flowers by breaking stems and biting off flowers, especially if other flowers are scarce. Control is by netting or human presence.

Weeds may become a major problem, especially in the eastern states. Mechanical control on a large scale is often difficult due to the herbaceous nature and habit of the plant. Plastic weed mat or mulches are very popular with commercial cut-flower growers in summer rainfall areas, especially to control broadleaf weeds. Care, however, must be taken with black weed mats due to elevated temperatures that occur under the mat. Small plants are especially vulnerable. Mowing or knock-down herbicides are used for interrow weed control. Grasses can be controlled with post-emergent herbicides. Some herbicides may cause damage to, or reduce the growth rate of kangaroo paws. Phytotoxic effects may vary with the rate, method of application and clone. Check to ensure that the herbicides you want to use are registered in your State for the intended purpose.

**Harvest /handling / postharvest treatments/processing requirements**

Flowers are usually harvested when the first one to three florets on the spike have opened. Harvesting at an earlier stage (in bud) may cause a condition known as ‘bent neck’. As soon as possible after harvesting, flowers should be placed in water or a preservative solution to prevent wilting.
Flowers must also be cooled as soon as possible.

After harvest, stems are usually re-cut to the desired length and bunched into five-stem units (10 stems if short, i.e. < 70 cm). Bunches are then usually sleeved into a micro-punched flower sleeve. Flowers are then disinfected by complete immersion in a Cislin® and Rovral® (or similar) mix to kill insects and to control Botrytis. Some growers, especially in Western Australia, disinfest with the above mixture and dry the flowers before sleeving.

Currently, insecticidal dips such as Cislin® would appear to offer the most effective means of disinfesting flowers. Treatment of kangaroo paws with aerosols, such as dichlorvos or pyrethrin, is moderately effective. Some growers use a combination of insecticidal dip followed by aerosol treatment. Before using pesticides check that they are registered for use on flowers in your State.

Freedom from live insects is necessary for the export of flowers from Australia, especially to countries with strict quarantine requirements, such as Japan and the USA. Live insects on flowers will require fumigation or destruction of the flowers in these markets. Fumigation may damage the flowers and will cause a reduction in auction prices, delays in selling and a reduction in consumer confidence. Insect contamination causes similar problems on the domestic market.

Use of pulsing solutions containing sucrose and other chemicals after harvest can extend the vase life of kangaroo paws. However, considerable variation exists in current recommendations, which range from 2–20% sucrose and above. Clean buckets and water should be used at all times.

Kangaroo paws should be stored at low temperatures (~2°C) and a high relative humidity (95–98%), including during pulsing. Forced air cooling should be used to reduce flower temperatures as soon as possible after harvesting, and again after flowers are packed into cartons. Flowers should be at less than 5°C at dispatch. The vase life of kangaroo paw flowers is reduced by cold storage and storage on the farm should be limited to no more than a few days. The maximum total storage time should be no more than about two weeks, and preferably less than one week over the entire marketing chain.

**About the authors**

Ross Worrall (PhD) is a senior research horticulturist with NSW Agriculture. He has specialised in the breeding and development of Australian native plants both as cut flower crops and pot plants since 1972.

Ken Young is an experienced grower and exporter of, and consultant on, Australian native cut flowers.

**Financial information**

The ‘typical’ estimated start-up costs for one hectare, not including land, machinery, clearing, labour, fencing or structures, is about $25,000 in New South Wales and south-eastern Queensland. This includes operating costs for one year. It is emphasised that costs will vary widely from site to site, even in the same locality.

The kangaroo paw export industry has reached a relatively mature stage with significant quantities having been exported for a number of years. There are also a number...
of competitors on the international market.

A ‘typical’ gross margin analysis is presented below for flowers exported to Japan. It should be emphasised that the net return to the grower (after sales and freight) can vary considerably with variety (over a twofold difference) and time of year (over a fivefold difference).

As can be seen from the gross margin figures, if other sale prices are substituted, both a profit and loss are possible, depending on variety and time of year.

Marketing knowledge and skills are needed to maintain profitability.

It may also be very difficult to sell certain types at particular times of the year. Any change in the sale price, freight costs and the Yen/$AUD exchange rate, all of which are largely outside the control of the grower, will also have a dramatic effect on the gross margin.

Due to these risks, and to spread costs and labour, it is recommended that kangaroo paws be grown in conjunction with other crops and that a range of varieties be grown.

Processing, packaging, sales and freight costs will be very much reduced for the domestic market due to the less stringent quality requirements. The sale price is also often much lower and the market relatively small. Losses, especially late in the season when prices usually decline, can be minimised by not harvesting flowers. However timely market feedback is required for this decision.

### Table 1: Indicative gross margin analysis at year 2-3 for Japanese export material, 7000 plants/ha (NSW Coast)


<table>
<thead>
<tr>
<th>Costs (not including overseas costs)</th>
<th>$/stem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting &amp; processing &amp; packaging</td>
<td>0.19</td>
</tr>
<tr>
<td>Production costs</td>
<td>0.05</td>
</tr>
<tr>
<td>Establishment costs</td>
<td>0.04</td>
</tr>
<tr>
<td>Plant replacement costs</td>
<td>0.02</td>
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<tr>
<td>Total costs</td>
<td>0.30</td>
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<table>
<thead>
<tr>
<th>Returns</th>
<th>$(/stem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sale price ($/stem – farm gate, av. 2001-3)</td>
<td>0.40 *</td>
</tr>
<tr>
<td>Gross margin/stem ($)</td>
<td>0.10</td>
</tr>
<tr>
<td>No. of stems (30 stems/plant)</td>
<td>210,000</td>
</tr>
<tr>
<td>Gross margin/ha ($)</td>
<td>$21,000</td>
</tr>
</tbody>
</table>

* Will vary greatly with time of year and exchange rate.

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### Key references


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Other State Departments of Agriculture, especially WA, have numerous publications on Australian native cut flowers in general, and kangaroo paws, in particular.
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**Introduction**

NSW Christmas bush (*Ceratopetalum gummiferum*) has been grown and sold as a filler cut flower in the Sydney area for well over a century. It makes an excellent cut flower. The vase life of quality ‘flowers’ (the red sepals develop after the white flowers) can be up to three weeks. As its name implies, it has become associated with Christmas, particularly because the bright red sepals, which contrast well with the green foliage, develop around that time of the year. Association with Christmas has proved to be more a strength than a weakness, i.e. reducing demand at other times of the year. The foliage alone also has some use in flower bunches.

Demand is strong on the local market immediately before Christmas, with the price dropping dramatically afterwards. Flowering times are quite variable. Often the red sepals develop after Christmas in the Sydney area, when the price is low. Efforts to establish an alternative name for the product, e.g. festival bush, have only been partially successful.

The quality of flowers on the local market is generally lower in...
terms of grading and postharvest life. There is a strong demand for high quality flowers in the Japanese market in November and December, and in the United States after Thanksgiving (26th November).

Current production is largely based on one early variety, ‘Albery’s Red’. New varieties need to be developed to spread harvesting times in any one locality. There are also various challenges facing the culture of Christmas bush. Hot dry winds, especially at flowering time, may cause a complete loss of the flowers, as do severe frosts. Nevertheless, although there have been some losses under adverse conditions, plants should last many years if properly cared for. The range of environments in which Christmas bush can be successfully grown commercially has yet to be fully determined.

Both horticultural (growing, harvesting and packaging) and marketing skills are very important in the production of Christmas bush. Especially critical is the ability to schedule harvesting and marketing.

### Markets and marketing issues

Bunches sold on the domestic market have variable stem lengths and sizes within and between bunches. Flowers for export are more carefully graded, principally on stem length. Other factors also taken into account are the number of sepals on the stem, their colour and how they are presented, and the total perceived volume of the stems. Perceived volume relates to flower density and ratio of stem width to length. Top quality AAA stems occupy a visual width of two thirds their height, so fewer stems are needed by the florist to fill a space. These stems have the classic pyramidal ‘Christmas tree’ shape, and command premium prices in the Japanese market. There are also a specified number of stems in a bunch. Although the export price received is much higher than from the domestic market, grading costs and proportion of product not meeting the specifications are also much higher.

Domestically the principal market for fresh cut flowers is Sydney. Relatively small quantities are sold in Brisbane and little in Melbourne. Early season prices are better in Brisbane than in Sydney. Large quantities are also sold directly to wholesalers and florists. Japan and the United States are the main export markets, with smaller quantities sold in Canada, and the Euro area.

Flowers are usually consolidated by Australian export agents, but some larger growers or grower groups export directly. North American sales are on a fixed price basis, and product for Japan is usually shipped on consignment. In Japan, flowers are placed by importers into the auction system. They are either sold at auction or by pre-selling, including on the internet, with the auctions functioning as a logistic and payment centre.

The timing of sales is critical in all markets to achieve the best price. Higher prices are currently obtained for best quality flowers on the Japanese market. Japanese prices recovered somewhat from low and erratic levels in 2002 to viable levels for good product in 2003. In line with world trends of generally falling flower prices, Christmas bush returns have never returned to the ‘gold rush’ levels of the 90s. Supply has increased considerably since 1998, and the

![Frost protection with overhead sprinklers](Photo: NSW Agriculture)

![Effect of shading on colour development of Christmas bush. Left- full shade; Right- full sun](Photo: NSW Agriculture)
higher level of the Australian dollar has been the biggest factor impacting on grower returns in 2003. USA prices are currently about the same or slightly higher than domestic prices, but much larger volumes can be sold.

Production requirements

The primary requirement for the production of quality flowers is protection from hot dry winds, especially at flowering time. These can cause an almost complete loss of flowers in a matter of days, or at least a significant reduction in quality, especially vase life. Degree of shelter from dehydrating conditions is the most significant factor in determining product vase life. Damage can occur even when soil moisture is sufficient. Adequate water is also important, especially from flowering time to harvest. Plants should be irrigated regularly. Two to three year-old plants require about 4 L/day. Established plants will tolerate moderate frosts to about -4°C.

Soil type does not appear to be important, provided drainage is good. Soil pH is best between 5.3 and 5.8. Christmas bush is intolerant of salty water.

The species occurs naturally in moist gullies and slopes in coastal New South Wales. It has been grown commercially near Toowoomba in Queensland and coastal areas of Victoria. Its commercial performance in other parts of Australia such as south-west Western Australia is not known. However, in a suitable microclimate it may well be successful. It should also be noted that, even within areas shown, some parts may not be suitable due to local conditions. Recent drought conditions in 2001-2003, with severe frosts and record high temperatures in the pre-harvest period, have demonstrated the relatively narrow band of climatic suitability in which this crop is consistently reliable and has a competitive advantage.

Varieties

It is strongly recommended that selected clones be used rather than seedlings, which may be highly variable. The most commonly grown variety is ‘Albery’s Red’. This is compact, dark red in colour, and early and free flowering. Almost all current plantings are of this variety. It is well accepted in the Japanese market and often brings the best price on the Australian market. There remains a need, however, to extend the flowering season and introduce a greater range of colours.

One variety which shows particular promise is ‘Festival’, a cross of ‘Albery’s Red’ and ‘Shiraz’. ‘Festival’ has larger and darker flowers, although flower density is lower than ‘Albery’s’. It flowers...
1-3 weeks later than ‘Albery’s Red’, and is particularly suitable for the USA market due to its darker red (poinsettia-like) colour. It is also more vigorous and productive than both its parents. ‘Shiraz’ flowers 2-4 weeks later than ‘Albery’s Red’, depending on location, and is a darker red with slightly cupped flowers. It is well accepted by the Japanese market and brings good stem prices but packouts are lower due to wide branch angle, and it is less productive than ‘Albery’s’. Two good white varieties are ‘Silent Night’ and ‘Mirrabooka’. There has been a good response from the Japanese market to trial shipments, although there are some problems with brown spots on white sepals. The spotting can result from rain, overhead irrigation or condensation. There is also a range of other colours available, especially pinks, some of which show particular promise in terms of plant form and vase life of the flowers.

**Agronomy**

After a suitable site is selected, and drainage installed if necessary, a basal dressing of fertiliser, usually including lime and a phosphate source and chicken manure, is incorporated into the beds. A soil test should be used to determine requirements. In the field, the distance between beds (usually 4 m) will depend on the equipment to be used for cultivation and transport of flowers. Failure to allow for this will greatly increase production and picking costs. Within beds, plants are usually spaced 1-2 m apart. Beds are often raised to provide better drainage and weed mats/mulches are also commonly used to control weeds. Planting in spring/autumn, and winter in frost-free areas to avoid very hot weather is preferred, especially on black weed mat. Trickle or drip irrigation is generally used, so as to avoid wetting the foliage.

Commercial production starts 1-2 years after planting, depending on the size of transplants. The most time and labour critical operation is harvesting. Flowers must be harvested at the right stage for maximum quality and processed, packed, cooled and transported to market promptly. Picking of varieties at any one location generally takes place over 2-4 weeks, depending on exact orientation of blocks and temperatures. A mixture of varieties will help to extend production over a greater period.

Christmas bush responds well to fertiliser the application of which is essential for commercial production. However, no fertiliser should be applied for 3-4 months before harvest, to reduce the risk of new shoots overgrowing the ‘flowers’, and thus reducing quality. Fertiliser application of NPK and minor elements combined with pelleted chicken manure applied in January and April, appears to give satisfactory results. Quantities and formulations should be determined after soil and leaf tests. Generally plants need high nitrogen after harvest for stem regrowth, with increasing amounts of potassium and calcium and phosphorus moving into autumn/winter, up to flowering. Use of organics such as chicken manure is beneficial for soil structure and micro-organisms, important for sustainable production of a long-term woody crop.

As a guide, 20-30 grams of high analysis fertiliser should be applied to one to two year-old plants (at least 1.5 m high) with an equal amount, in terms of nutrient content, of pelleted fowl manure. Solid fertilisers may be supplemented with additional liquid fertiliser applied through the irrigation system. Plants require at least moderate levels of phosphorus and other fertilisers for maximum growth.

Proper pruning of the bush is vital for maximum production and usually takes place as flowers are harvested or immediately afterwards. Any unharvested branches are cut back to 25-50% of their original length. The main trunks should be cut back to 2-2.5 m to facilitate harvesting. The general aim is to leave about 25% of the original foliage or regrowth will be reduced.
Pest and disease control

The main insect pests are leaf-curling psyllids, which often appear on new growth. They are difficult to control, even with repeated applications of insecticide.

Scale insects can also be a persistent problem, particularly if plants are not growing strongly. Other pests are aphids, caterpillars and thrips which can attack new shoots and flowers, although they have not been a major problem to date. It is important to reduce pests and other insects to a low level in the field, especially if flowers are to be exported. Major markets, Japan and the USA, require 100% freedom from insects.

The disinestation treatment commonly used is an insecticidal dip. This is only partially effective, therefore the chance of live insects contaminating flower shipments is greatly reduced if the insect population is reduced before harvest. Root diseases may also become a serious problem in sites that are not well drained.

Use of weed mats or mulches will greatly reduce the need for weed control. Glyphosate may cause damage by root transfer from perennial grasses under some circumstances (especially in very light sandy soils) and its frequent use can no longer be recommended. Contact herbicides may be safer for the plants, if not for the operator. Always read and follow the label directions for use, especially regarding personal protective equipment. Note that it is essential to check the registered uses of pesticides in your State before applying them.

Harvest, handling and postharvest treatments

Basic requirements for production and handling are a processing shed with facilities to treat flowers with fungicide/insecticide and to grade, bunch and box flowers, a forced-air cool room, buckets, chemicals, good quality water, tractor/transport vehicles for site preparation and movement of flowers, a slasher for weed control, spray equipment for pest and disease control, an irrigation system and access to refrigerated transport.

Harvest time is late October to late November in coastal Queensland, early November to mid December on the north coast of New South Wales, late November up to Christmas in cooler and higher altitude areas away from the coast, and New South Wales central coast and Blue Mountains, and late January to early March on New South Wales south coast, Victoria and New Zealand. Christmas bush is sold by the stem in 30, 40, 50, 60, 70, 80, 90 and 100 cm lengths for export markets.
Stems should be placed in water containing preservative as soon as possible after harvesting. They should be cooled to 8-10°C for overnight storage or to 5-6°C for longer periods. Use clean water and buckets. A suitable basic preservative is citric acid at 0.25g/L and a chlorine source, such as bleach or pool chlorine, at 1.25 ml/L for products with 4% available chlorine (adjust for other levels). These mainly act by inhibiting bacterial growth in the water, thus increasing vase life.

Leaves are stripped from the lower 10-20 cm, depending on their length. They are dipped in an insecticide/fungicide solution (e.g. Cislin® & Rovral®, check the registered uses in your state), and sleeved in microperforated sleeves when nearly dry. Packed boxes should be force-air cooled before transport.

The domestic market prices by the bunch, which may be from 5-25 stems, depending on their size and fullness. Export bunches for USA are made to buyer’s specifications, usually 5-10 stems in 40, 50 & 60 cm grades. Bunches for Japan have an exact stem number and need to be all the same in a bunch, graded in 10 cm increments.

Financial information

One person can handle about a one hectare planting of 2,000, with additional labour required at harvesting time.

However, due to the strongly seasonal nature of labour requirements and risks (growing and financial) associated with a single crop, it is recommended that NSW Christmas bush be grown in association with other cut flower crops. Current commercial plantings range from about 400 to 4,000 plants, however growers need enough plants to justify the required capital expense of cost-efficient processing facilities. Processing costs (harvest, postharvest and packing) are the biggest costs in production, with labour the biggest component. Some mechanisation is possible, such as air or electric cutting tools, rotating grading tables, conveyors, trolleys, bunch tying and box strapping machines, mechanised winch dipping and spin-drying systems. Use of these tools can lower costs considerably by increasing labour productivity; this may be the grower’s best defence against uncontrollable external factors such as currency fluctuations.

The estimated start-up cost for a hectare, not including land, machinery, clearing, labour, fencing or structures, is about $20,000 in coastal New South Wales. This includes operating costs for one year. With little mechanisation, up to one year’s labour could be required to establish 2,000 plants.

Growing and harvesting the Christmas bush for export accounts for only about 4% of the final wholesale price. Processing and packaging also account for only 14% of the final sale price. By far the greatest costs are sales and freight-in total accounting for 45% of the total cost of production. Any change in the sale price, freight costs and the yen-dollar exchange rate, all of which are largely outside the control of the grower, will have a dramatic effect on the gross margin. Processing, packaging, and sales and freight costs will be very much reduced for the domestic market due to the less stringent quality requirements. In the long term a gross margin of $25,000 - $30,000 per ha would be realistic for material sold on the export market. If all labour was costed, the gross margin in 2003 selling all material on the domestic market would have been between approximately $10,000 and $15,000/ha, depending on time of harvest. It is obvious that the export market is more profitable, but it requires a higher quality product.

Table 1. Typical gross margin analysis at year 5 for Japanese export material, 2000 plants/ha (NSW mid north coast)

<table>
<thead>
<tr>
<th>Costs</th>
<th>$/stem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales &amp; freight</td>
<td>0.63</td>
</tr>
<tr>
<td>Packaging &amp; processing</td>
<td>0.20 #</td>
</tr>
<tr>
<td>Harvesting &amp; growing</td>
<td>0.19</td>
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<tr>
<td>Plant costs</td>
<td>0.08</td>
</tr>
<tr>
<td>Total costs</td>
<td>1.10</td>
</tr>
<tr>
<td>Returns ($/stem)</td>
<td></td>
</tr>
<tr>
<td>Sale price ($/stem)</td>
<td>1.40 *</td>
</tr>
<tr>
<td>Gross margin/stem ($)</td>
<td>0.30</td>
</tr>
<tr>
<td>No. of stems (50 stems/plant)</td>
<td>100,000</td>
</tr>
<tr>
<td>Gross margin/ha ($)</td>
<td>$30,000</td>
</tr>
</tbody>
</table>

# some mechanisation is required to achieve this cost

* Prices are lower for USA and domestic markets; sales, packaging & processing costs are also lower
Key references


Key messages

• Well established domestic industry
• High-growth major export crop for eastern Australia
• Premium export returns for best product
• No significant competition from overseas countries as yet
• Needs specific climatic conditions
• High labour input in processing

Key statistics

• There are about 100 commercial growers of Christmas bush, most on the north coast of New South Wales (82%).
• In 2003 approximately one million stems were exported with an additional 500,000 sold on the local market.
• Production in 2003 was reduced due to frost and drought, as well as softening prices, mainly due to the appreciation of the $A, particularly against the yen

About the authors

Ross Worrall (Ph D) is a senior research horticulturist with NSW Agriculture. Since 1972 he has been involved in the breeding and development of Australian native flowers for both cut flowers and pot plants.

Paul Dalley is a cutflower grower, nurseryman and consultant with extensive experience in the development of eastern Australian native cutflower crops for export. He is one of the founders of GrandiFlora Growers Pty. Ltd., a grower-owned marketing group known for its premium quality branded Christmas bush export products.

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Smokebush

Introduction

Smokebush (Conospermum spp.) commonly occurs along highways north of Perth and appears as extensive fields of white to grey woolly flowers, which are said to resemble clouds of smoke. There are 53 species of Conospermum occurring throughout Australia, 80 of them found in Western Australia. Smokebush is mainly bush-picked and offers an opportunity for development as a cultivated export wildflower with a diversity of colours (white, grey, pink and blue) and varying flower displays. Cultivated material from trial plots in Perth, Western Australia was test marketed in 1996. The flowers were well received on the local and Japanese markets.

Conospermum species can be propagated vegetatively but some species are often difficult to strike and tissue culture is increasingly being used by propagators. A range of species is available from commercial nurseries. Methods of cultivating these plants are being developed by Agriculture Western Australia with financial support from RIRDC. To date, several commercial stands of smokebush have been established using results from these investigations.

![White flowered C. triplinervium species](image)
Grey-white flowered smokebush is used mainly as a filler flower, similar to Geraldton wax, but some of the blue forms may be used as feature fillers commanding a higher price. Introduction of new selections with form and colour variation provides an opportunity to compete with established feature filler products such as Gypsophila and statice.

Markets and marketing issues

Over 99% of smokebush entering the market is picked from natural populations. Flowering stems are available, depending on species, from July to February and are exported to Japan, the USA and Europe.

Table 1. Cut flower characteristics of Conospermum species from surveys of several naturally occurring and cultivated populations and cultivated stands

<table>
<thead>
<tr>
<th>Species</th>
<th>Flower colour</th>
<th>Average stem production per plant</th>
<th>Range of stem lengths (cm)</th>
<th>Growth habit</th>
<th>Flowering time</th>
</tr>
</thead>
<tbody>
<tr>
<td>C. caeruleum</td>
<td>blue</td>
<td>medium</td>
<td>50-65</td>
<td>spreading</td>
<td>July-Oct.</td>
</tr>
<tr>
<td>C. crassinervium</td>
<td>white</td>
<td>low</td>
<td>80-90</td>
<td>upright</td>
<td>Dec-Feb.</td>
</tr>
<tr>
<td>C. eatoniae</td>
<td>blue</td>
<td>high</td>
<td>50-80</td>
<td>upright</td>
<td>July-Sept</td>
</tr>
<tr>
<td>C. floribundum</td>
<td>blue/white</td>
<td>high</td>
<td>7-15</td>
<td>upright</td>
<td>July-Oct.</td>
</tr>
<tr>
<td>C. stoechadis</td>
<td>grey/white</td>
<td>high</td>
<td>50-800</td>
<td>spreading</td>
<td>July-Oct.</td>
</tr>
<tr>
<td>C. triplinervium</td>
<td>white</td>
<td>high</td>
<td>50-90</td>
<td>upright</td>
<td>June-Nov.</td>
</tr>
</tbody>
</table>

1 Low < 25 stems, medium 25-50, and high > 50 stems per plant

Stems are sold fresh (e.g. *Conospermum stoechadis*) or preserved and dried (e.g. *C. crassinervium*). Prices are low for the bush-picked product; e.g. 5-10 cents/stem. With the introduction of selected lines, it is expected that this situation will change with the availability of higher quality cultivated material.

Currently 100,000 stems/annum are exported (CALM 2003), 99% from bush-picked material. With today’s unfavorable exchange rates export prices have been down and growers can expect to return farm gate 20 to 30 cents per stem for white and 50 cents/stem for blue.

The cultivated material includes blue species which command the higher price. For white smokebush prices are limited while there is good quality bush picked material available. This may change as new selections gain popularity.

Production requirements

*Conospermum* species occur in 250-900 mm rainfall areas with yearly mean maximum/minimum temperature ranges from 23/13°C to 20/10°C.

They prefer sandy to sand over gravel soils with good drainage and a pH in the range 4.5-5.5 (1:5, CaCl). Species have some degree of frost tolerance to -1°C for short periods.

Plants require 3-8 ML of water/hectare/annum, depending on planting density (3,300-13,200 plants/ha) and potential evaporation. They are best established in spring using drip irrigation. The soil surface needs to be kept moist during establishment.

It is expected that *Conospermum* spp. could be grown in sandy locations in the areas of Australia indicated on the accompanying map.

Bunched smokebush arrived at export markets in Japan
**Varieties**

The main *Conospermum* species with potential as cut flowers are *C. caeruleum* (slender smoke), *C. crassinervium* (tassel smoke), *C. eatoniae* (blue smokebush), *C. floribundum* (blue/white smokebush), *C. incurvum* (feather smoke), *C. stoechadis* (common smokebush), and *C. triplinervium* (tree smoke). These have a range of flower colours, flowering times and growth habits, as summarised in Table 1.

*C. eatoniae* is suited to drier regions, while *C. caeruleum* prefers cooler climates. They have the potential to yield more than 50 stems/plant for 2-year-old bushes in cultivation.

*C. triplinervium* is a high yielder, producing strong, 90 cm long stems with panicles of white flowers. These species are currently available commercially in Western Australia.

Recently three White smokebush have been released for cultivation as cut flowers. These are Morning Cloud (*C. boreale*) a very early season, Misty Cloud (*C. stoechadis*) an early season narrow leaf type and White Cloud (*C. wycherleyi*) a mid season thick or elk stem type (Table 2). Several blue flowered species of *C. eatoniae* with varying shades of blue and flowering times have been identified but require commercialisation.

**Agronomy**

*C. eatoniae* requires a weed and disease-free sheltered site with a low nutrient status such as a sand. Planting is done in beds 3 m apart. For *C. triplinervium* each bed has a single row with 1 m between plants, and for *C. eatoniae* double rows 0.6 m apart and from 0.5 to 1.0 m between plants. Beds should be mulched to help weed control, reduce soil temperatures in summer and keep the soil surface moist.

Plant should be planted into moist soil and watered regularly during
establishment. Irrigation should be applied through drippers to maintain the soil at field capacity. Plants grow best when small amounts of nutrients are supplied regularly by fertigation. In a sandy soil, stem production was maximised with the application of 40 mg/plant/day of nitrogen and potassium and 5 mg/plant/day of phosphorous plus trace elements. *C. eatoniae* should be protected from wind damage and supported in the first year of growth by one layer of trellising (150 mm x 150 mm mesh) (Cyclone®) located at 200 mm above the ground, similar to that used for carnations. Pre-and post-planting weed control is needed.

Plants established in spring will have harvestable stems by the next flowering season with yields increasing in subsequent seasons. Stems should be pruned immediately after harvest.

**Harvest and handling**

Harvesting should begin as soon as flowers appear and, to prevent loss of quality, should cease before flowers lose freshness. Flowers must be picked in the cool of the day and the stems placed in water as they easily dehydrate. No special solution treatment after harvest is needed and vase life of these species is at least 10-12 days with proper postharvest handling. It is easier to grade and bunch in the packing shed than in the field. Care needs to be taken to ensure that bunches are uniform. Bunches of five stems are suitable for *C. eatoniae*, and 10 stems for *C. caeruleum*. For other species, the stem number per bunch varies between 10 and 15. Bunches of *C. eatoniae* are packed in perforated sleeves to keep stems from tangling, and allow bunches to be packed more tightly. Flowers can be treated for insects before export by aerosol fumigation with Insectigas D/Pestigas P. Bunches should be cooled to 2°C before export shipment.

**Financial information**

There are no data available on the economics of producing these wildflowers. However, they can be produced using the existing infrastructure for growing other wildflowers provided drip irrigation and fertigation is possible.

Being an unusual flower with little good quality product available on the market, smokebush, carefully marketed as a cultivated quality product, can command higher prices particularly during festivals. The availability of smokebush over an extended season through sourcing from different climatic zones and use of varieties such as early season Morning Cloud overlapped with Misty Cloud and finishing off the season with White Cloud.
Key messages

- Large range of unusual flower types
- Vibrant blue and white flowered species
- High production wildflowers

Key statistics

- Currently 100,000 stems/annum are exported, 99% from bush picked material
- Farmgate prices received range from 20 cents for white to 50 cents per stem for blue

About the author

Dr Kevin Seaton has conducted research into the agronomy, management and postharvest treatment of a range of wildflower species. He has developed methods for managing the nutrition and irrigation requirements of wildflowers, has researched tissue culture and root system development, flowering physiology and developed a number of postharvest insect disinfestations treatments for entry into quarantine sensitive markets. His research focuses on the introduction of new wildflowers for export.

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Introduction

There are various genera in the family Myrtaceae which have stems with numerous attractive flowers borne in the leaf axils. Genera such as Thryptomene, Micromyrtus, Scholtzia, Corynanthera, Malleostemon, Astarea, Baeckea and several undescribed but related genera have been used as both landscape plants and cut flowers.

The largest commercial industry is based on Thryptomene calycina, commonly known as Grampians thryptomene or Victorian laceflower. The industry is almost entirely based near the Grampians Range in western Victoria, with small plantings elsewhere in Victoria, New South Wales, South Australia, Queensland, New Zealand and California. Production has been increasing by approximately 10% per year due to continued expansion of plantings.

The best material of Grampians thryptomene represents a world class filler flower which greatly enhances feature flowers in arrangements. The opportunities for this crop are many, since the industry in Victoria has a virtual monopoly over both world production and germplasm. The limited production in California, which is based on inferior cultivars, does not compete with our industry because flowering in the USA is from November to February. Much of the Victorian production is however a second class product because of limited use of elite cultivars, poor husbandry, poor post harvest handling and inadequate marketing. The industry is slowly developing better post harvest facilities, and one major grower has adopted quality standards.

Production of export quality Grampians thryptomene requires considerable skills in interpretation of seasonal cultural requirements, including supplementary irrigation, pest and disease management and post harvest handling. There are also opportunities for growing other species of Thryptomene including T. australis, T. denticulata, T. baeckeaacea, T. stenophylla and T. saxicola from Western Australia, T. elliottii from Kangaroo Island, T. micrantha from Victoria and Tasmania, T. parviflora and T. hexandra from Queensland, and T. maisoneueei from central Australia. These, except for T. elliottii produce inferior flowering stems to T. calycina (Grampians thryptomene) (Beardsell 1996).

The following discussion thus
concentrates on Grampians thryptomene.

**Markets and marketing**

Most of the annual production (10 million flowering stems) of Grampians thryptomene is exported. Approximately 3 million stems are sold annually on the domestic market in the eastern states. It is the largest flower export from Victoria with between 250,000-300,000 kg sold annually to markets on the west coast of the USA. Although Asian markets like small white flowers, the generally poor quality of the product has limited its acceptance in the Japanese market. Early in the 1996 season, prices were high and this led to an oversupply of inferior flowers on the USA market causing a crash in the price. Such uncoordinated marketing almost ruined the reputation of thryptomene, although prices improved later in the season.

The wholesale price of Grampians thryptomene varies from $1.40 to $1.60 a bunch with between $0.90 and $1.20 returning to the farmgate. Export prices at the start of the ‘97 season were A$3.20 a bunch for quality product, with the grower receiving $1.80 a bunch.

In Victoria and California, Grampians thryptomene is used in a similar role to gypsophila: as a filler in floral arrangements complementing other major flowers such as roses. Flowering stems suitable for marketing are available from late May (with many flowers in bud on stems) until early September. Peak flowering occurs in Victoria in July-August, although this varies with both cultivar and the season. While the quality of flowers has improved dramatically in recent years, flower quality is variable in the season following a very dry summer-autumn. Attractive stems with unopened flowers can be picked in May and June, but stem quality falls quickly in September as spent flowers and fruits start to abscise and soft new season’s growth occurs. Late season flowers are more prone to fungal rots during transport, possibly due to the increase in nectar production or because of the soft new growth of stems. A quality assurance program is needed to define the standards for this crop. This is being developed by a major grower wanting to supply consistently high quality produce to the export market.

There has been little attempt to properly market *Thryptomene calycina*, and it is still sold as ‘thryptomene’ (in Australia), ‘Grampians thryptomene’ (in Victoria) and ‘calycina’ (in California). It needs to be actively promoted under one name, ‘Victorian laceflower.’ The adoption of quality assurance and market promotion should alter the image of this crop and increase its market value.

**Production requirements**

In Victoria, *T. calycina* is grown mostly on sandy well-drained soil, although it is also grown on heavy soils in the Black Range.

Nothing is known about the cultivation of the arid zone *Thryptomene* species, although they may be difficult to grow in areas with more than 300 mm annual rainfall and in heavy soils. Most of the non-arid land species are native to heathlands and are also difficult to grow outside of their natural habitats. All species cultivated so far need well-drained soils free of root rotting pathogens such as *Phytophthora cinnamomi*. The only species known to be a hardy plant in horticulture is *T. saxicola*.

The arid zone *Thryptomene* species, including those in Western Australia, occur in sandy soils where the rainfall is only 150-250 mm per year. In south-west Western Australia, *T. australis* and *T. saxicola* occur on soil pockets on granite outcrops. *Thryptomene micrantha*, *T. oligandra* and *T.
**parviflora** grow in moist sandy soils. The climate suitable for growing most species is temperate, although inland species would require sunny, hot climates for optimal growth and survival.

**Varieties**

Development of superior cultivars which are clonally propagated is a major requirement for cut flower production. The natural variability of Grampians thryptomene has enabled selection of plants with large flowers, even flowering, early or late flowering, short or long flowering laterals, plants with pink sepals, and anthocyanin-free flowers. The two main superior varieties are 'Ivory Lace' and 'Coral Lace' which were selected at the Department of Primary Industries, Knoxfield. Limited numbers of these are available from several nurseries and plant propagators in Victoria. The selection of early- and late-flowering clones of Grampians thryptomene will extend the harvest period to April-October. Superior clones can also be used in breeding programs. Interspecific hybrids can be produced between most members of Western Australian *Thryptomene*, but reproductive barriers limit hybridisation between these and members of the genus from eastern Australia. Breeding programs should aim to improve both flowering characteristics and resistance to diseases such as *Phytophthora cinnamomi*.

**Agronomy**

Sites need to be free draining, and frost hollows should be avoided. For cut flower production, rows of Grampians thryptomene should contain plants spaced at 0.5-1.5 m. Hilling-up should be done in heavier soils, and should closely follow land contours. Plants can be planted out as tubestock in autumn and watered in; subsequent irrigation depends on seasonal conditions. Tree guards may help early establishment. Early losses may occur from root diseases, corellas, cockatoos and rabbits.

While little is known about the nutritional requirements of *Thryptomene* and related genera, they are often found growing in soils of low fertility. Unlike some Australian plants they do not appear to be sensitive to high levels of phosphorus in potting mixtures. The only fertiliser required would be to replace nutrients removed in harvested flowers. This should be applied after flowering to enhance new shoot growth which provides the next season's flowers. Excessive fertiliser can result in soft shoot growth during spring which reduces the quality of flowering stems. Without irrigation in the Grampians region, shoot extension is not great enough to allow harvesting of all stems on a bush each year. Growers selectively harvest the longer stems and leave the short new leads to ensure a yearly harvest from individual plants.

Species from low to very low rainfall regions are very slow growing and supplementary watering to enhance shoot growth may ensure adequate stem length and flower production. The flowers of most of these species occur in the axils of leaves, and thus promotion of extension growth should produce more flowers. Supplementary watering in dry seasons also reduces flower and leaf abscission, thus enhancing flower quality at harvest time. Both drip and microjet irrigation has been used successfully in plantations of Grampians thryptomene in Victoria. Water used from dams should be chlorinated or chlorobrominated at 3 ppm for 4 minutes to prevent the spread of *Phytophthora cinnamomi*.

Depending on the size of planting stock and after-care, flowering stems can be harvested in the second or third season. Although harvesting of Grampians thryptomene only occurs from May to September, weed control, irrigation and maintenance of facilities make growing high quality flowers a full time operation.

Flowers can be damaged by severe frosts (below -3°C). Frosts of -5°C will kill bushes of Grampians thryptomene and *Thryptomene saxicola*; the bark splitting down to ground level. Inland species may have greater frost tolerance.

Most of the Western Australian species are easy to propagate from cuttings. Little is known about propagation of the central and South Australian species, although *T. maisoneuevi* has proven difficult to strike (W. Tregea pers. comm.). The eastern Australian species *T. calycina*, *T. micrantha* and *T. parviflora* can be propagated from tip cuttings of semi-firm shoots which are not in flower, but which may have flower buds. The strike rate varies enormously during the season with the highest rates achieved in early and late summer. Rooting is improved with treatment with 2,000–4,000 ppm Indole Butyric Acid.

No information is available on the use of growth regulators on any of these plants. Cyclocel (CCC)\textsuperscript{R}, Atrinal\textsuperscript{R} and Bonzi\textsuperscript{R} need to be tested, as they may be effective in inhibiting the undesirable soft new growth which occurs on many species towards the end of the flowering season.
Pests and diseases

A number of pests and diseases have been found on Grampians thryptomene (Beardsell 1992). The main threat to this species in cultivation, both as a cut flower plant and a landscape plant, is its extreme sensitivity to the root rotting pathogen Phytophthora cinnamomi. It can however be readily grafted onto the more adaptable T. saxicola which has some resistance to Phytophthora (Meyers 1993, Beardsell 1993). Tip die-back of branches also occurs from an interaction of the pathogens Botrytis sp., Pestalotiopsis sp. and Phoma sp., which can be controlled by application of Mancozeb® (Beardsell 1992). Large losses of cuttings have also occurred from the soil-borne fungus Cylindrocladium scoparium. Cuttings and young plants in the field of Thryptomene species are sensitive to dampening-off fungi from the genus Pythium. This disease only affects plants less than 10 cm high. To remove the threat from these fungal diseases, all plantations should be regarded as quarantine areas, with limited access to vehicles, machinery and persons from outside. All materials and equipment brought into plantations should be disinfected. Troughs containing a disinfectant should be located at the entrance of farms.

Webbing caterpillars (Strepsicrates ejectana (Walker)) feed on the foliage and borers can ring-bark stems. Thrips feed on the nectar and pollen produced by the flowers, and if exporting, these need to be controlled by fumigation or by dipping stems in an insecticide, otherwise shipments may be rejected by overseas quarantine authorities.

Harvesting, handling and post harvest treatment

Harvesting is usually done with secateurs and stems are tied into bunches for storage and transport. Limited post-harvest handling treatments are used, but the flowering stems have a shelf life of up to 14 days if the stems are quickly placed in a cool store in buckets containing a flower preserving solution or covered with moistened hessian covers. Covering with dry hessian does not extend shelf life. One of the main causes of poor quality of flowering stems of Grampians thryptomene and related species in florist shops is poor handling. After harvest the flowers should be cooled, placed in a preserving solution and marketed as soon as possible. Cooling to approximately 1°C is very important before and during all stages after harvest, including transport (Beardsell 1988). Rehydration of flower stems after storage and transport improves quality and vase life. This involves immersion of the lower parts of the stems in a solution containing a germicide and an acid (0.5 g/L citric acid) or commercial preservative for 24 hours (Jones et al. 1993).

Vase life varies between species and even within species. One clone of Grampians thryptomene has a vase life of nearly 14 days at 20°C whereas most clones only last 7 days. However these times can be dramatically improved by appropriate post-harvest handling treatments such as using flower preservatives, recutting stems and regularly changing vase water.

Stems of Grampians thryptomene can be stored for several weeks if treated with a fungicide and packed in boxes lined with moist newsprint. If they are properly rehydrated, there will only be a small reduction in subsequent vase life. This means that boxes of Grampians thryptomene could be sea freighted if treated correctly (Jones et al 1993).
Financial information

A farm growing quality flowering stems of Grampians thryptomene would need a small tractor or all terrain vehicle. The vehicle should be outfitted to spray the crop with insecticides and fungicides. Weeds should be controlled with mowing, herbicides or cultivation. The vehicle should have a trailer for harvesting and bringing the flowers back to the shed in buckets for grading and storage. A shed is required for sorting, grading and processing the flowers. Scales, trimming and banding equipment will be required. A cool room is required to cool the flowers as soon as they are processed, and access to reliable refrigerated transport is needed to take flowers to markets, wholesalers or exporters. Access to a good supply of quality water is important and water disinfection equipment may be required.

A much better return for Grampians thryptomene will be attained only by developing improved varieties, better cultural practices, better postharvest handling, reduced production of poor quality flowers, and better market promotion and product imaging.

The establishment costs for a 1 hectare plantation of Grampians thryptomene is shown in Table 1.

Table 2. Expected gross margin returns for thryptomene

<table>
<thead>
<tr>
<th></th>
<th>year 1</th>
<th>year 2</th>
<th>year 3</th>
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<tr>
<td>Assumptions</td>
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<tr>
<td>Plant life</td>
<td>10 yrs</td>
<td></td>
<td></td>
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<tr>
<td>No stem/plant</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>40</td>
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<tr>
<td>No plants/ha</td>
<td>3,300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No stems/bunch</td>
<td>10</td>
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<td></td>
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<tr>
<td>Return per stem</td>
<td>export grade $0.18</td>
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<td>Bunches/plant</td>
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<td>2</td>
<td>4</td>
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<tr>
<td>Bunches/ha</td>
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<td>Stems/ha</td>
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<td>Gross return/ha</td>
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<td>5,940</td>
<td>11,880</td>
<td>23,760</td>
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<td>Variable Costs</td>
<td></td>
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<td>Farm maintenance</td>
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<td>Labour @ $12/hr planting</td>
<td>60 plants/hr</td>
<td>660</td>
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<td>Labour @ $12/hr maintenance</td>
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<td>Fertiliser</td>
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<td>Operating expenses</td>
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<td>Harvest/postharvest</td>
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<td></td>
</tr>
<tr>
<td>Labour @ $12/hr harvesting</td>
<td>60 bunches/hr</td>
<td>0</td>
<td>660</td>
<td>1,320</td>
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<td>Labour @ $12/hr grading</td>
<td>80 bunches/hr</td>
<td>0</td>
<td>495</td>
<td>990</td>
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<td>Counting, dipping, boxing</td>
<td>$0.30 per bunch</td>
<td>0</td>
<td>990</td>
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<td>Boxes @ $4.50 ea</td>
<td>30 bunches per box</td>
<td>0</td>
<td>495</td>
<td>990</td>
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<td>Freight @ $2.50/box</td>
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<td>275</td>
<td>550</td>
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<tr>
<td>Subtotal</td>
<td>0</td>
<td>2,915</td>
<td>5,830</td>
<td>11,660</td>
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<tr>
<td>Total Variable costs</td>
<td>5,440</td>
<td>7,695</td>
<td>10,610</td>
<td>16,440</td>
</tr>
<tr>
<td>Gross margin</td>
<td>-5,440</td>
<td>-1,755</td>
<td>1,270</td>
<td>7,320</td>
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</table>

Table 1. Establishment costs for thryptomene

<table>
<thead>
<tr>
<th></th>
<th>Plants per ha</th>
<th>Plant costs</th>
<th>Irrigation*</th>
<th>Basal fertiliser</th>
<th>Buckets</th>
<th>Weed-mat*</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plants per ha</td>
<td>3,300</td>
<td>$2,640</td>
<td>$2,800</td>
<td>$200</td>
<td>$300</td>
<td>$4,000</td>
<td>$9,940</td>
</tr>
</tbody>
</table>

* Not all plantations use irrigation and weed mat

The estimation of the expected gross margin returns for a 1 hectare plot of Grampians thryptomene is shown in Table 2 (data from 1997).
Future developments

Several species including *T. ericaea*, *T. elliottii*, *T. micrantha* and *T. parviflora*, and related genera such as *Baeckea*, *Astartea*, *Micromyrtus* and *Scholtzia* could be potential cut flower crops if research is done on selection of good varieties, propagation methods, cultivation and post harvest technologies. More information is needed on the arid zone species before they could be introduced into cultivation in dry regions.

Key references


Key messages

- Grampians thryptomene has the potential to be a world class filler flower if only high quality flowering stems are marketed and promoted.
  - This market will be undermined if poor quality flowering stems continue to be produced
- Most species of *Thryptomene* are not well known in cultivation and much work needs to be done to develop them into high quality, profitable crops

Key statistics

- Most of the annual production (10 million flowering stems) of Grampians thryptomene is exported
- Approximately 3 million stems are sold annually on the domestic market in the eastern states
- Thryptomene is the largest flower export from Victoria with between 250,000-300,000 kg sold annually to markets on the west coast of the USA

Key contacts

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Tropical rainforest foliages

Joanna Srhoj

Introduction

Five new native cut foliage products are being developed in north Queensland with the help of a RIRDC and industry funded research project. *Grevillea baileyana*, *Athertonia diversifolia* and *Lomatia fraxinifolia* are endemic to rainforests in north Queensland and have been identified as having significant potential as cut foliage. *Stenocarpus* ‘Forest Lace’ PBR, and *Stenocarpus* ‘Forest Gem’ PBR have been developed from parent plants endemic to north Queensland rainforests and both varieties are protected by Plant Breeders Rights owned by Yuruga Nursery P/L.

Geraldton wax flower has been grown on the Atherton Tablelands previously, however the industry has declined significantly, which has been partly due to the devastating effects of *Phytophthora* and *Botrytis*. Researchers have now turned their attention to growing Australian plants native to north Queensland in an attempt to overcome potential disease problems.

The three species and two varieties being developed grow very well in a range of climates on the Atherton Tablelands.
Stenocarpus ‘Forest Gem’ and Stenocarpus ‘Forest Lace’ are new products to the market, whereas Grevillea baileyana, Lomatia fraxinifolia, and Athertonia diversifolia have been available to the market in small volumes for a few years. The two Stenocarpus varieties are considered filler foliages; Stenocarpus ‘Forest Lace’ is unlike any other cut foliage currently available and Stenocarpus ‘Forest Gem’ is similar in appearance to Persoonia longifolia, otherwise known as Snotty Gobble or Barker Bush. Grevillea baileyana, Lomatia fraxinifolia and Athertonia diversifolia are considered feature foliages and have their own unique characteristics.

The industry is in its infancy, however is developing quickly. All five foliages have recently been planted on farms on the Atherton Tablelands and on the Sunshine Coast. Small volumes of Athertonia diversifolia, Lomatia fraxinifolia and Grevillea baileyana have been produced on farms on the north coast of New South Wales for a number of years.

Markets and marketing issues

Foliage from north Queensland is marketed to local florists in the Cairns region and through a wholesaler at the National Flower Centre (NFC) in Melbourne. Foliage produced on the New South Wales north coast is sold through the Flemington markets in Sydney and the NFC in Melbourne. Currently, the industry in north Queensland does not produce enough material (of any species/variety) to support export markets, however trial shipments of the foliages have been sent to a number of overseas clients. Comments from export markets have been encouraging and export trials will be carried out more regularly over the coming years. Domestic and export market research is very important for the further development of all five foliages and is the subject of a proposed RIRDC project.

All five foliage products have unique characteristics that allow the foliages to display a point of difference in the market place. Grevillea baileyana has a strong bronze colouring on the underside of the leaves, which creates a dramatic contrast to the green topside of the leaf. Lomatia fraxinifolia leaves are striking, glossy and dark green and can be used as a base or backing in an arrangement. Athertonia diversifolia leaves are deeply lobed and very glossy and have a vase life of 21 days. Stenocarpus ‘Forest Lace’ is fern-like in appearance however in contrast to other ferns, it has a vase life of over 21 days and can produce stems of 60-80 cm in length. Stenocarpus ‘Forest Gem’ is filler foliage with a vase life of over 21 days; it is similar in appearance to Persoonia longifolia.

All five foliages mix very well with traditional and native flowers in arrangements and bouquets. The following table details the form in which each product has been traded to date and indications of prices paid to growers. The prices paid to growers will depend on a number of factors including quality, stem/leaf length and the particular market in which the product is sold.

Table 1. Wholesale price estimates for all five native foliages based on stem/leaf length and number of stems/leaves per bunch

<table>
<thead>
<tr>
<th>Product</th>
<th>Stem or leaf</th>
<th>Number of stems/leaves per bunch</th>
<th>Length of stems/leaves</th>
<th>Estimated wholesale price per bunch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grevillea baileyana</td>
<td>stem</td>
<td>5</td>
<td>40-60cm</td>
<td>$4.50 + GST</td>
</tr>
<tr>
<td>Athertonia diversifolia</td>
<td>leaf</td>
<td>5</td>
<td>30-60cm</td>
<td>$3.00 + GST</td>
</tr>
<tr>
<td>Lomatia fraxinifolia</td>
<td>leaf</td>
<td>5</td>
<td>30-60cm</td>
<td>$3.00 + GST</td>
</tr>
<tr>
<td>Stenocarpus ‘Forest Lace’</td>
<td>stem</td>
<td>5</td>
<td>60-100cm</td>
<td>$3.00 + GST</td>
</tr>
<tr>
<td>Stenocarpus ‘Forest Gem’</td>
<td>stem</td>
<td>5</td>
<td>60-100cm</td>
<td>$3.00 + GST</td>
</tr>
</tbody>
</table>

Production requirements

Athertonia diversifolia and Lomatia fraxinifolia are suited to the climatic conditions of the upper Tablelands in high rainfall and high altitude areas (700 m – 1,000 m above sea level). Both species prefer reasonably fertile soils and humid conditions. Production of these two species is recommended in the areas surrounding Yungaburra, Atherton, Malanda, Millaa Millaa, Topaz, Tarzali and Kairi. Lomatia fraxinifolia has also been grown successfully on the Sunshine Coast and on the north coast of New South Wales. Athertonia diversifolia has been grown previously at Coffs Harbour in sheltered areas.

For best results, plants should be grown under shade cloth, as this reduces wind and sunburn damage to leaves. Plants should be irrigated using drippers or sprinklers.
Recent trials have shown that *Stenocarpus ‘Forest Gem’* and *Stenocarpus ‘Forest Lace’* grow well in all climatic conditions and soil types on the Atherton Tablelands at a range of altitudes (400 m – 900 m above sea level). Production on poorer soils will require better nutritional management and both varieties can tolerate windy conditions without any adverse affects. *Stenocarpus ‘Forest Gem’* has been grown successfully on the Sunshine Coast in Queensland and it is anticipated that *Stenocarpus ‘Forest Lace’* will also. Both varieties have been irrigated using drippers, sprinklers and solid set overhead sprays with good results.

*Grevillea baileyana* is suited to climatic conditions of the lower Tablelands and does not cope with the cold conditions experienced at higher altitudes (800 m – 1,000 m above sea level) in the Upper Barron and Ravenshoe areas of the Atherton Tablelands. *Grevillea baileyana* can be grown on a range of soil types and production is recommended in the areas surrounding Yungaburra, Atherton, Tolga, Mareeba and Dimbulah. This species has also been grown successfully on the Sunshine Coast and on the north coast of New South Wales. Protection from prevailing winds is preferred and plants can be irrigated with drippers, sprinklers, or solid set overhead sprays.

The information provided in this section is based on research being carried out and is relevant to the range of growing conditions available on the Atherton Tablelands.

It is anticipated that all species/varieties will adapt to the climatic conditions in frost-free areas of southeast Queensland and northern New South Wales.

**Species/varieties**

**Lomatia fraxinifolia**

- Proteaceae. This species is widespread in north Queensland rainforests at mid to high altitude. Propagation is primarily from seed collected from wild stands. *Lomatia fraxinifolia* is available in forestry tubes from Yuruga Nursery in north Queensland and from other native plant nurseries in southeast Queensland.

**Athertonia diversifolia**

- Proteaceae. This species is found growing in very wet rainforest (low to high altitude) from Cape Tribulation to the southern Atherton Tablelands. Propagation is primarily from seed collected from wild stands. *Athertonia diversifolia* is available in forestry tubes from Yuruga Nursery in north Queensland and from other native plant nurseries in southeast Queensland.
Grevillea baileyana

– Proteaceae. This species is widespread in north Queensland rainforests at low to mid altitudes. Propagation is primarily from seed collected from cultivated plants and wild stands. *Grevillea baileyana* is available from a number of native plant nurseries in Queensland.

Stenocarpus ‘Forest Gem’

– Proteaceae. This variety is not found growing in the wild and has been selected by Yuruga Nursery Pty Ltd. The propagation of this plant is protected by Plant Breeders Rights owned by Yuruga Nursery. This variety is only available from Yuruga Nursery in north Queensland. Unauthorised propagation of this variety is an infringement under the Plant Breeders Rights Act 1994.

Stenocarpus ‘Forest Lace’

– Proteaceae. This variety is not found growing in the wild and has been selected by Yuruga Nursery Pty Ltd. The propagation of this plant is protected by Plant Breeders Rights owned by Yuruga Nursery. This variety is only available from Yuruga Nursery in north Queensland. Unauthorised propagation of this variety is an infringement under the Plant Breeders Rights Act 1994.
**Agronomy**

The following agronomic information is relevant to all five species. However, there may be slight variations for individual species/varieties, which are not included in the text. See key contacts for further information.

Ground preparation is an essential part of establishing the plantation and the layout will be determined by the production system chosen (i.e. single rows, double rows or multi rows). Prior to planting, the ground must be sufficiently ripped and rotary hoed to produce a well-tilled soil for planting. Rows should be raised up 30-50 cm to assist with drainage and disease control. The irrigation system should be installed and operational prior to planting, so the ground can be well watered before planting.

Young plants need to be sun-hardened by exposing the plants to full sun for three weeks before planting. They also need to be well fertilised, preferably by the supplying nursery prior to the sale of the plants. A basal application of fertiliser is not required at planting. However newly planted tube stock needs to be well watered for the first six to eight weeks. A suitable mulch should be applied to rows to suppress weed growth and reduce evaporation. Peanut shell and grass hay have been used in trials on the Atherton Tablelands with good results. Weed mat would also provide sufficient control of weeds.

The first application of fertiliser should be approximately three months after planting, providing this falls in a warm time of the year. Tube stock planted from January to April will not require fertiliser until the September of the same year, providing soil is relatively fertile. Plants should be fertilised a total number of four to five times per year after pruning and harvesting. Early indications suggest that plants can be harvested two or three times per year. Fertilisers recommended for use on these species include:

- CK77(S) – 250 kg/ha
- Nitrophoska Blue Special – 250 kg/ha
- Nitram – 85 kg/ha

All five species should be pruned (by cutting back the main stem) approximately six to eight months after planting, or when they are obviously well established and have reached a height of 1 m. Pruning should always be carried out hygienically using sharp secateurs and pruning should be avoided during wet weather. To sterilise secateurs spray with methylated spirits between each plant, or if this isn’t practical sterilise at least every 10 plants. To prevent fungal infection of the pruning cut, it is recommended that growers apply a sealant to the wound. Commercially available pruning and grafting compounds such as ‘Steriprune’ are suitable.

Efficient management of nutrition and pruning in the first year will enable the first stems/leaves to be harvested at the end of the second year. Efficient nutritional management should be based on the results and recommendations of a soil test. This takes a lot of the guesswork out of nutritional management, providing the nutrition consultant has experience with Australian natives.

**Pest and disease control**

Over the past year, a number of different pests and diseases affecting the native foliages have been sampled and identified. At the time of writing, three more pests (leaf miner, looper and hairy caterpillar) are being grown out in preparation for identification. Once identified, chemicals will be tested on these pests. The pests and diseases identified at this stage are:

- **Grevillea baileyana**
  Coccus longulus (Douglas) – long soft scale. For control apply white oil at a rate of 1-2 litres per 100 litres of water – two applications 14 days apart.

- **Stenocarpus ‘Forest Gem’ and S. ‘Forest Lace’**
  Coccus longulus (Douglas) – long soft scale. Same control as for Grevillea baileyana.

- **Stenocarpus ‘Forest Gem’**
  Rhyparida discopunctulata – swarming leaf beetle. Control not determined.

**Harvest/storage and post harvest treatments**

Leaves and stems of the three species and two varieties must only be harvested when mature. Material that is immature will not last after harvesting and will therefore not arrive at the market in acceptable condition. Product specifications addressing maturity will be developed over the next couple of years for each species. It is always best to harvest foliage early in the morning when turgor pressure in the foliage is high. Prepare buckets with post harvest solution prior to harvesting so that foliage can be transferred directly into it after harvest. A recommended post harvest solution is Chrysal Clear Professional 3, which can be purchased from major garden and nursery suppliers. Pulse the foliage in this solution, preferably in a coldroom at 14°C for a period of 6-12 hours prior to packaging. It is anticipated that the foliage...
Tropical rainforest foliages can be stored at 4°C without any adverse affects however good results have been achieved with storage at 14°C.

*Stenocarpus* ‘Forest Gem’ and *Stenocarpus* ‘Forest Lace’ have been packaged with 3 five stem bunches in a single sleeve. Placing perforated sleeves around the foliage means it can be packed neatly and tightly to allow for a maximum number of bunches per box. This is essential when freighting long distances, such as from north Queensland to Melbourne markets, to reduce costs and damage. *Athertonia diversifolia*, *Lomatia fraxinifolia*, and *Grevillea baileyana* have not been supplied to the domestic market from north Queensland in significant volumes. *Athertonia diversifolia* and *Lomatia fraxinifolia* leaves bruise easily and future research is planned to assess different methods of packaging for these two species. It is anticipated that *Grevillea baileyana* stems can be packaged in a similar way to the two *Stenocarpus* varieties.

Product specifications for each foliage product will depend on market requirements. It is best to work closely with your agent or customer to develop specifications on stem/leaf length, stems/leaves per bunch, leaf colour and maturity, stem thickness and packaging and handling protocols.

**Financial information**

The financial information in the following table has been calculated using early estimates of yields and farm gate prices. More accurate information will be available in the coming years as a result of the research project. The information provided is based on a double row production system with dripper irrigation.

<table>
<thead>
<tr>
<th>Table 2. Investment inputs required and expected returns for all five native foliage products</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Costs</strong></td>
</tr>
<tr>
<td><strong>Investment inputs required (not dependent on number of hectares)</strong></td>
</tr>
<tr>
<td>Soil analysis and recommendations</td>
</tr>
<tr>
<td>Packing shed</td>
</tr>
<tr>
<td>Industry association membership</td>
</tr>
<tr>
<td>Consumables</td>
</tr>
<tr>
<td>Tractor, ripper and rotary hoe</td>
</tr>
<tr>
<td>Working Capital</td>
</tr>
<tr>
<td><strong>Total Investment Inputs</strong></td>
</tr>
<tr>
<td><strong>Investment inputs per hectare</strong></td>
</tr>
<tr>
<td>Plants</td>
</tr>
<tr>
<td>Ground preparation</td>
</tr>
<tr>
<td>Irrigation equipment</td>
</tr>
<tr>
<td>Mulch (weed mat)</td>
</tr>
<tr>
<td><strong>Total Investment Inputs (per ha)</strong></td>
</tr>
<tr>
<td><strong>Recurrent inputs (per hectare per year)</strong></td>
</tr>
<tr>
<td>Soil analysis and recommendations</td>
</tr>
<tr>
<td>Replacement plants</td>
</tr>
<tr>
<td>Irrigation equipment maintenance</td>
</tr>
<tr>
<td>Water</td>
</tr>
<tr>
<td>Fertilisers</td>
</tr>
<tr>
<td>Herbicide</td>
</tr>
<tr>
<td>Pesticides</td>
</tr>
<tr>
<td>Industry association membership</td>
</tr>
<tr>
<td>Sleeves</td>
</tr>
<tr>
<td>Cartons</td>
</tr>
<tr>
<td>Freight</td>
</tr>
<tr>
<td><strong>Total Recurrent Inputs (per ha per year)</strong></td>
</tr>
<tr>
<td><strong>Estimated yield per hectare per year</strong></td>
</tr>
<tr>
<td>Number of bunches</td>
</tr>
<tr>
<td><strong>Return to growers per hectare per year</strong></td>
</tr>
<tr>
<td>Dollar returns per hectare</td>
</tr>
</tbody>
</table>

Please note these costs, estimated returns and yields are only indications at this stage. Returns will depend on a number of different factors such as stem length and quality. This information should be used only as a guide and calculations have been based on the north Queensland industry. Recurrent inputs will vary between regions.

It is recommended that *Lomatia fraxinifolia* and *Athertonia diversifolia* be grown under shade house conditions. Costs of establishing this production system have not been included in this financial evaluation.
Key references


About the author

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Key statistics

- 6,500 plants in ground (5 species)
- 6,000 plants on order (5 species)
- 9 growers (mostly north QLD)
- Average of 720 plants per grower
- Significant increases in plant numbers expected

Key contacts

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Waxflower

Introduction

Waxflower is the generic term for the Geraldton wax, *Chamelaucium uncinatum*, and other *Chamelaucium* species and hybrids. Together they are Australia’s most significant commercial native cutflower, and Australia’s leading export flower. They are popular because of their vase life, floral display and productivity. They are used primarily as feature fillers although some of the newer hybrids are now being used by some florists as feature flowers in their own right. The superior floral display and vase life is likely to increase demand for the newer hybrids. Vase life will become increasingly important for all flowers as production areas move further away from the major market centres.

Waxflowers are grown in many countries for sale in local and major international trading centres. Major production areas include California in the USA, Israel, Australia, Peru, Chile, and South Africa, with interest now being shown in China.

Australian growers will find it increasingly difficult to compete with growers from other Southern Hemisphere countries such as Peru and South Africa as these...
areas produce at similar times of the year and have far lower labour and freight costs. Northern Hemisphere growers complement the Australian growing season and provide product to the market when Australian growers cannot.

The future for Australian growers lies in developing and accessing new varieties using the genetic resource in Western Australia and targeting the premium quality part of the market, while at the same time reducing production costs.

Growing waxflower requires hard physical work and long hours. Like operators of most rural enterprises, those with practical skills and the ability to improvise and learn will have an advantage. Business and management skills and the ability to adapt to changing market conditions are also highly beneficial.

**Markets and marketing issues**

Australian produced waxflower is sold primarily to Japan and North America, with some product also going to Europe. The Japanese and European markets are normally provided with bunches based on stem number, while the North American markets receive product based on weight. The Australian market is also growing, particularly in Sydney and Melbourne. Product for the Japanese and European markets is normally sent to the flower auctions, although direct selling is becoming more prevalent in Europe. Product for the USA is normally sold pre-ordered to wholesalers.

Product is airfreighted overseas after being packed in boxes that weigh between 2kg and 16kg gross, depending on market destination. A 3kg box packed for the Japanese market can hold either fifty 70cm stems or seventy 60cm stems.

Larger sized boxes may be repacked once they reach Japan. A 16kg box destined for Europe will hold seventy 5 stem bunches while the same sized box packed for the US market will hold about forty 400g bunches.

Many growers sell to locally based wholesalers or exporters who then arrange sale and shipping to the market. These dealers mostly pay a rate per bunch, with the price dependent on variety and the amount of value adding, through bunching, and post-harvest treatment. From time to time, commission agents have also been part of the market, taking a percentage of the selling price for putting the product in the market.

Growers may receive better returns for their product through using such agents, but they also have higher risks as they are responsible for any transport chain or market failures. Some of the larger growers handle the export chain themselves and often buy product from smaller growers.

Waxflower performs well as an export product if the cool chain is unbroken from harvest through to the final market destination. However product is often unloaded during transit, sometimes onto hot airport tarmacs, leading to serious quality decline.

Australia produces up to 30 million waxflower stems per annum, with the major production centres being Western Australia and Queensland. A significant quantity of waxflower is also grown in Victoria and South Australia and to a lesser extent in New South Wales.

The major production area internationally is in the regions adjacent to the San Diego area in California, USA. Production is between 300 and 500 million stems per year, nearly all of which is sold on the US domestic market. Israel produces around 70 million stems per annum, for the European market. Growers in South America, particularly Chile and Peru, are expanding their operations, mainly targeting the US market, and also the European market. Waxflower growing is also expanding in South Africa, and China is showing interest in this crop.
### Recent prices and trends

Prices received for waxflower will vary depending on season, variety, quality and market. Data from the Ota Floriculture Auction in Japan indicate significant price variation (Table 2).

The price received of about 35 yen average over 4 months at 67 yen exchange rate equates to about $5.20 for a 10 stem bunch. For the same product at a 50 yen exchange rate, the price received equates to $7.00, while at an exchange rate of 80 yen it is $4.38. Therefore exchange rate can have a severe impact on profitability, to the extent that it may cost the grower or exporter money to sell product in that market.

Growers also need to be aware there are significant costs of getting the product to market (Table 3). In this example the supply chain is in deficit unless the stem price is about 50 yen or higher. This is without taking into account reasonable profit margins for the exporters.

Exporters would make significant losses at the average price of 35 yen shown in table 2, if the figures in table 3 reflected the true costs of the supply chain. In such a situation they would be forced to significantly lower the price paid to growers. Growers therefore need to understand their costs of production, to determine the level at which they will lose money putting their product on the market.

### Production requirements

Waxflower is endemic to Western Australia, occurring in the South West Botanical province. The species and varieties used for production, or those used as parents to produce artificial hybrids, mostly occur in well drained slightly acidic to neutral soils. These natural conditions are a good guide to their tolerances in cultivation. Sandy or sandy loam soils are preferred for cultivation. Waxflower is intolerant of poorly drained soils, particularly heavy clays or waterlogged conditions. Most varieties do not tolerate alkaline soils, although a few selections are better adapted to soils with a pH between 7.5 and 8.5.

Waxflower is intolerant of frost (screen temperature less than 0°C) which is likely to render the crop unmarketable due to flower and growing tip damage. Severe frosts can kill the whole plant. Warm humid conditions are also undesirable because the plants and flowers can be severely affected by the grey mould *Botrytis*.

Waxflower prefers high light intensity and does not flower well in shaded conditions. Plants
should be positioned where they get maximum sunshine. If the planting location has significant topographical variation avoid south facing slopes, particularly in the higher latitudes.

Waxflower needs to be well watered for optimum production, with total soluble salt levels less than 270 millisiemens per metre (about 1500 ppm) desirable. Water volume needs to be about 70% of pan evaporation for best results. Monitoring water use through tensiometers can be an excellent agronomic management tool.

The areas most suitable for producing waxflower are those with a Mediterranean type climate (cool wet winters, hot, dry summers) but with water available for irrigation during summer, their period for maximum growth under cultivation.

**Varieties/cultivars**

There are over 100 named varieties of waxflower, most of these being selections of the Geraldton wax, *C. uncinatum*. By far the most popular of these is ‘Purple Pride’, which has been grown for many years and has become an industry standard. It is floriferous with a reasonable vase life and little ongrowth. This variety is known as ‘Violet’ in Israel. ‘Mullering Brook’ is another popular *C. uncinatum* cultivar. It is a mid season variety with long straight stems with terminal light pink flowers about 12 mm in diameter. ‘Alba’, a vigorous mid season white flowered variety was widely grown in the late 1980’s to early 1990’s, but has declined significantly recently due to the availability of superior white flowered hybrid varieties.

Newer varieties are predominantly hybrids, with superior vase life and floral display. Some of the most sought after are hybrids between *C. uncinatum* and the large waxflower, *C. megalophelum*. These hybrids have commercial yields inherited from *C. uncinatum*, combined with the floral display and extended vase life of the *C. megalophelum* parent.

Examples of white flowered hybrids with this parentage include Bridal Pearl®, Esperance Pearl®, Denmark Pearl®, Crystal Pearl® and Ivory Pearl. These higher quality white flowered hybrids are collectively known as Pearlflowers, to distinguish them from the generic waxflower.

Examples of hybrids between *C. uncinatum* and *C. megalophelum* with coloured flowers include Purple Gem®, Pastel Gem® and Painted Lady®. These higher quality coloured hybrids are collectively known as Gemflowers, to distinguish them from waxflower.

Intergeneric hybrids between *C. uncinatum* and *Verticordia plumosa* are also becoming generally available. These varieties have small terminal massed flowers with pale to deep pink colours. They are generally more tolerant to ethylene than other cultivars. Examples include Jasper®, Southern Stars® and Eric John®. These are collectively called Starflowers.

Some of the newer hybrids are only available from licenced propagators, as they are protected under Plant Breeders Rights legislation. Contact your local Department of Agriculture, or industry body for contact details of licenced propagators. Older, common varieties should be widely available from most reputable propagators.

**Cultural practices/agronomy**

Soil conditions on the site on which you are planning to grow waxflower should be tested for soil pH. As discussed in ‘Production requirements’ the soil pH should be slightly acidic to neutral for most varieties. Growing waxflower on soils with a pH outside this range is likely to result in nutrient deficiencies and greater management requirements to overcome such deficiencies, adding to the costs of production. Growers in Israel have significant issues with yellowing foliage due to iron deficiency because of their alkaline soils.
The levels of soil nutrients should also be determined prior to planting, particularly if the area has been used in the past for crop or animal production. For instance high levels of nitrogen will cause excessive tip growth past the flowers prior to harvest, leading to a drop in quality. High levels of phosphorous could have a detrimental effect on some varieties, particularly intergeneric Verticordia hybrids.

Prior to planting or ordering planting stock the site chosen should be tested for soil pathogens, and treated accordingly if present. The plants should be purchased from a reputable propagator, preferably one who is accredited under the national nursery accreditation scheme. Buying high quality stock reduces the risk of introducing soil pathogens to the site in the potting mix. Growers have been known to introduce Phytophthora spp. to an otherwise uninfected site through purchasing plants grown in infected mix, leading to high death rates and an ongoing management problem.

Plants should also be checked for rootbinding before planting. Rootbinding is probably the highest cause of plant death in waxflower plantations. If there is any sign of root curling at the base of the tube, or roots encircling the insides of the tube rather than growing straight down, then the roots need to be pruned to ensure the roots are vertical. The top of the plant should also be pruned at the same time to prevent excessive moisture loss through transpiration that a reduced root system will be unable to compensate for.

Wind breaks are beneficial, particularly for young plants. However if using trees, shading and root competition are issues that will affect later growth and flowering. Protecting young plants with a growing bag for the first 3 to 6 months increases early plant growth and increases plant survival, particularly in harsher climates.

Site preparation will depend on which varieties are to be planted, as plant spacing will differ depending on the vigour and spread of the variety. Most new plantings are now in single rows. Between row spacing is often dependent on the size of machinery used in spraying and/or harvesting although 3 or 4 metres is fairly common. *C. uncinatum* cultivars often have within row plant spacings of 2m, while many of the interspecific Pearlflower and Gemflower types are planted at 1.5 m spacings. Intergeneric Verticordia hybrids can be planted at 1 m within row spacings.

Weed matting can be beneficial, particularly in the first year or two, to prevent young plants being out-competed by weeds, and to allow control measures to be effective without harming the plant. However the warm moist conditions under such matting may increase the incidence of soil borne pathogens.

**Equipment and facility requirements**

Growers will need access to spray equipment suitable for penetrating dense foliage and the machinery to apply it, such as a tractor or a 4 wheeled motor bike. A pump, irrigation and fertilising equipment is also essential.

Harvesting and pruning equipment may include various hand picking tools, hedge trimmers, and/or machinery adapted or designed for mechanical harvesting and pruning.
The packing shed needs to be equipped with cool store facilities, processing harvest equipment such as baths for STS uptake, stem hydration and dipping for disinfection. A fumigation room may also be beneficial.

Good cultural practices include regular monitoring for pests and diseases and spraying where necessary. Ongoing weed management is beneficial, while frequent irrigation and fertilising, plus maintenance of this equipment, is critical for the production of quality waxflower.

Pruning plants once harvest has finished is essential to getting maximum stem length the following season.

**Fertiliser requirements**

Waxflower requires regular fertilising for optimum production. Fertiliser is best delivered through a fertigation system. The main growing period for waxflower is over the warm summer months, so it is important that the plants have as much nutrition as they need to put on sufficient stem length. The plants can't access solid fertilisers applied at this time unless they are watered in. This will be less of an issue in areas with frequent summer rain.

The fertilisers applied should be well balanced with macro and micronutrients and should be applied at moderate rates. The NPK macro elements are normally applied at a ratio of 10:2:10. Intergeneric *Verticordia* hybrids may require far less phosphorous than this, especially in soils with a good nutrient holding capacity. An annual top dressing may be sufficient. Levels of N applied to the plants need to be reduced prior to flowering to prevent excessive tip growth.

**Irrigation requirements**

In the light sandy soils often found in Western Australia waxflower can benefit by irrigating up to three times per day in summer for optimum production. This allows the plants to access the water they need for maximum growth. Applying water less frequently at higher volumes can make the water unavailable as it will drain past the root zone, often taking valuable nutrients with it. For medium to large plantations such watering frequency requires a sophisticated irrigation system and a professional should be consulted.

Waxflower grown in heavier soils with better water holding capacity, normally requires less frequent irrigation.

A well managed crop provided with the optimum levels of water and nutrition can provide a harvest 12 to 15 months after planting, which is good for the cash flow of the enterprise. However most growers get their first returns in the second year after planting.

**Pest and disease control**

Pests and diseases need to be controlled both pre and post harvest. Harvested material must be free of insects, spiders, snails and other organisms that could be a quarantine issue. Levels of tolerance for the presence of pests and/or diseases vary depending on the market to which the flowers are sent.

**Insects**

A range of thrips, bugs, beetles, wasps, ants and bees are attracted to waxflower for the nectar and/or pollen. Some beetles will also chew the flowers. Field numbers need to be reduced through the application of insecticides as post-harvest disinfection on its own does not kill high enough numbers for effective quarantine treatment.

Consult your local Department of Agriculture or chemical supplier, for the most up to date registered insecticides.

Gall wasp can be a serious pest in Australia in some seasons. The wasp causes tiny galls on young leaves reducing the market appeal and causing a quarantine problem. Control of gall wasp can be difficult as regular spraying can severely reduce the numbers of natural predators, and may lead to increased infestation. Some varieties are more susceptible to this pest than others.

Waxflower can be ring-barked below the soil surface by the larvae of a weevil native to Western Australia, causing severe damage or death. Control is through an annual soil drench of a suitable registered chemical.

Leaf webbing caterpillars can also attack waxflower, causing distorted leaves and stems. Control is through regular applications of a synthetic pyrethroid.

**Soil borne diseases**

While soil borne diseases can be a significant problem in waxflower, probably the most common cause of plant death is from root binding. The symptoms of root binding are very similar to those caused by soil borne diseases.

The most significant disease of waxflower is *Phytophthora* spp. Species include *P. nicotianae* and *P. cinamomi*. Symptoms of infection are leaf yellowing, leaf drop and tip death followed by the whole plant dying. Control is difficult once a plantation is infected with this disease. Therefore it is best to avoid contamination. This begins with site selection, and testing for the presence of the disease before purchasing the property or planting a new.
area. Other avoidance methods include ensuring all planting stock and machinery are free of the disease and the use of chemical baths when entering the site. Chlorinating irrigation water may also be necessary.

Elimination of the disease once present is difficult but can be achieved through sterilisation. Suppressing the disease is probably the most effective treatment once it is present. The most widely used technique is a foliar spray with phosphonic acid at regular intervals. This does not kill the disease but prevents infection while the chemical is active.

Other soil borne problems include collar rot caused by *Rhizoctonia* spp. and *Cylindrocladium* spp. *Cylindrocladium* spp. can also cause root rots, as can *Pythium* spp, particularly on young plants. These diseases can be controlled through the use of fungicides. For the most up to date registered products contact your local chemical supplier or Department of Agriculture.

The other major soil borne pathogen on waxflower is nematodes. Infected plants generally are less vigorous and unhealthy. Root symptoms can be increased branching or galls. However, these symptoms are not always present. Control is normally through soil sterilisation prior to planting or through the application of Nemacur® in plantations. However the effectiveness of Nemacur® can decline with repeated applications due to enhanced biodegradation.

Recently some growers have been growing waxflower grafted onto rootstocks tolerant to soil borne diseases. While grafted plants will have a higher initial cost, this is likely to be far less than the ongoing management and replanting costs and the costs of lost production.

**Foliar diseases**

Fungal foliar diseases can be a major problem for waxflower growers. The general principles of good hygiene and planting and pruning to maintain a good airflow around plants will aid in controlling fungal infections. Chemical control of foliar diseases can be achieved through the application of fungicides. These chemicals should be rotated to prevent the build up of resistant fungal strains, with no more than three consecutive applications from the one chemical group. Consult your local Department of Agriculture or chemical supplier for the most up to date registered products.

*Botrytis cinerea* is the most significant fungal disease and needs to be controlled from bud emergence through to post harvest, particularly during or immediately after cool wet weather. Flowers are the most susceptible part of the plant. *Botrytis* can cause discolouration and flower deformity and flower drop after harvest. The fresh new shoots on plants can die off following infection from this disease.

*Alternaria alternata* is a fungal disease that also affects flowers and causes stem and leaf discoloration and death. Symptoms include small dead spots with a reddish border on leaves and stems, and brown lesions on the outer edges of the petals.

Powdery mildew is the third major fungal disease of waxflower. Varieties vary significantly in susceptibility to this disease, with some hybrids between *C. uncinatum* and *C. megalopetalum* and intergeneric hybrids between *C. uncinatum* and *Verticordia plumosa* being more susceptible than most *C. uncinatum* selections. This fungus can thrive in warm dry conditions. Infection with powdery mildew can cause severe leaf drop under some conditions. Other symptoms include a white powdery substance on the leaves and stems or banded chlorosis on the leaves.

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**Harvest/handling/storage/post harvest treatments/processing requirements**

The highest costs of waxflower production are from harvest onwards, and therefore efficiencies in this area are critical for good economic outcomes. Harvest and handling practices are likely to differ depending on the production scale. However, the principles are the same.

Stems are normally hand cut when the number of flowers open is between 30 and 70%. The level of flowers open is dependent on variety time of season and market requirements. Stems can be
graded either as they are cut or once they are in the packing shed. The better-synchronised flowering of some of the new hybrids may allow greater use of mechanical harvesting and therefore reducing labour costs.

Stems are normally graded depending on the market to which they are being sent. Traditionally stems for the Japanese and European markets are bunched according to length and stem number for example – ten 60 or 70cm stems, or five 80 cm stems. Product for the USA is normally bunched by weight and stem length. Bunches are normally 400 or 600g bunches either 60 or 70 cm long.

Waxflower can suffer severe flower drop from the effects of ethylene, rendering the product unsaleable. Ethylene is a gas produced naturally from ripening fruit and from artificial sources such as engine emissions. Ethylene can also be produced as a wound response from infection by *Botrytis*.

It is critical for the production of quality waxflower that stems are treated to prevent flower drop. The compound normally used for this is silver thiosulphate (STS). STS works by binding to the flower abscission layer, preventing flower drop. Stems are normally treated by placing the lower part of the stems in an STS solution and allowing the solution to be taken up to the flowering region.

Uptake of STS solution for sufficient protection takes about 20 minutes at 20°C and 50% relative humidity. However in cooler conditions or if foliage is wet or humidity is high, uptake can be far longer. Uptake should therefore be checked using a transparent cylinder with STS solution in which a standard bunch has been placed.

Silver is regarded as a dangerous heavy metal and its use is banned in some countries. Alternatives to treating with STS including 1-MCP, are currently being researched.

Postharvest disinfestation treatments include dipping in a solution containing an insecticide, fungicide and a wetting agent.

It is important that field heat is removed from the stems as quickly as possible. Once flowers have been suitably treated with STS and disinfested they need to be cooled, to about 2°C for optimal quality. The type of packing may insulate the stems against fast cooling and growers need to monitor their system’s ability to quickly cool their product. Low cost temperature monitors are now available and can be placed in cartons to help growers and exporters better understand the temperature fluctuations during cooling and transport.

**Financial information**

Production economics varies greatly amongst the different waxflower growing enterprises. This is due to the varying size of establishments which influence economies of scale, the range and age of varieties, location and costs of market access.

As waxflower is normally only harvested over a maximum of a 5 month period, those wishing to manage a full time commercially viable flower growing operation need to consider growing a range of other crops that flower outside the harvest period for wax. If used, this will maintain a labour force and a cash flow. A family sized operation may have a different crop structure than a large commercial enterprise, particularly if they don’t access outside labour.

The volume of production for each variety needs to be carefully managed so it is as even as possible over the year. This is not always easy to predict as different varieties flower in response to different environmental cues such as temperature and daylength.

Western Australian growers wishing to access the US market pay more for freight than their eastern States’ counterparts to
the extent that the total costs of market access may make the Western Australian growers uncompetitive for this market, particularly for commodity product. These growers should seek other markets, either in a different location or for a higher quality product.

There also may be opportunities to develop a more cost efficient growing and harvesting system. Many waxflower growers have little idea of their costs of production. One of the best ways to do this is through benchmarking their operation to highlight where improvements can occur. Benchmarking is often used in agriculture industries to compare performance against other producers. However, information for waxflower growers is limited and requires some degree of cooperation to compile the baseline data. This can be done on a confidential basis.

Waxflower growing and harvesting is very labour intensive. Mechanisation of some of the production and harvesting chain could significantly reduce production costs leading to greater profitability.

An example gross margin budget for a 10 hectare operation is shown in table 4. This does not include development or environmental costs, depreciation or taxation. However it allows a quick comparison with other intensive agricultural enterprises.

### Table 4: Waxflower gross margin estimate

<table>
<thead>
<tr>
<th>Waxflower</th>
<th>Gross margin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Income</strong></td>
<td></td>
</tr>
<tr>
<td>Total area (hectare)</td>
<td>10</td>
</tr>
<tr>
<td>Average bunch per hectare</td>
<td>20,000</td>
</tr>
<tr>
<td>Total production</td>
<td>200,000</td>
</tr>
<tr>
<td>Average price per bunch</td>
<td>$2.11</td>
</tr>
<tr>
<td>Grade 1</td>
<td>$2.80 20%</td>
</tr>
<tr>
<td>Grade 2</td>
<td>$2.00 70%</td>
</tr>
<tr>
<td>Grade 3</td>
<td>$1.50 10%</td>
</tr>
<tr>
<td><strong>Total income</strong></td>
<td><strong>$422,000</strong></td>
</tr>
<tr>
<td><strong>Costs of production</strong></td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>$200</td>
</tr>
<tr>
<td>Replacement plants 10%</td>
<td>$3,000</td>
</tr>
<tr>
<td>Pruning</td>
<td>$600</td>
</tr>
<tr>
<td>Weed control</td>
<td>$4,500</td>
</tr>
<tr>
<td>Disease control</td>
<td>$5,620</td>
</tr>
<tr>
<td>Insect control</td>
<td>$1,240</td>
</tr>
<tr>
<td>Tissue/soil test</td>
<td>$600</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>$770</td>
</tr>
<tr>
<td>Irrigation</td>
<td>$10,000</td>
</tr>
<tr>
<td>Fuel</td>
<td>$6,000</td>
</tr>
<tr>
<td>Harvest/post harvest</td>
<td>$128,000</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>$2,000</td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
<td><strong>$162,530</strong></td>
</tr>
<tr>
<td>Gross margin</td>
<td>$259,470</td>
</tr>
<tr>
<td>Gross margin per hectare</td>
<td>$25,947</td>
</tr>
</tbody>
</table>

Note: This is an example only, and is to be used as a guide. Individual growers will need to consult with their financial advisers as costs of production vary widely.

### Acknowledgements

The author thanks the many people who contributed to this article, especially Gerry Parlevliet, Kevin Seaton and Aileen Reid.

### Key references


Mr. D. Growns. (B. Hort Sc (Hons.)), is the Floriculture Project Manager at the Western Australian Department of Agriculture, where he has worked since 1993. Mr Growns oversees and participates in research to develop the Australian native flora for commercial use in the cutflower and nursery industries, with a focus on the export chain.

Mr Growns has a particular expertise with waxflowers (Chamelaucium spp.) and Verticordia spp. He has been researching waxflowers since 1991, and has been involved in intraspecific, interspecific and intergeneric (with Verticordia spp.) hybridisation since 1995. Since this time, 20 selections and hybrids from the Floriculture project have been commercially released to industry in Australia, and internationally.
Introduction

This chapter builds on previous work that was carried out by Hassall & Associates to develop financial indicators for new rural industries (Hassall, 1999 and Hassall, 2000). This work, which was carried out for RIRDC, developed a three-staged approach for assessing industry opportunities, developed two financial model templates (gross margin and cashflow), and also provided examples (using the models) of new industry information gained from consultation with industry stakeholders. Three stages were recommended in the approach. These were:

Stage One: Preliminary Concept Screening - to ensure fundamental components are in place and to identify and data gaps;

Stage Two: Financial feasibility - to ensure commercial worth of the prospect; and

Stage Three: Is the establishment of site and scale, and the incorporation of confirmed data. This may also include the proposed enterprise within the whole farm plan.

Complete details on the suggested methodology, ideas and concepts behind the evaluation of individual crops, and the models behind the assessment, can be viewed in Hassall 2000, available from RIRDC.

This chapter updates some of the industry examples that were previously generated, and includes new industry examples from this report. There are nine key industry categories included in this report, correspondingly nine examples have been chosen, each one selected as indicative of the specific category. A list of the categories and the industries modelled for each is provided in Table 1.

At the end of this chapter, a gross margin and cashflow model is presented for each of these industries. All of the models contain estimated costs (investment and recurrent) and revenues, sourced from industry practitioners, and calculated results such as estimated costs and revenues, returns on investment and recurrent inputs, internal rates of return and benefit cost ratios.

A MS Excel financial model template was used that had been developed previously for the RIRDC evaluations (Hassall 2000). All original financial calculations were revised with the assistance of industry experts. All new examples were developed in consultation with the authors of the associated chapter in this document, seeking additional specific advice from public and private enterprises where necessary.

Source of information and methodology

The selection of specific industry examples was made in consultation with RIRDC. In deciding upon

<table>
<thead>
<tr>
<th>Category</th>
<th>Industry modelled</th>
<th>New / Updated*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native food</td>
<td>Lemon myrtle</td>
<td>New</td>
</tr>
<tr>
<td>Fruits and berries</td>
<td>Rambutans</td>
<td>New</td>
</tr>
<tr>
<td>Grain legumes</td>
<td>Azuki Beans</td>
<td>New</td>
</tr>
<tr>
<td>Nuts</td>
<td>Hazelnuts</td>
<td>New</td>
</tr>
<tr>
<td>Herbs and spices</td>
<td>Medicinal herbs</td>
<td>Updated</td>
</tr>
<tr>
<td>Misc crops</td>
<td>Coffee</td>
<td>Updated</td>
</tr>
<tr>
<td>Wildflowers</td>
<td>Geraldton wax flower</td>
<td>Updated</td>
</tr>
<tr>
<td>Asian vegetables</td>
<td>Bok Choy</td>
<td>New</td>
</tr>
</tbody>
</table>

* According to work carried out previously - Hassall (2000)
the source of information, the first contact was always the author of the chapter about the specific industry. Where further detail was required, guidance was taken from the author for contacts that included both public and private industry practitioners.

Where possible two or more contacts were used to source and/or review the modelled information. A list of all the contacts used is presented at the end of this chapter.

Most information was sourced and estimated in discussion with the key contacts and those that provided the model reviews. In some instances guidance was also taken from:

- Australian Bureau of Agricultural Economics – AgSurf - Exploring ABARE’s Farm Survey Data. See website - [http://agsurf.abareconomics.com](http://agsurf.abareconomics.com)

### Indicative industry results

Results summaries were calculated for both the gross margin analysis (Stage 1) and the cashflow analysis (Stage 2). The results of the cashflow analysis are shown in Table 2.

#### Table 2: Cashflow results (20 year period @ 7% discount rate).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Location (enterprise scale)</th>
<th>NPV</th>
<th>BCR @ 7%</th>
<th>Breakeven (Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lemon myrtle</td>
<td>Lismore, NSW (5ha)</td>
<td>$37,000</td>
<td>1.03</td>
<td>20</td>
</tr>
<tr>
<td>Rambutans</td>
<td>Northern QLD (5ha)</td>
<td>$510,000</td>
<td>1.45</td>
<td>9</td>
</tr>
<tr>
<td>Azuki Beans¹</td>
<td>Central-Southern NSW (50ha)</td>
<td>$264,000</td>
<td>1.73</td>
<td>na²</td>
</tr>
<tr>
<td>Hazelnuts</td>
<td>Victorian Highlands (10ha)</td>
<td>$22,000</td>
<td>1.06</td>
<td>20</td>
</tr>
<tr>
<td>Medicinal herbs – Echinacea</td>
<td>North-East NSW (1 ha)</td>
<td>$15,000</td>
<td>1.06</td>
<td>17</td>
</tr>
<tr>
<td>Coffee</td>
<td>Northern QLD (20 ha)</td>
<td>$282,000</td>
<td>1.23</td>
<td>13</td>
</tr>
<tr>
<td>Geraldton wax flower</td>
<td>Western Australia (10 ha)</td>
<td>$372,000</td>
<td>1.13</td>
<td>8</td>
</tr>
<tr>
<td>Bok Choy²</td>
<td>Sydney Region</td>
<td>$27,500 (negative)b</td>
<td>1.12 (0.81)</td>
<td>10 (+ 20)</td>
</tr>
</tbody>
</table>

**Notes:**

a. Shows positive return from first year.
b. The initial model was based on a larger farm, mechanised model. Model review led to the suggestion that there should be increased labour in the model, representative of the Vietnamese/Chinese market garden model (i.e. including the producers time). Both have been included in the results.
c. Crops are grown in rotation. Further analysis required to account for total land productivity and returns.

### Precautions

In selecting the information to be used for this report, an attempt was made to provide a representative example of the chosen industry. This took into account factors such as:

- Geographic location and conditions;
- Stage of development of the industry; and
- Size of enterprise.

There were a couple of issues that arose in developing the models that require attention when interpreting the results, namely crop rotations and interpretation of key risks.

To allow for crop rotations, the cashflow analysis was included for only those years (or part thereof) that the crop was grown (eg. Azuki beans for four years every four years; Bok Choy for two months in a year). Costs and revenues were not included for those periods in-between, thus the calculated figures do not reflect the productive capacity of the land for the entire 20 year evaluation period.

Crop rotations also proved difficult as shared machinery meant that investment costs were difficult to establish and attribute accordingly. As a result, basic gross margin input costs were taken from the NSW Agriculture farm budget sites and adjustments made accordingly. It is recommended in these instances that a third stage of analysis should be carried out to include a whole of farm (budget) approach. In this way, decisions can be made to compare substitutes at a more detailed level (eg. Azuki vs Soya beans).

One of the key aspects focused on in the revised models was the key.
risk associated with the production of each crop/product. In summary these risks included:

- oversupply in the market;
- selection of appropriate stock for planting given climatic and soil condition variability;
- effect of imports; and
- effect of imported diseases.

More specific risks were associated with individual crops. For example, it became obvious during discussions over lemon myrtle that significant effort was required to develop the business, also including marketing, quality assurance and equipment research and development (in-house). Thus, these costs may be underestimated in the model, and considerable care would need to be taken during any follow up analysis to ensure that all the costs are appropriately addressed for the individual situation.

Examples are indicative only and care should be taken to adjust the inputs for the local conditions. Where special care should be taken, the individual conditions under which the information was modelled have been outlined in the text associated with each model.

**Summary of findings**

Following are the results tables from each of the stage two – Model Cashflow summaries. Further details for stage one and stage two evaluations are represented in the following section.

---

**Rambutans (Hassall & Associates) March 2004**

Key Assumptions:
- Enterprise scale: 5 hectares
- Geographic location: Northern QLD
- Initial investment: $222,250
- Typical recurrent input costs: $137,750
- Key yield factors: Pruning
- Farm gate (or other) prices: $9,000 per kg
- Discount rate: 7%
- Inflation rate (if any): n/a
- Analysis period: 20 years

<table>
<thead>
<tr>
<th>Present Value @ 7% over 20 years:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment inputs</td>
</tr>
<tr>
<td>Recurrent inputs</td>
</tr>
<tr>
<td>Revenues</td>
</tr>
<tr>
<td>Residual values</td>
</tr>
<tr>
<td>Net Present Value of Enterprise @ 7% over 20 years</td>
</tr>
</tbody>
</table>

Financial Analysis Results:
- Return on recurrent inputs: 31% static state
- Return on investment and recurrent inputs: 7% static state
- Internal Rate of Return: 20%
- Benefit Cost Ratio @ 7%: 1.45

Breakeven on cumulative discounted basis after: 9 years

Threshold Analysis Results:
- Net Present Value of Enterprise equals ZERO when:
  - Yield / Prices decreases by (%): 31%
  - Investment Expenditure increases by (%): 219%
  - Recurrent Inputs increases by (%): 56%

Major Risks to Financial Viability:
- Picking and packing costs
- Oversupply on the domestic market

A Rambutan enterprise in North Queensland was found to break even in year 9. The financial analysis indicates a marginal NPV of $510,000, an IRR of 20% and a BCR of 1.45 (20 year analysis period @ 7% discount rate).

The development of the model was assisted, and reviewed by, Yan Diczbalis (QLD Department of Primary Industries), and review carried out by a local producer and found to be representative.
A lemon myrtle oil enterprise in Lismore, NSW was found to breakeven in year 20. The financial analysis indicates a small NPV surplus of $37,000, an IRR of 7.63% and a BCR of 1.02 (20 year analysis period @ 7% discount rate). This is considered to be a maximum value (with one product only), and negative return would otherwise result. The spreadsheet has been set up to emphasise the key aspects of lemon myrtle oil production. It is important to note the following when interpreting this model:

- The results have been obtained from a commercial orchard but are not necessarily representative of all orchards;
- The time and effort required for product and market development has not been fully costed, an initial estimate of $100,000 has been made; and
- There is currently an oversupply of lemon myrtle oil in the market;

The development of the model was assisted by Sibylla Hess-Bushmann (Australian Rainforest Products) and found to be representative.
Azuki beans (Hassall & Associates) March 2004

Key Assumptions:
- Enterprise scale: 50 hectares
- Geographic location: Central-Southern NSW
- Initial investment: $67,750
- Typical recurrent input costs: $55,250
- Key yield factors: Management of crops (eg. timing)
- Farm gate (or other) prices: $1,020/tonne
- Discount rate: 7%
- Inflation rate (if any): n/a
- Analysis period: 20 years

Present Value @ 7% over 20 years:
- Investment inputs: $13,834
- Recurrent inputs: $359,455
- Revenues: $627,338
- Residual values: $10,337
- Net Present Value of Enterprise @ 7% over 20 years: $264,386

Financial Analysis Results:
- Return on recurrent inputs: 90% static state
- Return on investment and recurrent inputs: 69% static state
- Internal Rate of Return: na
- Benefit Cost Ratio @ 7%: 1.73
- Breakeven on cumulative discounted basis after na years (positive net cashflow from beginning)

Threshold Analysis Results:
- Net Present Value of Enterprise equals ZERO when....
  - Yield / Prices decreases by (%): 42%
  - Investment Expenditure increases by (%): 191%
  - Recurrent Inputs increases by (%): 74%

Major Risks to Financial Viability:
- Quota allocation from Japan (main market)
- Over production - leading to severe price reduction
- Establishing the contract price (every year)
- Competition from US and China

An azuki beans enterprise in central-southern NSW was found to show a positive return from the first year. The financial analysis indicates a significant NPV of $264,386 and a BCR of 1.73 (20 year analysis period @ 7% discount rate).

Azuki beans are farmed as part of a double cropping system and complement other crops such as irrigated wheat, in rotation with lucerne hay. Initial investment costs for machinery and harvesting equipment that are common across crops were not included in the analysis. Installation of a central pivot has been included. Figures can be taken as an indicative maximum. In discussions with NSW Agriculture, it was suggested that after an initial evaluation, a systems approach (including figures for the double and rotation crops) when carrying out further analysis should be used.

The spreadsheet and results used for the Azuki bean have been reviewed by Tony Hamilton (NSW Producer) and Ken Motley (NSW Agriculture) and found to be representative.
A hazelnut enterprise in the Victorian highlands was found to breakeven in year 20. The financial analysis indicates a low NPV of $22,600, an IRR of 8% and a BCR of 1.06 (20 year analysis period @ 7% discount rate). Both the gross margin calculations, and cashflow estimates show a small positive result based on a conservative yield and medium size hazelnut. Improved yields and nut sizes would be expected to offer higher returns.

The spreadsheet and results from the hazelnut analysis have been reviewed by Peter Wheelwright (Victorian Producer and President of the Hazelnut Growers of Australia ‘HGA’) and the results were found to be representative. Further valuable comments were provided by other members of the HGA and incorporated into the analysis.
Echinacea – medicinal herbs (Hassall & Associates)
March 2004

Key Assumptions:

<table>
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<tr>
<th>Enterprise scale</th>
<th>1 hectare</th>
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<tr>
<td>Geographic location</td>
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<td>Initial investment</td>
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<td>Typical recurrent input costs</td>
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<td>Key yield factors</td>
<td>Yield roots at 2000 kg/ha</td>
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<td>Farm gate (or other) prices</td>
<td>$ 25.00 per kg</td>
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<tr>
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<td>Inflation rate (if any)</td>
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</tr>
<tr>
<td>Analysis period</td>
<td>20 years</td>
</tr>
</tbody>
</table>

Present Value @ 7% over 20 years:

| Investment inputs | $ 112,201 |
| Recurrent inputs | $ 151,317 |
| Revenues | $ 273,807 |
| Residual values | $ 4,496 |

Net Present Value of Enterprise @ 7% over 20 years |

$ 15,119

Financial Analysis Results:

Return on recurrent inputs - Stage One 65% static state
Return on investment and recurrent inputs - Stage One 9% static state
Internal Rate of Return 10%
Benefit Cost Ratio @ 7% 1.06

Breakeven on cumulative discounted basis after 17 years

Threshold Analysis Results:

Net Present Value of Enterprise equals ZERO when:
- Yield / Prices decreased by 6%
- Investment Expenditure increased by 13%
- Recurrent Inputs increased by 10%

Major Risks to Financial Viability:

There is currently a large oversupply of Echinacea in the market, with associated reduction in market price. This combined with a severe decline in the demand for Echinacea Aerial parts (that used to provide an additional revenue stream) provides a major risk to its ongoing financial viability. Outcome very sensitive to yield / price assumptions and investment expenditure assumptions.

A medicinal herb enterprise in North Eastern NSW was found to break even in year 17. The financial analysis indicates a modest NPV of $15,119, an IRR of 10% and a BCR of 1.06 (20 year analysis period @ 7% discount rate).

A major change to previous modelling carried out (RIRDC 00/133) is that this analysis is for a medicinal herb enterprise in north eastern NSW as opposed to Victoria, consequently some of the results may vary from the early analysis. A further point to note is the removal of aerial parts from production in this analysis. This was brought about from a large decline in demand, and anticipated complete decline in demand in years to come.

The update of the model was assisted by Peter Purbrick (MediHerb Pty Ltd) and reviewed by Kym Grant (Austral Herbs & Seeds Pty Ltd) and found to be representative.
Coffee (Hassall & Associates) March 2004

Key Assumptions:
Enterprise scale 20 hectares
Geographic location Northern QLD
Initial investment $406,500
Typical recurrent input costs $98,700
Key yield factors Average of 1600 kg/ha
Farm gate (or other) prices $6.00 per kg
Discount rate 7%
Inflation rate (if any) n/a
Analysis period 20 years

Present Value @ 7% over 20 years:
Investment inputs $406,512
Recurrent inputs $880,297
Revenues $1,530,182
Residual values $38,763
Net Present Value of Enterprise @ 7% over 20 ye $282,136

Financial Analysis Results:
Return on recurrent inputs 82% static state
Return on investment and recurrent inputs 17% static state
Internal Rate of Return 13%
Benefit Cost Ratio @ 7% 1.23

Breakeven on cumulative discounted basis after 13 years

Threshold Analysis Results:
Net Present Value of Enterprise equals ZERO when……
Yield / Prices decreases by (%) 18%
Investment Expenditure increases by (%) 69%
Recurrent Inputs increases by (%) 32%

Major Risks to Financial Viability:
Imported disease
Irrigation availability at establishment
Outcome sensitive to yield / price assumptions

A coffee enterprise in northern QLD was found to breakeven in year 13. The financial analysis indicates a significant NPV of $282,136, an IRR of 12.7% and a BCR of 1.23 (20 year analysis period @ 7% discount rate).

The spreadsheet and results used for the coffee model was reviewed by James Drinnan (QLD Department of Primary Industries) and found to be representative.
A Geraldton waxflower enterprise in Western Australia was found to break even in year 8. The financial analysis indicates a high NPV of $372,000, an IRR of 18% and a BCR of 1.13 (20 year analysis period @ 7% discount rate). It must be noted that there is a large variability in price received due to competition (from overseas).

The spreadsheet and results from the waxflower analysis have been reviewed by Gerry Parlevliet (Western Australian - Department of Primary Industries) and the results were found to be representative. Further valuable comments were provided by Gerry’s colleagues at the WA DPI and incorporated into the analysis.
Bok Choy (Hassall & Associates) March 2004

Key Assumptions:
- Enterprise scale: 1 hectares
- Geographic location: Camden - Sydney Basin
- Initial investment: $60,447
- Typical recurrent input costs: $15,947
- Key yield factors: na
- Farm gate (or other) prices: $48,000 per ha
- Discount rate: 7%
- Inflation rate (if any): n/a
- Analysis period: 20 years

Present Value @ 7% over 20 years:
- Investment inputs: $59,880
- Recurrent inputs: $168,943
- Revenues: $254,256
- Residual values: $2,081
- Net Present Value of Enterprise @ 7% over 20 years: $27,515

Financial Analysis Results:
- Return on recurrent inputs: 50% static state
- Return on investment and recurrent inputs: 22% static state
- Internal Rate of Return: 14%
- Benefit Cost Ratio @ 7%: 1.12
- Breakeven on cumulative discounted basis after 10 years

Threshold Analysis Results:
- Net Present Value of Enterprise equals ZERO when:
  - Yield / Prices decreases by (%): 11%
  - Investment Expenditure increases by (%): 46%
  - Recurrent Inputs increases by (%): 16%

Major Risks to Financial Viability:
- Price discounting (increased bunch size eg. 2 to 3 plants per bunch)
- Picking time (correct size for market) and handling

A bok choy enterprise in the Sydney area was found to breakeven in year 10. The financial analysis indicated a low NPV of $27,500, an IRR of 14% and a BCR of 1.12 (20 year analysis period @ 7% discount rate). Estimates were based on a 1 ha crop in a much larger diversified farm (50 ha), and one crop a year (55 day growing cycle).

Further review led to the suggestion that there should be increased labour, representative of the Vietnamese/Chinese market garden model (ie. including the producer’s time). This resulted in a negative NPV and BCR of 0.81. This reaffirmed the view that, consistent with that model, bok choy production was carried out at a loss.

The initial model was built up with the assistance of Eddie Galea (Producer) and further review carried out by Vong Nyugen (NSW Dept Agriculture). Both have found the model to be representative.

Results are very sensitive to changes in key variables.
Key contacts

During the modelling of the data, a number of industry practitioners were consulted to assist in developing, and reviewing the model. These individuals are listed in Table 3.

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<thead>
<tr>
<th>Crop</th>
<th>Primary contact</th>
<th>Reviewer</th>
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<tbody>
<tr>
<td>Lemon myrtle</td>
<td>Sibylla Hess-Bushmann Australian Rainforest Products Pty Ltd</td>
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<td>Rambutans</td>
<td>Yan Diczbalis (QLD Department of Primary Industries)</td>
<td>Local Producer (Northern QLD)</td>
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<td>Azuki beans</td>
<td>Tony Hamilton</td>
<td>Ken Motley</td>
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<td></td>
<td>NSW Producer</td>
<td>NSW Department of Agriculture</td>
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<td>Hazelnuts</td>
<td>Peter Wheelwright (Victorian Producer and President of the Hazelnut Growers of Australia (HGA))</td>
<td>Further comments provided by Peter’s colleagues - HGA Board/Association members</td>
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<td>Peter Purbrick (MediHerb Pty Ltd)</td>
<td>Kym Grant (Austral Herbs &amp; Seeds Pty Ltd)</td>
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<td>Geraldton wax flower</td>
<td>Gerry Parlevliet (Western Australian - Department of Primary Industries)</td>
<td>Further comments provided by Gerry’s colleagues at WA DPI</td>
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<td>Eddie Galea</td>
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<td>Producer – Sydney Area</td>
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Key references


AgSurf - Australian Bureau of Agricultural Economics - Exploring ABARE’s Farm Survey Data. See website - [http://agsurf.abareconomics.com](http://agsurf.abareconomics.com)

Disclaimer

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### Recurrent Inputs

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### Demand/Revenues

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### CASH FLOW ANALYSIS

#### for enterprise of 50 hectares

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<th>Investment Inputs</th>
<th>Total Value @ 7%</th>
<th>Present Value</th>
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**SUB-TOTAL:** $-17,500 $-13,834
## Recurrent Inputs

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## NET CASH FLOW

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## Threshold Analysis:

- **Net Present Value equals ZERO with ...**
  - Outcome not sensitive to yield / price assumptions
  - Outcome not sensitive to investment expenditure assumptions
  - Outcome not sensitive to seasonal input assumptions

### Sensitive to:

- **Discount rate of 9% pa $227,881**

### Internal Rate of Return with:

- **Yield / prices decreased by 10% #DIV/0! #DIV/0!**
- **Investment expenditure increased by 10% #DIV/0! #DIV/0!**
- **Seasonal inputs increased by 10% #DIV/0! #DIV/0!**
Farmers today, both those in existing businesses and new entrants, live in an environment where they by necessity have to keep an eye on new opportunities.

Changes in commodity prices, or new value chain opportunities let alone changes in types of food or new products demand a flexible approach to farming. Many crops themselves have a “fashion” element where a new variety or cultivar of fruit or vegetable can be “in” for a period then “out” with the market. Consumers expect farmers to be able to continue to provide their needs in both food and fibre when they follow these new trends.

As well diversification of cropping opportunities, within the limits of good business sense, provides an essential part of the risk management in modern farming.

The Rural Industries Research and Development Corporation is tasked, within a number of its programs, with assisting agribusiness and the food industries to stay ahead of changes by looking at new potential crops, their management and potential in the food and fibre industries. Some of these crops are aimed at Australian markets others are aimed at a mix of domestic and export.

Undertaking the research and supporting industries searching for new products is only the first stage of their work. Unless that work is communicated to the widest possible audience the potential of these new crops will never be fully realised.

This book is aimed at consolidating much of the recent research information into a handy format for those searching for the latest information on new crops. I am sure it will prove to be as valuable to both potential and existing farmers as the first edition was.

Senator the Hon Judith Troeth
Parliamentary Secretary to the Minister for Agriculture, Fisheries and Forestry

September 2004
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### Financial models

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Each month almost a million visitors go to the RIRDC web site. There they surf through or research over 1,000 reports. One of the most visited areas and consistently so over many years, has been *The New Rural Industries* and the popularity of this site is confirmed by the continuous demand for, and sales of, the hard copy of this book.

Two of my predecessors Mr Keith Hyde and Mr Peter Core were responsible for the production of *The New Rural Industries* the “first edition” of this publication and it proved to be an excellent initiative. Each week our research managers get numerous enquiries which often follow from people looking at this publication either in hard copy or on-line so the editors believed it was essential to bring out a new and fully revised edition.

Now we are updating the contents but because it has grown we are splitting it into a “new crops” and a “new animals” format. We have also included updated financial indicators for some crops, using the same models as those used in the previous two volumes of *The New Rural Industries Financial Indicators*.

This Handbook will also differ from the first by being released as a CD as well as hard copy, which will provide substantial cost savings for those purchasing that format, but also provide users with easy searchability.

Each chapter in the book aims to provide a comprehensive introduction to a particular crop, but it is important to repeat the caveats in the previous edition of *The New Rural Industries*. Potential investors and industry advisors should make their own more detailed enquiries about a crop or industry before making decisions or providing advice about them. While every effort has been made to ensure the accuracy of information in each chapter, the markets are changing and new information is becoming available regularly.

Also the fact that a crop has been included in this book should not be regarded as an automatic endorsement of its prospects. A decision to invest in a new crop industry depends very much on an individual’s circumstances and, while success is not guaranteed, there are some important factors that must be taken into account if there is to be any chance of success. The first two chapters in this publication are essential reading for a better understanding of what is involved in considering a new crop investment.

The authors of the individual chapters have been chosen from amongst research or industry agribusiness experts with an intimate knowledge of the crop they are writing about. The chapters have also been reviewed by others with close knowledge of the industry or crop.

The main editorial work for the publication was done by Sue Salvin of Hassall and Associates. She was assisted by Max Bourke and Tony Byrne, the two RIRDC Research Managers responsible for new crop programs. The design and layout of the book was undertaken by RIRDC’s communications team, Cecile Ferguson and Martin Field. I would also like to thank the many authors who contributed their time and expertise to this publication.

This book is further evidence of RIRDC’s commitment to communication and accessibility of information. It is meant to inform both future economic activity and further research. We hope it is also an interesting read.

**Simon Hearn**
Managing Director
Rural Industries Research and Development Corporation

September 2004
New crops

Rob Fletcher and Ray Collins

Introduction

This chapter discusses the nature of new crops and some of the key factors involved in making decisions about them. The next chapter illustrates the new crop development process by describing a set of courses that help new entrants work through these decisions.

New crops defined

New crop industries usually involve new species or varieties, new locations or technologies for producing a product, new markets or some combination of these factors. For example, the seedless melon industry is based on new varieties and much of its production is in new locations; freekah wheat involves a new adaptation of ancient technology; and the Asian vegetable industry in Australia is based on new markets for existing products.

Several of Australia’s current major industries have been developed from new crops since 1950. They include cotton, mushroom, lupin, sunflower, broccoli, soybean, melon, canola, triticale, avocado, macadamia, chickpea, mango, kiwifruit and almond. Most of these were previously grown successfully overseas or perhaps on a small scale somewhere else within Australia. To be successful in their current areas, they needed breeding, new or modified production systems and/or exposure to markets.

New crops, supply chains and consumers

Successful new industries need satisfied consumers. Consumers will be satisfied when the products they purchase meet their needs at a price that represents, to them, value for money. This price must cover the growing, harvesting, processing and marketing costs of the product, as well as the profit margins for each business in the chain between the producer and the consumer.

The chain of firms that produces the raw material, converts it into a saleable product and makes it available to the consumer is called a supply chain. Each business in a supply chain does something for the final product and is paid accordingly. So supply chains have to exist, if only to ensure that the product gets from the producer to the consumer.

If firms in a supply chain consciously manage their interacting activities for the benefit of the consumer, greater consumer satisfaction can be achieved along with greater benefits for the members of the supply chain. This is a business strategy called supply chain management and it has been shown to be a highly effective way for firms in new crop industries to organise themselves.

For example, the Australian non-astringent persimmon industry has a core group, the Australian Persimmon Export Company, which has built its own supply chain based on the involvement of

The Australian Persimmon Export Company is owned and managed by the growers and a marketer. (Source: Options for Change—New ideas for Australian farmers RIRDC Pub. No. 03/030)
At this level, successful new crop development is about people and how they can improve their individual results by working together.

chain partners such as exporters and importers, and a clear focus on what the consumer wants. It began by twelve growers getting together to discuss how they could work together instead of competing against each other in the marketplace. In many new industries it is common for growers to meet to discuss issues of mutual interest. These meetings can become the stimulus for the first stage of supply chain building, simply by shifting the focus to questions about which firms, technologies and systems the new industry will have to deal with so that its product can reach and satisfy consumers. Working co-operatively with the right firms downstream of the producer is essential in creating and sharing the benefits from adopting a supply chain management strategy.

At this level, successful new crop development is about people and how they can improve their individual results by working together.

Learning to work together pays dividends because it leads to stronger relationships at all levels of the supply chain. Stronger relationships allow problems to be solved more easily, initiatives to be taken between chain partners and joint strategies to be developed to counter competition. In a new crop industry, these activities are especially important because they have the potential to flow through to increase consumer satisfaction and sustain the new crop’s advantages for everyone in the supply chain.

Thus, by building stronger relationships and ensuring satisfied consumers, effective supply chain management can contribute to the success of a new crop venture. Developing a successful business around a new crop is as much about the effectiveness of people working together as it is about the effectiveness of the product itself.

In the following sections we explore what attracts people to new crops, some of the challenges involved with developing a new crop or a new product, what risk is and how it is managed and the benefits of collaboration. Throughout these sections, the focus is maintained on the central role of people and their decision-making processes. In the next chapter, we provide details of some of the resources available to assist with the new crop development process.

A supply chain is the chain of firms that produces the raw material, converts it into a saleable product and makes it available to the consumer. By building stronger relationships and ensuring satisfied consumers, effective supply chain management can contribute to the success of a new crop venture.

**Facing up to the new crop decision**

**Why the interest in new crops?**

The reasons that people are attracted to new crops vary widely. The issues discussed below have become evident from the responses given by hundreds of participants in Do Our Own Research (DOOR) Marketing short courses conducted throughout Australasia over the past six years and more than one hundred conferences and workshops addressed by the authors over that period.

**I want a change**

The most frequently declared purpose amongst Australian new crop developers has been their desire to introduce changes to the way they manage their farms, the supply chains in which they operate, or their lifestyles, before change is forced upon them. Increasing numbers of people are also coming from the cities, seeking a “sea change” or “change of life”.

While curiosity drives much new crop activity, the pursuit of a new crop as a hobby may provide a change from everyday activity but it does not have the same profit motive as a commercial business.
Hobbies are for pleasure, and the pursuit of pleasure usually costs money.

**I want to improve**

When Australian new crop developers have been asked why they want to make a change (that is, when asked the “purpose of their purpose”), they have usually indicated that they want to make money.

There have been some new crop schemes in the past that have provided significant returns for promoters. Such entrepreneurs have attracted attention because their idea is unusual, but their products have often not satisfied the consumer for very long. These products are unable to sustain a presence in the market because they are not attractive enough to consumers or cannot be marketed at a value-for-money price.

In a similar way, new crops have also often featured in tax-driven schemes. Such schemes have sometimes failed to produce a viable product in the market, perhaps because the promoters and/or the managers responsible did not have the skills, motivation or desire to properly nurture the development of the product’s supply chain.

While they may provide short term benefits to a small number of people, neither of these two approaches to new crop development amount to improvement in any long term sense.

New crop developers have often indicated that their businesses should be performing better than they are; new crops are therefore sought to stabilise or improve rural incomes.

New crops have also been targeted as possible solutions during reorganisation in a primary industry sector, for example, as alternative enterprises to the dairy, tobacco or sugar industries in some areas.

**I want to create some benefit**

When Australian new crop developers have been asked why they want to make money, they have frequently indicated that they wish to provide some sustainable long term benefit, which is not necessarily just for themselves.

Such purposes have included the establishment of a new sustainable rural industry for a region or the improvement of the value of their business assets before they are eventually transferred to the next generation.

**I expect it will be worthwhile**

It is possible to examine whether an interest in new crops is worthwhile by testing its future purpose. This assumes that the current, realistic new crop aims will be achieved in the time frame allowed. Looking back from the future, once achieved, was it worth the effort?

For example, assume the purpose amongst the members of a horticultural supply chain is to build up to a $1 million turnover over fifteen years. If achieved, Table 1. Challenges of new crops and new products compared with existing crops

<table>
<thead>
<tr>
<th>Existing Crop - Product Already Traded</th>
<th>Existing Crop - New Product</th>
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<tbody>
<tr>
<td>Improving the way the crop is grown and harvested</td>
<td>Making the product available to more consumers who are likely to want it</td>
</tr>
<tr>
<td>Making the product available to more consumers who are likely to want it</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>New Crop - Product Already Traded</th>
<th>New Crop - New Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establishing an efficient way to grow and harvest the crop</td>
<td>Making sensible alternative crop choices available to farmers so they can diversify their farming systems</td>
</tr>
<tr>
<td>Finding out from current consumers what they like about the product and finding ways that the new crop can offer them more benefits</td>
<td>Establishing an efficient way to grow and harvest the crop</td>
</tr>
<tr>
<td>Organising the supply chain for the new product to get it to market</td>
<td>Finding out from potential consumers what they want in the new product</td>
</tr>
<tr>
<td>Making the product available to more consumers who are likely to want it</td>
<td>Making the product available to more consumers who are likely to want it</td>
</tr>
<tr>
<td>Making the product available to more consumers who are likely to want it</td>
<td>Organising the supply chain for the new product to get it to market</td>
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<tr>
<td>Making the product available to more consumers who are likely to want it</td>
<td>Making the product available to more consumers who are likely to want it</td>
</tr>
</tbody>
</table>
would it seem worthwhile after this time, given the initial investment required, the effort expended over fifteen years and the risks taken?

To have any hope of hitting a target, we must aim at it. The aim of new crop development is to be profitable. This needs to be realistically stated and it should become the focus of planning. If we eventually hit the target, was it worth the trouble?

New crops and new products: know the challenges

Amongst the Australian new crops mentioned in the introduction, all but lupin and macadamia had previously been grown and traded in a market somewhere. Such experience was helpful in making them commercial here. In each case, although there was still a major marketing challenge to be resolved, there was at least existing knowledge about the crop’s production requirements.

Developers of new crops which do not have a previous growing and trading history face the greatest challenges of all, as outlined in Table 1. However, if successful, they also have significant profit potential.

Better information leads to better decisions

“Information” can be envisaged as one point in a continuous range from media reports to wisdom (Figure 1).

Each point in the range varies in availability (vertical axis) and usefulness (horizontal axis). Media reports are plentiful and of little relevance to specific new crop businesses. Wisdom is very useful but much harder to find.

In the field of new crop development there is no shortage of media reports and hunches, but there is a distinct lack of reliable data, information and knowledge. This is partially because of the nature of the problems being addressed and partially because some people believe that if they keep data, information and knowledge to themselves and do not share it, they have an advantage over others. The advantages of becoming more competitive through co-operation are addressed below.

New crops are often promoted using the news media as a form of publicity. It may be the first time that many people have heard of a particular crop and they may find the new crop interesting. However, the factual content or relevance of such media reports will vary. The circumstances of most media reports mean that the information is only relevant to those featured in the report. Interesting new crop ideas are extremely plentiful and by themselves add little commercial value to an enterprise.

So, in such an uncertain environment, while it is clear that decisions need to be based on the best possible information, problems can only be solved by testing possible solutions through trial and error.

The difficulty with this approach is that the successful commercialisation of a new crop does not depend on a single factor with a single solution. It consists of a great many factors operating together across the entire supply chain from producer to consumer. The need to deal with such complexity, even on a trial and error basis, brings the solution once again back to starting with the best possible information and the best possible people and accepting the additional challenge of managing a higher than usual level of risk.

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![Figure 1. The continuum from media reports to wisdom in relation to availability and usefulness](image-url)
New crop information is of no value unless it can apply to our specific new crop supply chain. We need to be our own experts since we know our own part of the supply chain. We must not act independently of the chain and we must be conscious of the risks involved for all chain participants.

Acknowledging and managing risk

Risk is the chance of injury or loss. The level of risk depends on the chance of the injury or loss actually occurring and its impact when it does.

Injury or loss can be internal or external to the new crop business. If it is internal, it arises from production problems or difficulties with the planning for the business or the management of its people. If it is external, it results from problems with the market in which the product is traded, the supply chain to which the business belongs or the economic and political environment in which the business operates.

External risk factors usually have the greater influence on the ultimate commercial success of the new crop product.

Attempts to estimate external risk by imagining the future can provide some benefit in preparing for future management action but have less validity if the product is new.

External risk factors are best investigated through having a product in the market.

By following the 13 step commercialisation process outlined below, new crop supply chain members can enter a market with a product, under a strict set of benchmark and monitoring conditions, and test its appeal to the consumer directly. The steps are as follows:

1. the proposal of the new crop by those willing to commit themselves financially to such development.
2. the acknowledgment that new crop development is a high risk adventure.
3. the recognition of the need to protect intellectual property rights.
4. the assessment of the appeal of the new crop product to the potential purchaser, using all relevant available criteria with an indication of those criteria for which no information is available.
5. a theoretical assessment of the production potential of the new crop using all relevant available criteria with an indication of those criteria for which no information is available.
6. the establishment of an integrated development group comprising producers, processors, distribution and marketing partners with research providers in a facilitation role.
7. agreement within the group on resource requirements, expected outcomes, action plans to achieve them and proposed distribution of any profits.
8. the establishment of a process of project monitoring to identify and resolve problems quickly and efficiently.
9. the establishment of economic benchmarks and an agreement to abandon the proposed development if these have not been met.
10. the establishment of a system of review to determine whether the development is worthwhile and to analyse the critical contributions for success or failure.
11. trial production for trial marketing.
12. trial production for trial processing and packaging.
13. experimental production, using properly designed scientific trials.
What are the “best bets”?

Attempting to predict which new crops are likely to be commercially successful in a general sense is probably a waste of resources. New crop options that may become ‘best bets’ for one person may be rejected by another.

There are no generic ‘best bets’ because new crop commercialisation systems behave chaotically, just like weather systems and market systems. Such chaotic systems:

- are in a state of continuous change
- are influenced by a large number of factors, each of which is changing as well
- are strongly influenced by interactions among these factors
- have feedback and regulatory mechanisms so that past behaviour can influence future behaviour.

One of the main reasons that the future behaviour of a chaotic system, such as a new crop supply chain, is very difficult to predict is because very small changes can influence outcomes in a major way. However, it is a mistake to conclude that because a system is chaotic there is no point in trying to manage it. On the contrary, managers who are better at making ‘best bet’ decisions can prosper in such environments.

One way to improve the chances of making ‘best bet’ decisions in new crop development is to base such decisions on the best possible information, evaluated in a non-emotional way and to make these decisions in collaboration with other members of the supply chain. Such an approach reflects the findings of Collins (2003) who showed that the three major impediments to success in new crop industries are lack of reliable information, lack of an orientation to the market, and lack of collective behaviour.

The courses described in the following chapter help participants build a personal ‘best bet’ list of new crops.

Then, having made the decision about which crop to become involved with they help managers to learn what is required to ‘hand craft’ their own supply chain as a way of improving their new crop enterprise’s chances of success.

The choice of ‘best bet’ new crops must be left to the participants. Best bets are influenced by self-motivation and the ability to learn and should be based on objective analysis in collaboration with other members of the supply chain. Wishful thinking and excitement over the rare and unusual is a personal response that rarely translates to enduring market success.

Co-operating to compete

Some new crop developers work alone, others choose to work in groups. Those who work alone are often successful by keeping information to themselves and in the short term at least, profit from their way of growing and marketing the new crop.

However, because no business can operate independently of the supply chain for its product, sooner or later the success of the individual attracts competitors whose objective is to copy successful systems.

Frequently, once the ‘secrets’ of the individual have been learned, the system is easy to copy and intense competition between individual firms is the result.

Such competition usually reduces the returns to all competing firms, and if one partner competes to gain an advantage over the other, future hopes of co-operation are severely diminished.

On the other hand, new crop developers can choose to work collaboratively and they can choose to consider the whole supply chain as the ‘field’ for their work.
Then it becomes possible to generate and share a far greater range of data, information and knowledge and ultimately to improve the chances of success for everyone by making better decisions.

As shown earlier in the case of the Australian Persimmon Export Company, over the longer term, co-operation produces the most beneficial outcomes.

There are presently a number of other new crop groups in industries such as bamboo, native flowers, tropical fruits and vegetables who are exploring ways of becoming more competitive through co-operation and adopting a whole of supply chain strategy.

The downside of collaboration is the need to manage interpersonal relationships and the dynamics of a group of people trying to jointly solve a common problem.

However, these are exactly the same skills that will be required in the on-going management of the supply chain for the new crop product.

So collaboration can also provide a learning opportunity that will continue to pay off commercially.

Learning how to co-operate to become more competitive is the aim of the “Forming and Managing Supply Chains in Agribusiness” short course described in the next chapter.

**Key references (see page 13)**

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### About the authors

**Dr Rob Fletcher** teaches biology and plant breeding at the University of Queensland Gatton. His research interests for the past fourteen years have focused upon commercial innovation in the establishment of new rural industries. He manages the Australian New Crops Web Site (www.newcrops.uq.edu.au) and has facilitated short courses and spoken at conferences and workshops on new rural industries throughout Australia and overseas.

**Dr Ray Collins** is Associate Professor in Agribusiness in the School of Natural and Rural Systems Management, at the University of Queensland. His teaching and research focus on new agribusiness enterprises, supply chain management and export development strategies. Over the last 15 years Ray has worked with new rural industries as both researcher and consultant. His contribution to the Australian persimmon industry is sometimes quoted as a model of how a new export oriented horticultural industry can guide its own future. Ray is a recipient of the University of Queensland Excellence in Teaching Award, and two International Collaborative Research Awards.

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The new crop development process

Rob Fletcher and Ray Collins

Introduction

The previous chapter described some of the main factors involved in decisions about investing in new crops, focusing particularly on the importance of understanding markets and building a supply chain. This chapter provides more detail about new crop development by outlining the content of three courses available to assist and encourage commercialisation of new crop products.

The DOOR (Do Our Own Research) Marketing short course

The DOOR Marketing short course comprises a two day workshop for groups of up to thirty motivated new rural industry participants (producers to consumers) at a time. The principles behind the DOOR Marketing course can be summarised as follows:

- new crop participants cast themselves as experts in their own farming systems or supply chain components and cooperate with others to find solutions
- participants need to focus on their principal motivation;
- there is no pre-determined outcome
- participants own the outcomes themselves.

The course assists new crop participants in determining whether their selected new crop product warrants investment in the types of strategic plan prepared in the Fresh Fields short course, described below.

The DOOR Marketing program consists of the following:

1. **Introduction of participants to each other**

Psychological research has indicated that primary producers tend to be “loners”. Production dominates their minds. It may therefore be difficult for them at first to think laterally, that is, “past the farm gate” and to collaborate in new crops planning along the supply chain. Experience with DOOR Marketing and similar short courses throughout Australia has indicated that once participants understand who else is involved in a course, they have no trouble collaborating or planning together.

At the commencement of the course, participants provide their names, affiliations, reasons for attending and expectations for the course. Each person also nominates a new crop/rural industry upon which to focus her/his attention.

The facilitator vigorously interacts with all participants during these introductions and subtly encourages the participants to interact with one another as well.

As a result, each participant knows something about every other participant since they have all been able to speak about themselves. Each participant also experiences the difficulties of publicly committing to a single new crop for the course.

Participants in DOOR Marketing realise they all share the same problem; namely, they want to do better through designing their own future.
2. **The 10 steps for planning**

The 10 steps for planning were originally developed in response to enquiries from individuals wanting to know about ‘best bets’ amongst new crops but they have also come to be useful in the DOOR Marketing short course.

The exercise provides an introduction to the issues relevant to new crop development and demonstrates for participants the usefulness of sharing problem solving with others.

The questions relating to each of the planning steps are shown in Table 1.

3. **Systems exercise**

To encourage systems thinking, a series of generic questions has been designed to target each participant’s future scenario, enquiring about:

- likely information sources
- the participants' principal motivations
- the physical and economic environment
- the availability of colleagues and partners;
- the types of inputs required, including equipment and technology;
- the outcomes sought.

Four scenarios have been used:

- wishful thinking
- reality
- the local modifications needed
- the likely action plans.

This exercise encourages lateral thinking and encourages each participant to consider likely relevant sources of information for the modification of her/his farming and supply chain system.

4. **A brainstorming session on the types of information required**

Participants cooperate in a brainstorming exercise to identify the types of information required to bring their new crop developments to reality. After the session, each type of information is classified as a marketing, economic, research and/or production issue and the marketing issues are ranked for perceived importance amongst the participants.

Brainstorming is also a useful tactic to encourage new crop developers to think laterally, since no criticism or discussion is permitted following any contributions.

Often, possible solutions to problems which appear to be difficult to surmount can be discarded before the implications are properly analysed; brainstorming amongst motivated individuals extends the range of possibilities in problem solving/solution finding.

5. **Strategic marketing management**

Strategic marketing management asks the question: “what market conditions are necessary to stimulate the commercialisation of new crop products?”

The questions in Table 2 comprise the outline of the “homework” for participants and once attempted, permit the completion of the SWOT analysis during the second day of the DOOR Marketing short course.

During the brainstorming session, it is invariably external issues which predominate, with market research perceived as more important than consumers, competition or the business environment (Table 2).

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### Table 1. The 10 steps for planning

<table>
<thead>
<tr>
<th>Step</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The participant's current situation</td>
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<tr>
<td>2.</td>
<td>The participant's principal motivation for change</td>
</tr>
<tr>
<td>3.</td>
<td>Personal skills</td>
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<tr>
<td>4.</td>
<td>Commitment</td>
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<tr>
<td>5.</td>
<td>Information available</td>
</tr>
<tr>
<td>6.</td>
<td>New crop supply chain</td>
</tr>
<tr>
<td>7.</td>
<td>Market research</td>
</tr>
<tr>
<td>8.</td>
<td>Production</td>
</tr>
<tr>
<td>9.</td>
<td>Personal factors</td>
</tr>
<tr>
<td>10.</td>
<td>Economics</td>
</tr>
</tbody>
</table>
Table 2. The outline for a strategic marketing management investigation for a new crop participant (adapted from Aaker 1995).

<table>
<thead>
<tr>
<th>External factors</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Customers</strong></td>
<td></td>
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<tr>
<td>Who are our customers?</td>
<td></td>
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<tr>
<td>Are the customers a uniform group?</td>
<td></td>
</tr>
<tr>
<td>Will the product satisfy our customers’ needs?</td>
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<tr>
<td>What is our customers’ motivation in buying the product?</td>
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<tr>
<td>What are our customers’ unmet needs?</td>
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<tr>
<td><strong>Competitors</strong></td>
<td></td>
</tr>
<tr>
<td>Who are our current and potential competitors?</td>
<td></td>
</tr>
<tr>
<td>Is our product likely to encourage fierce competition in the market?</td>
<td></td>
</tr>
<tr>
<td>Are our competitors a uniform group?</td>
<td></td>
</tr>
<tr>
<td>What are the characteristics of our competitors?</td>
<td></td>
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<tr>
<td><strong>Market analysis</strong></td>
<td></td>
</tr>
<tr>
<td>What is the size of the market?</td>
<td></td>
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<tr>
<td>How long is the product life-cycle expected to be?</td>
<td></td>
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<tr>
<td>What will the profitability of the market be?</td>
<td></td>
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<tr>
<td>What are the cost structures along the supply chain?</td>
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<tr>
<td>What distribution channels will be used for our product?</td>
<td></td>
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<tr>
<td>What are the overall market trends?</td>
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<tr>
<td>Are there any key success factors within the industry requiring attention?</td>
<td></td>
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<tr>
<td><strong>Environment</strong></td>
<td></td>
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<tr>
<td>What important forces outside our company and the immediate market that may have an effect on success of the new crop product?</td>
<td></td>
</tr>
<tr>
<td>Is it possible to develop optimistic, realistic or pessimistic scenarios?</td>
<td></td>
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<tr>
<td>What areas of information are currently limited, requiring attention?</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Internal factors</th>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Performance</strong></td>
<td></td>
</tr>
<tr>
<td>What measures for profitability and performance should we use?</td>
<td></td>
</tr>
<tr>
<td><strong>Strategic options</strong></td>
<td></td>
</tr>
<tr>
<td>What kinds of strategies have we used in the past?</td>
<td></td>
</tr>
<tr>
<td>Do the strategies need to change in the future?</td>
<td></td>
</tr>
<tr>
<td>What is our company’s sustainable competitive advantage?</td>
<td></td>
</tr>
<tr>
<td>What are our problems?</td>
<td></td>
</tr>
<tr>
<td>How will these problems be overcome?</td>
<td></td>
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<tr>
<td>What are the financial resources available?</td>
<td></td>
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<tr>
<td>What business are we in?</td>
<td></td>
</tr>
<tr>
<td>What type of enterprise are we?</td>
<td></td>
</tr>
<tr>
<td>What is our strategic vision?</td>
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</table>

6. **SWOT analysis**

The core activity of the DOOR Marketing course is preparing for the SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis of new crop products, the products having been chosen by the participants themselves.

There has usually been a break of two days to seven weeks between the first and second days of the course so participants can complete their “homework” in preparation for the SWOT.

The second meeting of the DOOR Marketing short course commences with another introduction session with similar questions to those asked on the first day, focusing on this occasion on new crop products and the outcomes of the homework.

The SWOT analysis is then completed (Table 3).

The focus in the SWOT analysis is not on picking winners, but on a qualitative identification of any fatal flaws in a proposal.

The intention is to find a reason to throw every proposal away; those that are not thrown away can be considered for potential commercialisation.

In Table 3, only the clear boxes need to be considered (the others are not relevant) and fatal flaws are marked with a hash sign.

If participants identify any threats in terms of customer demand, current market price, industry trends or production factors or any weaknesses in terms of expected returns, then their proposals cannot be considered viable.
Approximately 90% of the initial proposals from participants in DOOR Marketing short courses so far conducted throughout Australasia have been abandoned by them as a result of such findings.

Most participants have then repeated the process, focusing on other products from the same new crop and/or other new crop species.

**Fresh Fields short course**

The Fresh Fields short course uses the same principles as the DOOR Marketing short course. New crop developers plan strategies for their businesses, leading to the creation of business and marketing plans. The course was designed to assist those participants whose new crop product ideas survived the DOOR Marketing SWOT analysis described above. In a sense, it helps participants to build a personal ‘best bet’ list of new crops.

The Fresh Fields program focuses on the business satisfying its customers’ needs profitably and consists of the following:

- identifying the needs of each member of the supply chain
- understanding the way that these needs will be met
- setting realistic targets
- identifying a process to follow
- analysing the businesses with which to deal
- establishing priorities;
- selecting future actions to take
- creating a plan to follow.

**Forming and Managing Supply Chains in Agribusiness learning package**

The Forming and Managing Supply Chains in Agribusiness short course will help managers to learn what is required to ‘hand craft’ their own supply chain as a way of improving their new crop enterprise’s chances of success. This learning package would be of interest to anyone in the new crop development process, but is specially targeted at those who are close to the full commercialisation stage.

The learning package (comprising a workshop, CD and workbook) was developed out of a need expressed by large numbers of applicants for funding under the federal government’s New Industries Development Program (NIDP) run by the Australian Government Department of Agriculture, Fisheries and Forestry. These applicants often had a clear idea of the product or service they were developing, but very poorly thought out strategies to ensure that the supply chain that would deliver their product to consumers would do so competitively and at a profit.

The learning package is a joint venture between NIDP and the University of Queensland. Its aims are:

- to demonstrate the need for a whole-of-supply-chain perspective on new enterprise development
- to show how a supply chain can be ‘hand crafted’
- to ensure that new enterprise
developers know what must be managed, and how, in making their supply chains as competitive as possible.

The CD contains formal instructional material that is heavily supported by recorded interviews where practising managers recount their own experiences and strategies in respect of each supply chain learning principle. Thus the CD is oriented towards learning from the experiences of others. It also contains the downloadable workbook, two complete case studies of supply chain management in action in new enterprise development, a library of additional reading resources and a list of contacts for further information.

Participants usually begin by attending a one day workshop where they are introduced to the CD and workbook, and begin working on their own new enterprise's supply chain.

Having their own copy of the CD and being familiar with how to use it as a learning tool means that they can then work towards developing supply chain strategies in their own time and with prospective chain partners. Using the workbook to record what they are thinking and doing brings a level of discipline and structure to the process, and creates a record for future evaluation of progress.

These workshops are organised through NIDP or the University of Queensland.

**Conclusions**

The future viability of new crop options cannot be predicted accurately because biophysical, marketing, economic and human systems often behave chaotically.

Rather than trying to predict winners, members of new crop industries can use the resources outlined above to collectively focus their goals and pursue them in ways that improve their chances of making ‘best bet’ decisions. This will involve identifying consumer needs, clearly defining the new crop product, establishing the human and technical components of the supply chain and entering a commercial market, once appropriate benchmarks for investment, growth and returns have been set.

Such an approach can be applied to firms in any new crop industry. At a collective level this can also provide a framework for the industry to determine its needs in terms of future research and development.

Some new crop industries will eventually prove to be commercially significant over large areas, but trying to predict in advance which ones will achieve this level of success has proven to be a waste of resources.

A new crop industry’s most valuable resource is its people.

Horticultural workers planting native seedlings at Yuruga Nursery, Mareeba, Queensland

Joe Zappala, tropical fruit grower, Mareeba Queensland

Joe Zappala, tropical fruit grower, Mareeba Queensland
Acknowledgments

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Key references


Medicinal herb products are a growing market in Australia and around the world
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Asian brassicas
(Chinese broccoli, Chinese cabbage, bok choy and choy sum)

Michael Clark

Acknowledgement is given to Stephen Moore, Wendy Morgan, Bruce Tomkins, Paul Daly and Mandy Chew, the authors of the chapters on Asian brassicas in the first edition of this publication.

Introduction
Asian brassicas belong to the Brassica family – the Brassicaceae, which includes vegetables such as cabbage, broccoli, cauliflower, radish and turnips.


Chinese broccoli is also known as kai lan and gai lum. The whole plant can be eaten, but the older leaves and stems are generally stringy and discarded. Young leaves and stalks (15–20 cm high) with compact florets are selected. These parts of the plant are sweet and tender.

Depending on cultivar Chinese cabbage can vary substantially in appearance, from the short squat wong bok types to the long, slender rocket or michihili types. Chinese cabbage is the most frequently eaten vegetable in Asia. It is commonly eaten as a freshly cooked vegetable in stir fries and is often further processed as brined product or used in pickles such as kim-chi.

Bok choy or pak choi does not form a true head. The whole plant (minus the roots) is eaten with only the older leaves being discarded. Bok choi is eaten in both mature and ‘baby’ forms. After Chinese cabbage, bok choy is the most commonly consumed Asian vegetable in Australia.

Choy sum is also known as Chinese flowering cabbage and tsoi sum. The whole plant can be eaten including the normally yellow flowers.

The height of the plant varies from 20 to 30 cm. The pleasant taste and cooking qualities of choy sum have made it the most common leafy
Asian brassicas are annual or biennial plants that are normally grown commercially as an annual. Asian brassicas have been grown successfully and are available in all Australian states. Farms vary from smaller urban market gardens, plots of around 1 to 2 ha, to larger and more remote holdings, say 5 to 15 ha.

**Markets and marketing issues**

Asian brassicas are available nationally throughout the year in wholesale markets, Asian grocery stores and supermarkets. All Asian brassicas are sold fresh or fresh-processed as a constituent of a salad-mix. The marketing chain is relatively simple. Growers pick, wash and pack or bunch product and deliver it to market on the same day as harvest. Chinese cabbage is packed into cartons, other species are sold in bunches. The fresh-cut salad market is more sophisticated – only leaves are harvested, washed, spun, refrigerated, either packaged for food-service, or sent to a secondary processor for inclusion in a salad mix, followed by packaging again and retail. Asian brassicas (usually in a baby-leaf form) that may be included in a salad-mix include mizuna (*B. rapa* var. *nipposinica*), tatsuoi (*B. rapa* var. *rosularis*), Chinese mustard (*B. juncea*). Recent price and volume data for Chinese cabbages and bunching lines at major wholesale markets are shown in Table 1. It is estimated that around 80% of New South Wales and Victorian production passes through the central markets while in other states the proportion is closer to one half.

**Table 1.** Asian brassica sales by volume and value at wholesale markets (2001)

<table>
<thead>
<tr>
<th>Market</th>
<th>Volume (tonnes)</th>
<th>Value of sales ($/t)</th>
<th>Gross value of total sales ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSW – Flemington</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>3,112</td>
<td>645</td>
<td>2,008,073</td>
</tr>
<tr>
<td>Chinese Vegetables#</td>
<td>2,316</td>
<td>1,853</td>
<td>4,291,030</td>
</tr>
<tr>
<td>Victoria – Melbourne *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>3,795</td>
<td>683</td>
<td>3,653,475</td>
</tr>
<tr>
<td>Chinese Vegetables#</td>
<td>1,653</td>
<td>2,211</td>
<td>4,415,417</td>
</tr>
<tr>
<td>Queensland – Brisbane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>1,418</td>
<td>506</td>
<td>718,454</td>
</tr>
<tr>
<td>Chinese Vegetables#</td>
<td>788</td>
<td>1,948</td>
<td>1,535,254</td>
</tr>
<tr>
<td>South Australia–</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adelaide</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>369</td>
<td>914</td>
<td>336,954</td>
</tr>
<tr>
<td>Chinese Vegetables#</td>
<td>262</td>
<td>2,750</td>
<td>720,033</td>
</tr>
<tr>
<td>Western Australia–</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perth</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chinese Cabbage</td>
<td>840</td>
<td>535</td>
<td>449,034</td>
</tr>
<tr>
<td>Chinese Vegetables#</td>
<td>572</td>
<td>1,679</td>
<td>959,534</td>
</tr>
</tbody>
</table>

Source: AusMarket Consultants, # no disaggregated data available believed to include Chinese broccoli, bok choi, Chinese flowering cabbage, * Only Year 2000 data available. Small amounts also grown in Tasmania, Northern Territory and Australian Capital Territory

While export growth has stalled in recent years, Singapore, Hong Kong and Taiwan remain important outlets for Australian product. Australian exports face strong competition in these markets from an increasingly well-organised and low cost production base in China. Chinese competition based on low cost labour also limits the potential of highly processed product such as pickles in both export and domestic markets. Fresh-processed salads containing Asian brassicas do not compete with product imported into Australia which is restricted on phytosanitary grounds.

**Production requirements**

Asian brassicas are cool season crops that prefer uniform moist conditions and full sunlight. The ideal temperature for growing is between 15 and 20°C. High temperatures and long days tend to induce bolting. Tropical cultivars of Chinese cabbage should be sought out for production in hotter climates. Most varieties tolerate light frosts.

Preferred soils are fertile, high in organic matter and moisture-retentive. Ideal pH is around 6.5 to 7.0 for bok choi, 5.5 to 7.0 for Chinese cabbage and 6.0 to 7.0 for Chinese flowering cabbage and Chinese broccoli. The addition of lime will help control club root and planting into raised beds can prevent soft rots.

Asian brassicas are shallow rooted and require frequent light watering. This will also prevent the leaching of nutrients from the soil. Lack of moisture at any stage can promote bolting and poor quality plants. Young plants are fragile and should be protected from the wind.
Asian vegetables

Varieties/cultivars

Australian growers of Asian brassicas use hybrid seed in preference to open-pollinated seed or retaining seed from their own crops. Seed for most Asian brassica varieties is sourced from China and multiplied under contract in Australia. Popular and emerging varieties are shown in Table 2.

Agronomy

Asian brassicas can be either sown directly from seed or transplanted into a fine well-prepared seedbed. Seed sowing is typically at a rate of two to three seeds per station 12-15 mm deep. Seedlings are hand thinned after germination. Chinese cabbage seeds are sown at a rate of 500-750 g/ha, with plant spacing of approximately 35 cm. A similar distance is required between rows.

Chinese broccoli and choy sum are sown at about 0.6 cm in depth in rows about 30 cm apart and thinned to about 10 cm. Close spacing will produce less fibrous plants with better eating quality. Bok choy is normally grown in rows spaced around 20 cm apart, large types like 'Chinese White' require more space and baby bok choi less.

Table 2. Asian brassica varieties

<table>
<thead>
<tr>
<th>Asian Brassica</th>
<th>Varieties</th>
<th>Strengths/features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese broccoli</td>
<td>F2 Green Lance, Chinese Yellow Broccoli</td>
<td>A more vigorous hybrid than the common white-flowered varieties. A smaller yellow flowering variety recommended for summer production.</td>
</tr>
<tr>
<td>Chinese cabbage</td>
<td>WR Green 60, RS1446 and China Pride wong bok types, Cream and Manoka, Yuki, Treasure Island and WR Green 60</td>
<td>Most tolerant to gomasho, bolting and internal rots and provided high marketable yields in WA, Tas and SA. Good late planting varieties with high marketable yield, Victoria. Best performing early varieties, WR Green 60 also showed least evidence of chilling injury.</td>
</tr>
<tr>
<td>Bok choy</td>
<td>Chinese White Bok Choy (eg Joi Choi), Shanghai Bok Choy (eg Mei Qing), &quot;Soup Spoon&quot; type (eg Japanese white celery mustard, Tai Sai Nikanme, Seppaku), Canton or squat</td>
<td>Sturdy variety with thick green leaves that curl outwards and bright white stems, 30 cm at harvest. Cold tolerant but with a tendency to bolt. Leaf stalks are light green, broad flat and widen at the base, 15 cm at harvest. Hardy and will grow all year round. Thin leaves and stalks, leaves lightly cupped, stalks are semi-circular, 45 cm at harvest. Vigorous and versatile. Tolerate both heat and cold. Compact with dark green leaves. Stalks are white, short and thick. Can be harvested as baby bok choy or left to maturity. Best in warmer areas and bolt in the cold.</td>
</tr>
<tr>
<td>Choy sum</td>
<td>sze sap yat (40 days), ng sap yat (50 days), luk sap yat (60 days), bat sap yat (80 days)</td>
<td>Varieties are classified by the number of days from sowing to harvest and their susceptibility to bolting.</td>
</tr>
</tbody>
</table>
Transplants are generally raised in a greenhouse or polyhouse for three to four weeks before planting in the field. Transplanting is more expensive than direct seeding but assists with environmental control during the early phases of the plant’s life.

Fertiliser requirements differ markedly between soil types and soil testing is the best way to determine the elements needed for crop production. In general terms Asian brassicas require large amounts of fertiliser, particularly nitrogen, potassium and phosphorus. Fertilisation often starts with an application of animal manure two weeks before planting followed by regular applications of nitrogen and potassium. Application of fertiliser through the watering system is effective. Over-fertilisation can result in soft rot and plant tip damage.

Maturation takes anywhere from 30 days for bok choy to 100 days for Chinese cabbage.

**Pest and disease control**

The availability of registered agricultural chemicals for pest and disease control in Asian brassicas is problematic.

Asian brassicas compete poorly with weeds in their first few weeks of life. Hand weeding or Dutch hoeing is commonly used to control weeds. A pre and post transplant herbicide application may also be necessary.

Major diseases of Asian brassicas include:

- **clubroot** – a soil born fungus that results in malformation of the roots and plant wilting during warm weather. Control is via crop rotation, fumigation, sanitation, maintenance of high soil organic matter and a pH above 7.3

- **downy mildew** – infected leaves develop purple, yellow or brown patches on the upper surface and white or grey downy fungal growth underneath. Older leaves develop dead spots. Control through improved ventilation to decrease humidity and avoid overhead irrigation

- **white rust or white blister** – small circular spots raised on both sides of the leaves, underside a mass of white powdery spores. Control through the removal of cruciferous weeds, crop rotations and ensuring that all plant residuals are removed or composted before the next crop is sown

- edema – wart like structures on the underside of leaves. Control of the disorder can be achieved by not allowing the soil to become too wet and improving the ventilation of polyhouses.

Major pests of Asian brassicas include:

- **aphids** – live on the underside of leaves. Affected plants will wilt, look distorted and curled. Aphids are also vectors for viruses. Control cruciferous weeds in the vicinity of Asian brassicas

- **caterpillars** – will attack and severely damage brassica crops. Many species, especially diamondback moth, have developed resistance to common control chemicals and Integrated Pest Management is recommended

- **snails and slugs** – eat whole young plants and are especially active during mild damp weather. Control with pellets.

**Harvest, handling, storage, post harvest treatments and processing**

Harvest should occur in the cool early morning. Asian brassicas are hand-harvested at the base with a knife. Old or damaged outer leaves are trimmed off and the butt trimmed flush at the base. All blemishes and defects should be removed.

Harvest should occur before the outer leaves become yellow and the plant becomes fibrous.
Asian vegetables

For the fresh-cut salad industry, leaves can be either mechanically or hand-harvested. Leaves are cut at the petiole. Leaves are often washed in sanitised water, spun-dried, packaged and cooled.

Brassicas should be stored at 2–5°C. Product should be covered with plastic sheet to maintain high humidity and keep out air-currents from the refrigeration system. Bunching lines can be stored for up to a week, Chinese cabbage will store for longer periods. Brassicas should be handled carefully as they are easily damaged.

**Key Messages**

- **Asian Brassicas** are cool season crops that prefer moist conditions and full sunlight.
- Seed from most Asian Brassica varieties is sourced from China and multiplied under contract in Australia.
- The industry is experiencing price pressure as supply continues to grow and domestic and export markets mature.

**Key statistics**

- Australia produced over 15,125 t of Asian Brassicas in 2001.
- The gross value of Asian Brassicas sales produced in Australia for 2001 was over $19 million.
- After Chinese cabbage, bok choy is the most commonly consumed Asian vegetable.

**Financial information**

Asian brassicas, especially bunching types are often grown on rented land in the urban fringe of capital cities with few establishment costs. They offer a low entry cost enterprise for newly arrived migrants. Chinese cabbage tends to be grown on larger more remote farms and requires greater mechanisation.

Establishing a cost of production and generating crop gross margins is limited by the availability of data and the cultural expectations of growers. For example, growers in New South Wales of Vietnamese origin do not consider labour to be a cost of production. Profit is based on the gross return of the crop minus the cost of materials (seed fertiliser, chemicals, rent, etc.). This perception of production returns is exacerbated by difficulties in obtaining labour costs and yield data from growers wary of revealing financial information.

Typically the extended family provides the farm labour and appropriately priced external labour is difficult to secure.

The industry is experiencing price pressure as supply continues to grow and domestic and export markets mature. Strong price competition has placed downward pressure on product quality. The general perception is that an acceptable profit margin is still available on most crops, but that it is insufficient to retain the second generation of growers. Representative yield, unit prices and gross returns are shown in Table 3 below.

**Table 3. Yield and gross income estimates**

<table>
<thead>
<tr>
<th>Asian Brassica</th>
<th>Yield range (t/ha)</th>
<th>Av yield (t/ha)</th>
<th>Sale price ($/t)</th>
<th>Gross sales ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinese broccoli</td>
<td>6 to 10</td>
<td>9</td>
<td>2,000</td>
<td>18,000</td>
</tr>
<tr>
<td>Chinese cabbage</td>
<td>35 to 80</td>
<td>60</td>
<td>600</td>
<td>36,000</td>
</tr>
<tr>
<td>Chinese chard</td>
<td>8 to 17</td>
<td>15</td>
<td>2,000</td>
<td>30,000</td>
</tr>
<tr>
<td>Chinese flowering cabbage</td>
<td>6 to 18</td>
<td>12</td>
<td>2,000</td>
<td>24,000</td>
</tr>
</tbody>
</table>

Source: Asian Vegetable Industry Situation Assessment, RIRDC 2003
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Key references


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Introduction

Bitter melon (*Momordica charantia* L.) is a cucurbit vegetable consumed as an immature fruit in many Asian and Indian cuisines. It is considered by Asian cultures to confer a wide range of health benefits. The fruit is cut open, the seeds and membranes discarded and the remaining flesh used in soups and stir fry, or stuffed. Young shoots, leaves and flowers are also consumed, but this article is concerned with production the fruit.

Bitter melon is a sub tropical or tropical crop, and recent trial data shows that it can be grown in most Australian states in the correct season (Morgan and Midmore 2002). Growers with experience in vegetable production should find the production of bitter melon similar in many ways to that of other cucurbit crops such as zucchini and cucumber. However, the most difficult task is determining harvest maturity which has a major impact on the crop quality and price.

Current supply of bitter melon is to the Australian domestic market, particularly Australians of Asian descent. Unlike other Asian type vegetables, bitter melon may not be readily adopted by Australians from other backgrounds due to its strongly bitter flavour.

Alternative names for bitter melon include Alligator pear, balsam pear, bitter gourd, and foo gwa (Chinese).

Markets and marketing issues

Farm areas of production are usually small, commonly only 0.5 ha on 5 or 20 ha properties, which
may be producing several other crops concurrently. Bitter melon is harvested, cooled, packed and refrigerated transport is used to take it to market.

Within Australia, most bitter melon is sold in Sydney and Melbourne. This is largely due to the greater population of Australians from Asian descent in these cities. Distribution is both within and outside the major produce markets. They are commonly sold in a 10 kg box. Wholesale prices range between $1.00 and $3.50/kg depending on supply, the average price is between $2.00 and $2.50.

The main producers of bitter melon are in the Northern Territory, where production has been steadily increasing since 1996 (Table 1). Data is not available for national production.

**Table 1. Northern Territory production of bitter melon**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tonnes</td>
<td>337</td>
<td>514</td>
<td>611</td>
<td>864</td>
</tr>
<tr>
<td>Value ($'000)</td>
<td>981</td>
<td>1028</td>
<td>1370</td>
<td>2159</td>
</tr>
</tbody>
</table>


Bitter melon is grown and consumed in most Asian countries, however bitter melon is not currently exported from Australia.

The main constraint to developing export markets is the cost of transport of bitter melon relative to its low value, and its highly perishable nature. Competition from low priced local product in importing countries would limit the price.

Fresh bitter melon is not imported into Australia.

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**Production requirements**

Bitter melon is a tropical or sub tropical crop, it can be grown around Australia at different times of the year. It is currently harvested around Darwin and northern Western Australia during May to October, in the Northern Rivers district of New South Wales from January to May and around Sydney and Melbourne from December to February. These production areas are based on either the location of market garden type enterprises or proximity to the markets of Sydney and Melbourne. Considerable areas of the East and West Coasts with a sub tropical or tropical climate and available water would be suitable for bitter melon production. It can also be grown in hot houses, however this is generally uneconomical.

Minimum temperatures of 18°C are preferred for growth; a reduction in growth occurs with temperature lower than 16°C. Areas prone to frosts are not suitable for this tropical vegetable; 24 to 27°C is optimum temperature range, although it copes reasonably well with higher temperatures. Irrigation is required where rainfall is inadequate.

**Varieties/cultivars**

The current preferred type of bitter melon in the market is medium green, 18 to 22 cm long and 5 to 7 cm diameter. It has many small but prominent bumps over the surface, and few ridges. A wide range of shape and size can be seen in seed catalogues from overseas companies. It is important to establish the local market requirements before ordering seed.

A Quality Descriptor Manual for bitter melon (Vujovic et al., 2000) is a useful tool for describing some of these characteristics.

Most of the bitter melon produced in Australia is from open pollinated seed. Seed is selected by the farmer and stored for the next crop. Several hybrid varieties are available from seed companies within Australia and overseas. These have the advantages in consistency and yield over some open pollinated varieties, however open pollinated types selected for their performance in specific environments can yield as well as the hybrids. Preferred
Bitter melon, commercially available varieties include Baizin (available from Fairbank’s Selected Seed Co.) and Moonlight (Known You Seed Co., Taiwan).

White flesh bitter melon are also available, however there is currently no known domestic market for the white type.

**Cultural practices/agronomy**

Bitter melon is grown on trellises, which are in turn placed on raised beds or ridges. These can be covered in mulch to improve growth where necessary. Trellises are usually steel posts 2 m high, with wires at 50 cm from the ground and then 20 cm intervals, and 100 mm nylon netting. Overhead trellises are also used, these are similar in construction but have additional horizontal spans. Lateral branches below the first production wire are removed, as is the tip of the main runner when it reaches the top of a vertical trellis.

Bitter melon grows best in well-drained soils rich in organic matter, but will tolerate many soil types with adequate fertiliser application. Optimum soil pH is 6.0 to 6.5. Plant spacing varies from 2 to 3 m between rows and 0.5 to 1 m between plants. Seeds are generally established in trays and transplanted into prepared beds.

Fertiliser application should be determined depending on the soil type and history. Adequate basal fertiliser is essential to establish vigorous vine growth prior to flowering, as the largest production peak is due to the first flowering. Nitrogen application is reduced during fruit set to promote flowering and fruit development. Plants should be irrigated to maintain 10 to 20 centibar tension in the root zone, this can be measured with tensiometers. Irrigation with drip tape, microsprinklers or drippers to the root zone is preferable to overhead watering, which can increase disease in the crop.

Bitter melon will produce its first flowers 45 to 55 days from sowing. Pollination is by insects, and poor pollination can be improved by importing beehives. Fruit are harvested approximately 15 to 20 days from fruit set. As the fruit need to be picked every 2 to 3 days, there is a high labour requirement.

 Marketable yields of 20 to 30 t/ha are commonly reported, however total yields over 50 t/ha are also possible. Non-marketable fruit can be from 10 to 20% of the total crop, this is usually due to misshapen fruit, insect damage and ripening.

**Pest and disease control**

Thrips, cucumber moth, heliothis, whitefly and root knot nematodes all affect bitter melon. No pesticides are specifically registered for bitter melon in Australia, however off-label use permits are available. It is necessary to check with the relevant state department for current permits. Biological insecticides and ‘soft’ chemicals such as potassium soaps are also available to control some pests. Nematodes can be controlled by growing an off-season cover crop, such as sorghum.

Powdery mildew has been reported affecting bitter melon in the Northern Territory, Queensland and NSW. It can be difficult to distinguish from downy mildew, and diagnosis should be confirmed...
before implementing a spray program.

Bitter melon are also susceptible to cucumber mosaic viruses and aphids, which transmit the virus and should be carefully controlled.

**Harvest and postharvest**

One of the most difficult tasks in producing bitter melon is determining the stage of harvest. Bitter melon is picked and consumed immature. However, if allowed to mature on the vine or after harvest they rapidly change colour to bright yellow flesh with red seeds, then split, rendering them inedible and unsaleable. Bitter melon are also sensitive to ethylene, so one ripening melon will cause adjacent melons to ripen.

Harvest indices are difficult to detect, but include the fullness of the ridges and bumps and a slight change in colour. The seed coats change colour from a creamy white through pink to red – any tinge of pink is over-mature. However this cannot be detected without opening the fruit.

After harvest it is important to cool the fruit to between 7 to 10°C. Above this temperature the fruit may continue to ripen, below this chilling injury, observed as pitting of the fruit surface, may develop. Fruit are commonly transported at low temperatures of 4°C, however prolonged exposure to these temperatures will result in chilling injury. Storage at high humidity maintains turgidity. Plastic packaging is not recommended due to the potential for ethylene to build up in non-vented bags. Bitter melon are packed into 10 kg boxes. Interstate quarantine requirements should be investigated prior to marketing interstate.

**Financial information**

Establishment costs for bitter melon include firstly the land, then a tractor and some type of bed former, trellis materials, irrigation and spray equipment, and a cooling and cool storage facility after harvest. Production costs include fertiliser and irrigation costs, and pest and disease control plus the labour required to carry out these activities.

The greatest costs in bitter melon production are labour for the repeated harvests and packing, packaging, and transport. Packaging includes cartons and liners, and transport costs vary depending on the distance between the farm and market. Successful marketing also requires time to follow up the quality of the product and, of course, payments.

The main potential risks for successful production of bitter melon are selection of planting material, correct harvest maturity, establishing a market for the product and within and between season price fluctuations. The latter are caused primarily by fluctuations in supply. While some of these issues are common for many vegetable crops, they can be traps for new growers. Careful planning before planting will increase the success of bitter melon production.

**Key references**


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About the author

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Key messages

• Trellises are essential for quality
• Harvest maturity is critical
• Harvest every second day
• Cool fruit after harvest
• Establish a market before planting

Key statistics

• Production volume from the NT is steadily increasing
• Main supply is during winter months
• Prices average from $2.00 to $2.50/kg

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Burdock is a biennial plant that is grown and harvested as an annual. Seeds are not produced until the second year. The plant carries its leaves on long stems of about 60cm, originating from the crown. Leaves are large, almost heart-shaped, have a rough texture and are covered with short white hairs, dark green on the top and a paler green underneath with pinkish veins.

The long, tapering tap-root can reach lengths of up to 120cm. However, roots grown for fresh markets need to be 60-90cm long and less than 3.5cm in diameter at the crown. Roots usually have a brown skin with white flesh that oxidises (discolours) quickly when exposed to the air.

The roots of burdock are the most commonly eaten part of the plant. Burdock is tasty and high in fibre, potassium, calcium, iron, silicon, sulphur, volatile oil and resin as well as containing several antibiotics and it has recognised medicinal properties.

While the consumption of burdock in Japan is stable, the production is falling (Table 1). This offers an opportunity for Australia to supply the market, particularly during the period of Japan’s off-season.
**Markets and marketing issues**

Burdock is a new crop to Australia and is grown year-round on the coastal areas of New South Wales and Queensland. In WA burdock has potential to be grown during late spring and early autumn in the sandy loam soils of the Swan Coast Plain from Medina to Guilderton. Most burdock including fresh and frozen forms are sold through niche markets and Japanese supermarkets. Dried burdock which is used as a tonic is sold in the Chinese medicinal stores or Asian groceries. Estimates for the domestic market are not reliable and quality data has not been collected. However, statistics from Japan's Ministry of Agriculture, Forestry and Fisheries have shown that Australia has exported some burdock to Japan, around 100-200 t per annum (Table 2).

International trade in burdock focuses on Japan where burdock production was approximately 200,000 t in the 1990’s. In the early 2000’s Japan produced only 130-150,000 t per annum. Table 1 shows that the size of the Japanese market is still stable at approximately 210,000-230,000 t per annum, valued at ¥53 billion, equivalent to A$534 million (Table 1).

China has supplied the greatest amount of burdock to Japan since 1999, representing about 90% of the importation and occupying 34% of Japanese market. This is probably due to cheap CIF imported prices from China (Table 2). Burdock has also been imported into Japan from Taiwan, South Korea, Australia, France and Indonesia. Exports from these countries are, however, very small.

**Table 1. Production and importation of burdock in Japan, 1989-2002**

<table>
<thead>
<tr>
<th>Year</th>
<th>Production</th>
<th>Importation</th>
<th>CIF Prices (Fresh) 2,3, Yen/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area, ha</td>
<td>Volume, ton</td>
<td>Fresh, ton</td>
<td>Processed, ton</td>
</tr>
<tr>
<td>1989</td>
<td>15,200</td>
<td>219,000</td>
<td>Nil</td>
</tr>
<tr>
<td>1995</td>
<td>13,400</td>
<td>190,000</td>
<td>Nil</td>
</tr>
<tr>
<td>1999</td>
<td>11,400</td>
<td>164,900</td>
<td>71,715</td>
</tr>
<tr>
<td>2000</td>
<td>10,700</td>
<td>153,900</td>
<td>81,676</td>
</tr>
<tr>
<td>2001</td>
<td>10,100</td>
<td>143,600</td>
<td>80,683</td>
</tr>
<tr>
<td>2002</td>
<td>9,670</td>
<td>134,600</td>
<td>74,665</td>
</tr>
</tbody>
</table>

2) Yasai Yunyu no Doko, 2002.
4) Processed including frozen and salted burdock.
5) Prices (CIF) of processed burdock.

**Table 2. Prices of imported burdock into Japanese market, 1999-2002**

<table>
<thead>
<tr>
<th>Year</th>
<th>Prices, CIF- ¥/kg</th>
<th>China (Fresh) ¥/kg</th>
<th>Taiwan (Fresh) ¥/kg</th>
<th>Australia (Fresh) ¥/kg</th>
<th>French (Frozen) ¥/kg</th>
<th>Indonesia (Salted) ¥/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>Frozen</td>
<td>Salted</td>
<td>Fresh</td>
<td>Frozen</td>
<td>Salted</td>
<td>Fresh</td>
</tr>
<tr>
<td>1999</td>
<td>49</td>
<td>115</td>
<td>93</td>
<td>4</td>
<td>143</td>
<td>Nil</td>
</tr>
<tr>
<td>2000</td>
<td>60</td>
<td>93</td>
<td>71</td>
<td>55</td>
<td>82</td>
<td>111</td>
</tr>
<tr>
<td>2001</td>
<td>64</td>
<td>103</td>
<td>81</td>
<td>59</td>
<td>87</td>
<td>(154t)</td>
</tr>
<tr>
<td>2002</td>
<td>44</td>
<td>102</td>
<td>78</td>
<td>41</td>
<td>69</td>
<td>120 (185t)</td>
</tr>
</tbody>
</table>

Burdock can be sown year round but best in spring and autumn. Spring burdock can be sown as soon as soil temperatures are above 10°C. A better establishment will be achieved if planting is delayed until the soil has reached 15°C. Seed germination is very slow, taking 10–14 days for emergence, and can be uneven. In fact, some seeds may lie dormant in the soil and germinate the following autumn. Using primed seed breaks this dormancy and increases both the rate of germination and overall percentage of germinated seed (Figure 1). Autumn burdock must be sown late so that plants are still very small when the first frost occurs. Leaves will die back and the plant stops growing until temperatures become warmer in

Growing burdock in New South Wales for Australian fresh markets and export to Japan

Figure 1. Priming burdock seed increased both the rate of germination and the final percentage of germinated seed at both 15°C and 20°C.
spring. There is a risk of plants bolting (going to seed) in spring if roots are larger than 5 mm diameter before winter. Autumn sowing produces an earlier crop during the following spring/summer.

Before sowing, the soil must be cultivated very deeply – up to 90 cm if possible. Soil must be left in a loose, friable state for roots to penetrate otherwise they will fork and the yield of “A” grade roots will drop dramatically. Up to 80% of roots that fork do so in the top 15 cm due to either a change in soil structure where soil has been shallow cultivated, or if fertiliser with a high N content is banded below the seed line (Figure 2).

A fertiliser with low nitrogen and high phosphate to encourage root growth can be worked into the soil before sowing during deep cultivation. Apply approximately 120 kg/ha P in sandy soils. This rate can be reduced in more fertile, sandy loam or alluvial soils.

Two side dressings of nitrogen and potassium fertiliser should be applied, the first at the two-three leaf stage (approximately 60 kg/ha of elemental N and K) and the second approximately three months after sowing (100 kg/ha of elemental N and K).

Burdock is direct-seeded with 10 cm between plants and approximately 50 cm between rows. Seeds should be sown at about 1-2 cm deep and kept wet until after seedlings become established. Once plants are established, water can be cut back to force roots to seek moisture deeper in the soil profile. It is important not to over-irrigate and saturate the soil profile as excessive moisture can lead to root rot diseases.

Pest and diseases control

As burdock is a new crop to Australia, there are no registered chemicals available for weed, pest and disease control. However, burdock is a hardy plant and has few pests or diseases and weeds can be controlled with cultivation and hand chipping.

Burdock in the Ota wholesale market, Tokyo, Japan

The slow establishment rate of burdock gives weeds a head start on the crop so it is important to ensure that the site is prepared well in advance of the sowing date. The site should be pre-irrigated and any emerging weeds sprayed off with a knockdown herbicide just before or immediately after sowing. Weeds that establish after the crop has emerged have to be cultivated out or hand chipped.
The crop will form a complete canopy approximately eight weeks after germination, which restricts further weed establishment.

A burdock crop grown chemical-free may attract a premium price in Japan and even in Australia where consumers are very health conscious and have shown a willingness to pay extra for “organically clean”, healthy, quality foods.

Nematodes (burrowing nematode; *Radopholus similis*) is a major pest and soils should be assessed for nematode population before sowing. A nematode-repelling crop, such as oats or canola, may be sown as a cover crop during winter and incorporated into the soil before sowing burdock.

In some years, red-legged earth mite can cause damage to young seedlings early in the season. If earth mite are likely to be a problem, planting should be delayed until their activity diminishes.

Powdery mildew may become a problem in mid- to late summer if wet, humid conditions prevail. Symptoms are similar to powdery mildew on cucurbits though the causal agent is different. In most cases the crop will tolerate a mildew infection and it is only in extreme circumstances that crop losses will occur. Wettable sulphur (a natural compound) can be used to control powdery mildew if it is deemed necessary.

Black root is a fungal disease caused by *Aphanomyces raphani*, which may also cause crop losses. Warm, hot weather and water-logged soil favour its development. The disease is controlled by correct irrigation scheduling, good drainage and crop rotation.

### Harvesting and packaging

Spring-sown burdock will be ready for harvesting about 4-4.5 months after sowing. To obtain the best commercial return, the crop should be harvested when most of the roots are 20-35 mm diameter and at least 70 cm long. If harvest is delayed to increase tonnage, quality will decline. Roots will be over-mature and become woody and pithy and the market will not accept them.

To harvest burdock, shoots are first removed by slashing or mulching the tops, leaving approximately 10 cm of stalk. Roots are then loosened with a vibrating ripper then pulled out by hand. It may be possible to pick up the roots with a modified carrot harvester once they have been loosened. After the roots are lifted from the soil, they must not be left exposed to the hot sun as this causes them to wilt and the flesh quickly oxidises and becomes discoloured.

Harvesting should be carried out early in the morning and the burdock taken to a shady area or packing shed as quick as possible.

### Table 3. Burdock size grading for Japanese markets

<table>
<thead>
<tr>
<th>Grade</th>
<th>Size</th>
<th>Root diameter, mm</th>
<th>Root length, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3L</td>
<td>≥36</td>
<td>&gt;60</td>
</tr>
<tr>
<td></td>
<td>2L</td>
<td>31-35</td>
<td>&gt;60</td>
</tr>
<tr>
<td></td>
<td>L</td>
<td>26-30</td>
<td>&gt;60</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>21-25</td>
<td>&gt;60</td>
</tr>
<tr>
<td></td>
<td>2M</td>
<td>16-20</td>
<td>&gt;60</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>11-15</td>
<td>&gt;55</td>
</tr>
<tr>
<td></td>
<td>2S</td>
<td>≤10</td>
<td>&gt;35</td>
</tr>
<tr>
<td>B</td>
<td>BL</td>
<td>≥35</td>
<td>45-60</td>
</tr>
<tr>
<td></td>
<td>BM</td>
<td>25-35</td>
<td>45-60</td>
</tr>
<tr>
<td></td>
<td>BS</td>
<td>&gt;15</td>
<td>45-60</td>
</tr>
<tr>
<td></td>
<td>Process</td>
<td>≥20</td>
<td>&gt;40</td>
</tr>
</tbody>
</table>

The fresh market in Australia and Japan demands long, straight roots without any forks or side shoots. Roots need to be at least 60 cm long (preferably 70 cm) and between 16-35 mm diameter (Table 3). The market in Japan has recently accepted the Oura type for salads. Oura burdock needs to be 40 cm long and 30-40 mm diameter. Shorter or forked roots may be sent for processing at reduced price.

Roots are then washed and side shoots and root hairs are removed. After washing and trimming, roots

Burdock sold in Tokyo supermarket, Japan
are graded and packed into plastic-lined 10kg cartons. Table 3 also lists the fresh market grades that are used in Japan.

**Quarantine requirements**

A declaration must be provided to the Australian Quarantine and Inspection Service (AQIS) that the burdock crop has been inspected by an authorised person and is free of burrowing nematode (*Radopholus similis*). The crop must have been grown on a farm that has been inspected by soil sampling during the growing season and found to be free from *Radopholus similis*. *Radopholus similis* does not occur in the Riverina of New South Wales, but is present along the north-east coast of Australia, especially in banana-producing areas. A further requirement is that all soil must be removed from the roots.

**Financial information**

The production costs vary between seasons, growing locations, time of consignment and the business resources. Field trials on the Central Coast of New South Wales have shown that high gross margins for Australian burdock, estimated at A$2.51/kg (Table 4), would never be competitive with China in the Japanese market, where China’s CIF prices have achieved only in the range of ¥41-59/kg (A$=¥75) (Table 2). However, exporting of Australian burdock remains potentially high if the Australian burdock industry can reduce its production cost by mechanising the weeding and harvesting operations, translating its “Clean & Green” vegetable into sale with acceptable margins.

Table 4 shows an enterprise budget for 1.0ha for Burdock Tohoku Riso located in Somersby, NSW, for a period of 4-5 months.

### Table 4. Gross margin for Burdock growing on the Central Coast of New South Wales, 2004

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost (A$)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>800 cartons</td>
<td>10kg</td>
<td>4.00</td>
<td>32,000</td>
</tr>
<tr>
<td><strong>A. TOTAL INCOME</strong></td>
<td></td>
<td></td>
<td></td>
<td>32,000</td>
</tr>
<tr>
<td><strong>Variable costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cash</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>8hrs</td>
<td></td>
<td>18.48/hr</td>
<td>147.84</td>
</tr>
<tr>
<td>Burdock seed</td>
<td>2.5kg</td>
<td></td>
<td>366.00/kg</td>
<td>915.00</td>
</tr>
<tr>
<td>Planting labour</td>
<td>4hrs</td>
<td></td>
<td>18.48/hr</td>
<td>73.92</td>
</tr>
<tr>
<td><strong>Fertilisers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural lime</td>
<td>4.0t/ha</td>
<td></td>
<td>130/t</td>
<td>520.00</td>
</tr>
<tr>
<td>Fertilisers Multigro</td>
<td>1.5t/ha</td>
<td></td>
<td>495/t</td>
<td>742.50</td>
</tr>
<tr>
<td>Spreader machinery cost</td>
<td></td>
<td></td>
<td></td>
<td>3.88</td>
</tr>
<tr>
<td>Labour</td>
<td>2hrs</td>
<td></td>
<td>18.48/hr</td>
<td>36.96</td>
</tr>
<tr>
<td><strong>Nematode control</strong></td>
<td></td>
<td></td>
<td></td>
<td>85.00</td>
</tr>
<tr>
<td><strong>Weed control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand weed labour (3-4 times)</td>
<td>20days</td>
<td>8hrs/day</td>
<td>18.48/hr</td>
<td>2,956.80</td>
</tr>
<tr>
<td>Pesticides, machinery, labour</td>
<td></td>
<td></td>
<td></td>
<td>48.14</td>
</tr>
<tr>
<td>Irrigation (water pump &amp; maintence)</td>
<td></td>
<td></td>
<td></td>
<td>219.50</td>
</tr>
<tr>
<td><strong>Harvesting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carton 10kg</td>
<td>800</td>
<td></td>
<td>2.00/carton</td>
<td>1,600.00</td>
</tr>
<tr>
<td>Slashing tops machine cost</td>
<td>2hrs</td>
<td></td>
<td>10/hr</td>
<td>20.00</td>
</tr>
<tr>
<td>Slashing labour cost</td>
<td>2hrs</td>
<td></td>
<td>18.48/hr</td>
<td>36.96</td>
</tr>
<tr>
<td>Per carton cost for all harvesting</td>
<td>800</td>
<td></td>
<td>15.00/ctn</td>
<td>12,000.00</td>
</tr>
<tr>
<td><strong>Transportation &amp; fees</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freight to Sydney</td>
<td>800</td>
<td></td>
<td>0.50/ctn</td>
<td>400.00</td>
</tr>
<tr>
<td>Levies</td>
<td>800</td>
<td></td>
<td>0.25/ctn</td>
<td>200.00</td>
</tr>
<tr>
<td>Agent commission 10%</td>
<td>800</td>
<td></td>
<td>0.10/ctn</td>
<td>80.00</td>
</tr>
<tr>
<td><strong>B. TOTAL VARIATION COSTS</strong></td>
<td></td>
<td></td>
<td></td>
<td>20,086.50</td>
</tr>
<tr>
<td><strong>GROSS MARGIN (A-B)</strong></td>
<td></td>
<td></td>
<td>$/ha</td>
<td>11,914.50</td>
</tr>
<tr>
<td><strong>Break even</strong></td>
<td></td>
<td></td>
<td>$/kg</td>
<td>2.51</td>
</tr>
</tbody>
</table>
**Key contacts**

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**Key Messages**

- High capital investment and long term commitment required  
- Labour intensive  
- High returns are possible

**Key statistics**

- A potential market in Japan where demand is 210,000 t/year - Japan produces only 130,000 t and imports about 80,000 t/year

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Chinese waterchestnut

David Midmore and Peter Gersteling

Introduction

Chinese waterchestnut (*Eleocharis dulcis* (Burm. f.) Trin. ex Henschel) is a tropical member of the sedge family and as its name implies, it is an aquatic species. Plants consist of four to six upright tubular stems approximately 1.5 m tall. Vegetatively propagated, the corms (or tubers), the edible portion, are produced at the end of underground stems (or rhizomes).

A botanical novelty twenty years ago, although in its wild form it was reputedly harvested by Aboriginals, it is now produced and marketed commercially in Australia, substituting for the importation of canned produce but offering the Australian consumer the opportunity to savour the fresh product. However, it is only available over the period June to October, thereby limiting the effectiveness of import substitution.

Premium Australian waterchestnuts are >38 mm in diameter with no visible or internal injuries (bruising), have a crisp coconut-like texture and a detectable sweetness, which adds to their unique flavour. Their taste is best enjoyed by firstly peeling the thin skin which sometimes harbours muddy flavours. Fresh diced or sliced pieces are a useful salad ingredient. Light steaming releases an appetising aroma of corn with a hint of macadamia. As such, they are better than those from traditional production zones in Thailand (*Suphanburi*), China (*Guai Lin*) and Taiwan (*Tainan County*) but, according to connoisseurs, Australian produce at times lacks sweetness and tastes starchy.

The crispy texture, which is retained after processing or cooking, is due to the presence of the ferulic acid-containing hemicelluloses in cell walls of the waterchestnuts. The product is...
favoured for fresh stir-fry mixes and apart from the domestic kitchen market, is particularly sought after by Asian restaurants, which predominantly buy the large size corms (>38 mm) due to ease of peeling. It also forms the basis for heavily sweetened drinks in Asia, appearing in cans and “popper” drinks as well as dry granule sachets, which can all be found as imported products in most Asian style supermarkets and stores within Australia.

A tradition of production in Taiwan and China, and the recent introduction of a canning industry in Thailand - underpin the world trade in waterchestnut, and the US is the major importer of the canned form, marketing approximately 40 million cans.

Markets and marketing issues

Waterchestnuts are marketed in Australia in the fresh, frozen and canned forms. Frozen and canned forms are peeled and predominantly originate from China and Thailand; fresh waterchestnuts are sold with their skins (the lignified 0.75 mm thick peel) intact. In Asian wet markets fresh waterchestnuts are peeled by hand in quantities to satisfy demand. The fresh nature of waterchestnuts (i.e., with approximately 86% moisture) necessitates their storage, transport and display under cool (<10º C) and humid conditions. The importance of this to retail markets cannot be over-emphasised.

Currently levels of canned imports into Australia are unknown because ABS data are pooled with those of true chestnuts and retailers prefer not to divulge such information.

Retail prices for canned waterchestnuts (approx. 90 cents/227 g [gross]) are similar to, or less than those in Asian countries (Singapore A$1.20/340 g [gross]; Thailand A$1.25/227 g [gross], and wholesale prices of canned waterchestnut in Australia (48 cents to 79 cents/230 g [gross]) convert to $3.7 to $6.0/kg of net waterchestnut. Current illustrative farm gate prices for fresh Australian waterchestnuts range from $4.00 for small (i.e., 25-32 mm) to $12.00 for large corms, which is highly competitive with the net retail cost of canned produce, although 10 to 20 % of fresh product will be lost through peeling, the larger figure for smaller corms.

A recent survey indicated that consumers, although preferring large fresh corms, are discouraged by high retail prices – up to $20/kg. Non-Asian consumers are largely ignorant of the uses, availability and taste of fresh waterchestnut.

The current production in Australia has apparently declined from around 20 t/year in 1997 to less than 8 t/year in 2003. The bulk of this production has come from three growers; two in New South Wales and another from Central Queensland, with a number of small-scale producers located not only in these states but Victoria and WA as well. The recent survey disclosed product sourced from Darwin. Product is predominantly offloaded at the Sydney and Melbourne Wholesale Markets in bagged and boxed form where demand can fluctuate wildly depending on the vagaries of the weather and concurrent eating habits.

Consumers tend to be of Asian extraction because of their familiarity with the product and the fact that agents get the highest response from Asian shop-owners aware of the existing demand. A ready market has been identified for a fresh peeled product. Just one of at least ten food processors is known to currently import over 7 t of peeled product annually to incorporate in their dim sim and fish ball line of products. That same processor indicated that they could envisage a demand for over 100 t of peeled product if it could be sourced from Australia for their product line. A number
of producers still believe that an economically viable method of producing a peeled product will greatly magnify both the existing and potential markets. This will go hand in hand with an improvement in commercial harvesting equipment. An added benefit would be the greater utilisation of smaller corms, perhaps down to 15 or even 10 mm depending on the efficiency of the technology employed.

Overseas markets are of interest; production in Japan is on the decline (1600 t in 1984 to 1200 t in 1992) as it is in Taiwan (1200 t in 1991 to 860 in 1995). The best retail prices are gained in Japan from September to December, ranging from A$9.0 to A$30.0/kg while in Taiwan retail price is quite stable at A$6.0/kg, double that of the farm-gate price. Australian production currently pales into insignificance compared with that of Japan and Taiwan, and with that of China which dominates the supply of canned and semi-preserved waterchestnuts to the USA. Approximately US $35 million as canned and US $8 million as semi-preserved product was imported to the USA in 1996. With an established and potentially larger national market, it is opportune to embark upon export ventures, especially now that the Australian industry draws upon four mechanised harvesting systems which considerably reduces the labour requirement for the crop.

Production requirements

A puddled or clay-base soil, along the same lines as for paddy rice, is ideal for waterchestnut cultivation. Highly porous and sandy soils are not suitable because ponds drain rapidly, unless lined with industrial quality (200 – 500 micron) polyethylene sheets. Although clay soils favour water retention and puddling, they present serious drawbacks for some harvest systems, particularly since they need more labour for hand-harvesting. In such instances, producers may add sand or composted filter press mud, from sugar mills, to clay soils to ease the harvest burden.

Since the crop is grown in an almost entirely flooded condition, flat or terraced land is necessary. Access to irrigation that will replenish at least the evaporative demand (measured as pan evaporation at standard weather stations) is essential if rainfall during the cultivation season does not exceed evaporation. Although an inland species in the wild, cultivated waterchestnut does not tolerate irrigation water salinity values of greater than 3.3 dS m⁻¹ without loss of germination and corm yield.

The crop is customarily grown in a sub-tropical to temperate climate, planted in the spring where the growing temperatures are 15°C - 25°C. Immature corms, with white undeveloped skins, may appear throughout the growing season forming at nodes along the root stem where new culms arise as daughter plants. Mature corms seem to appear in response to stress such as a drying soil (drought), overcrowding (lack of space and nutrients) and/or shortening daylight hours (autumn).

Corms form as the day length becomes less than 12.5 hours and stems senesce in autumn in response to plant maturity rather than as a response to low temperature.
Generally a 220 day frost-free period is necessary for natural completion of the crop cycle. High daytime air temperature (~30°C) favours growth of the crop. Current and potential production areas in Australia are indicated on the accompanying map.

**Varieties**

The wild form of waterchestnuts, with small hard corms (approx 10-20 mm diameter), grows extensively in South Asia and much of Oceania. The cultivated form has larger corms, selected in China for their sweetness and juiciness. On various occasions superior cultivated lines (≅ varieties) have been imported to Australia. A summary of the officially reported importations and acquisitions is presented in Table 1. The distinction between varieties currently cultivated was all but lost, but using the technique of DNA-based genetic finger-printing, the identity and origins of various lines in Australia is now known. This is of primary importance for maintenance of quality standards for local and export markets. Prospective growers should be aware of the genetic identity of the material to be planted. It is possible that some lines are more suited to the climatic conditions of Victoria as opposed to those of Queensland, but without clear identification of lines such information is impossible to confirm.

Quite recently, the variety named “Shu-Lin” was imported for trials in Australia, and is now referred to as “Taiwan”. In 2003 it was sold for the first time through Sydney Markets – about 350 kg. Chosen for its superior texture and flavour it will comprise a significant part of the 2004 harvest.

**Agronomy**

Land preparation comprises construction of ponds, or paddies, the dimensions of which should relate to the proposed form of harvesting. Fertiliser application depends upon soil type and expected corm yield. For a 30 t/ha crop, nutrient demand would be: 160 kg N/ha; 80 kg P/ha and 280 kg K/ha. One half N and all P and K should be applied and incorporated in the dry soil before planting, and may be substituted by an earlier application of organic manure at rates of c. 12 t/ha. The soil is then well watered but not flooded. Sound corms, preferably sweet (for evidence suggests that planting sweeter corms leads to better harvest) and with a viable terminal bud, are used as planting material. The terminal bud is face-up at planting. Corms may be directly planted to the field, or planted at high density (corms almost touching each other) in a nursery for production of transplants. Corms sprout as ground and water temperature rise above 13°C, and this may be hastened under nursery conditions in cooler climates by the judicious use of clear polyethylene sheet covers. Following direct planting to the wet field, at a depth not exceeding 4 cm, the field is flooded and allowed to drain naturally. Further flooding may be undertaken within three weeks, or when stems are 20 to 30 cm tall. Deeper flooding will usually cool the environment around the corm and slow germination, hence shallow flooding is to be favoured in southern climates, both for plant establishment and during the grand period of growth.

Corms in nurseries are treated similarly to those in the field, and germinate approximately 10 days after planting. They are transplanted into moist or flooded ponds when they reach 20 to 30 cm height, and in the warm tropics the tops may be trimmed before transplanting if too tall. Crops from transplants in temperate climates will usually mature 5/6 weeks earlier than crops directly planted to the field on the same date as transplanting. This difference diminishes where temperature, especially at night, is more equable year-round.

Plant spacing in the field depends largely upon climate and planting date (more southerly climates and/or later planting reduces opportunity for rhizome and daughter plant production and filling-in by the canopy to capture

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**Table 1. Origins of known imported lines of Chinese waterchestnut**

<table>
<thead>
<tr>
<th>Year</th>
<th>Importer</th>
<th>Local name</th>
<th>Origin/source</th>
</tr>
</thead>
<tbody>
<tr>
<td>?</td>
<td>Allan Hibberd</td>
<td>Botanical garden at Mt Coot</td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>Allan Hibberd</td>
<td>Black skin</td>
<td>Taiwan to Qld</td>
</tr>
<tr>
<td>1988</td>
<td>Allan Hibberd</td>
<td>Red skin</td>
<td>Taiwan to Qld</td>
</tr>
<tr>
<td>1989</td>
<td>Dallis Raynor</td>
<td>Dallis</td>
<td>Taiwan to Qld</td>
</tr>
<tr>
<td>1989</td>
<td>Hans Erkin</td>
<td>Matali ‘supreme’</td>
<td>Chinese farmer in Qld</td>
</tr>
<tr>
<td>1988</td>
<td>Werner Leutert</td>
<td>Hon Matali</td>
<td>China to USA (PI 106274) to WA</td>
</tr>
<tr>
<td>1995</td>
<td>Greg Gunning</td>
<td>Thailan to Qld</td>
<td></td>
</tr>
<tr>
<td>1994, 1996</td>
<td>Greg Gunning</td>
<td>China to Qld</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Greg Gunning</td>
<td>Shu-Lin</td>
<td>Taiwan to Qld</td>
</tr>
</tbody>
</table>
Chinese waterchestnuts

all light energy, therefore closer spacing should be used), but soil fertility and level of fertiliser input will govern plant vigour, and plant spacing should be adjusted accordingly. On average between two to five transplants (or corms) are planted per one square metre, with a triangular positioning often preferred.

Once established, the crop is continually maintained in a flooded condition, even during the application of the remainder of the inorganic fertiliser, which should conveniently be split and applied incrementally at monthly intervals. Eight to ten weeks after planting the secondary (daughter) plants appear and just prior to the autumn equinox notable development of corms is evident. Seeding the pond with the water fern *Azolla* can reduce the overall need for N fertiliser in the subsequent crop. The nitrogen-fixing fern can fix about 50 kg N ha/yr. Besides NPK, calcium and magnesium should also be added (at 6 and 25 kg/ha respectively) and micro-nutrients if the soil substrate is known to be deficient. Removed nutrients must be replenished to minimise ‘mining’ of soil nutrients. Nitrogen fertiliser is best applied in the NH$_4^+$ (ammonium) form, for this is the favoured form for uptake by waterchestnut, and is less easily leached than the NO$_3^-$ (nitrate) form.

After planting, crop attention centres around prophylactic pest control, fertiliser application, water-level monitoring/adjustment and weed minimisation both within and around the ponds.

Once corms have formed they are susceptible to physical damage as a result of trampling in the field. The canopy of the crop, in reality the stems for the plants have no true leaves, is so dense that it is best to prevent physical entry to the field for fear of lodging and loss of photosynthetic activity. Stems should as far as possible be kept free from damage by wind, herbivores, and pests and diseases.

Experimentally, artificial shortening of daylight using blackout plastic sheets from early January in Victoria can hasten formation of corms and provide a longer duration corm growth before frosts kill the stems in winter. Conversely, extending the natural day length with suspended lamps in the tropics from March onwards can delay corm formation and lead to later harvest, thereby extending the duration of fresh product availability.

The incidence of both larger corms and high yield appears to be linked to a lengthy (>5 months) hot growing season combined with optimum plant spacing and adequate nutrition which culminates in medium-high density culm formation just prior to the onset of senescence.

Farm-level yields in Australia reach >20 t/ha but maximum marketable yields (i.e. > 25 mm corm diameter) are less than 20 t/ha. These values are similar to those reported for China, although small plot yields of up to 40 t/ha have been reported in Australia.

**Pests, weeds and disease control**

Regular slashing and brush cutting of pond margins and perimeters helps reduce habitat for rodents and pests. Ponds should be effectively fenced from herbivores such as cattle and horses. Well-tilled land treated with general purpose herbicides (e.g. Roundup) reduces the incidence of most weeds, as does the use of compact and composted mulches (e.g., filter press mud) during the fallow season. If soil type dictates that ponds and bunds are lined with polyethylene sheets, then the incidence of weeds is much reduced. Aquatic species such as the giant sedge (*Cyperus exaltatus*) are well adapted to compete with waterchestnut and seed sources should be eliminated wherever possible.

Insect pests of waterchestnut are known, but with few exceptions are not devastating. Green and long-horned grasshopper and snout moth larvae bite the bases of stems and the rice water weevil (*Lissorhoptrus oryzophilus*) damages corms, as do mole crickets (*Gryllotalpa* sp.). Stem damage has reportedly been prevented by use of Lorsban 500EC although this chemical is not registered for use in Chinese waterchestnuts in Australia. There is no easy remedy for corm damage in the field.

In 1997 outbreaks of *Nisia grandiceps* (a sucking insect) and *Scirpophaga* (a moth species) were reported in Queensland and also...
controlled by use of Lorsban 500 EC. A rust (Uromyces sp.) attacks waterchestnut, and is controlled in its early stages by sulphur dust. Stem blight present on acid soils (pH 5.5) caused by Cylindrosorium eleocharidis (Lentz) is chemically controlled by copper dressings or spray with Benomyl, Thiophanate and Amban, and can be controlled by rotation with non-host crops. Waterchestnut wilt, reported in China and caused by a specific race of Fusarium oxysporum, is not present in Australia, and underpins the need to maintain effective quarantine protocols for import of fresh waterchestnut materials.

Ducks represent a major concern to some producers (30% of respondents to an industry survey) and more recently, swamp hens have been identified as potentially the most destructive pest, owing to their habit of crushing stems and uprooting young plants to gain access to germinating and adventitious corms. Netting, sound and lights are effectively used to reduce damage. Bandicoots, rats and mice also cause damage to corms and liners if ponds have been drained.

Harvest, handling and post-harvest

Ponds must be drained for hand harvest, and for one of the four mechanical harvesters developed in Australia. The advantage of the other three harvesters is in their flexibility of use; they can operate during or after rainfall. Harvest can take place once the stems have browned off and been removed either physically or burned to ashes in a drained pond. Corms store well underground if frosts are not severe, for the corms are found at depths ranging from 7-20 cm. In-field storage can extend the harvest period, and raises the sweetness of corms, but once temperatures around the corms rise to 13°C shoot formation occurs and the retail attractiveness of the corms is lessened.

Waterchestnuts are readily bruised during harvest – drop tests from as little as 5 cm show damage – leading to saprophytic fungal and bacterial activity and at times fermentation; therefore they must be handled with care. Following harvest, corms are washed, cleaned, and graded for discards and by size according to market outlet. Likewise, packaging form and size also depends on market outlet, with types ranging from 200 g plastic bags to 5 kg cartons. Currently corms are not graded for sweetness. Non-invasive near infra-red apparatus are available to quantify sweetness, but the market is not of a sufficient size to warrant commercialisation.

Cool storage is essential for the holding of produce in Queensland, while ambient winter temperature storage suffices in Victoria and most of New South Wales for short periods. Sound, dry corms may be stored for up to six months at c. 4°C in low density polyethylene bags, and surface sterilising with sodium hypochlorite reputedly extends that period. A small proportion of the harvest is saved for next year’s crop, and is usually stored in this manner. To gain chain store markets for fresh produce in Australia, it is important to have fresh produce available throughout the whole year, hence the interest in extending storage life of fresh waterchestnut.

Currently no large-scale peeling of Australian produce is undertaken, although core punching of small waterchestnuts is used as a means of value-adding for the low priced small-size category. A range of bottled produce, at the cottage industry level, is niche-marketed.

Financial information

Costs of production were variously estimated at from $2.00/kg to $5.75/kg as a response to a 1997 survey amongst waterchestnut growers, and a study in 2000 calculated breakeven farm gate prices to range between $2.80 and $12.42/kg, but precise data are not available. Table 2 outlines the most probable general costs involved, expressed as that required for setting up 0.1 ha of commercial production. Economies of scale are evident particularly in the fixed costs, and hiring of facilities, especially the harvester and cold storage and will prove more attractive to the smaller-scale grower.

Table 2. Set-up and ongoing costs of production for 0.1 ha

<table>
<thead>
<tr>
<th>Fixed costs</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pond construction</td>
<td>1,000-5,000</td>
</tr>
<tr>
<td>Harvester (range)</td>
<td>10,000-200,000</td>
</tr>
<tr>
<td>Sorting &amp; grading equipment</td>
<td>Up to 10,000</td>
</tr>
<tr>
<td>Pump &amp; irrigation</td>
<td>1,000 +</td>
</tr>
<tr>
<td>Cold storage</td>
<td>Market price acc. to volume</td>
</tr>
<tr>
<td>Netting</td>
<td>500-800</td>
</tr>
<tr>
<td>Variable costs</td>
<td></td>
</tr>
<tr>
<td>Planting material (annual)</td>
<td>200-500¹</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>400-600</td>
</tr>
<tr>
<td>Labour costs production</td>
<td>1,000</td>
</tr>
<tr>
<td>Labour costs harvest</td>
<td>1,500-3,000</td>
</tr>
<tr>
<td>(mechanical)</td>
<td></td>
</tr>
<tr>
<td>Packaging and transport</td>
<td>1,500</td>
</tr>
<tr>
<td>Sundries</td>
<td>1,500</td>
</tr>
</tbody>
</table>

¹Owner produced after first year, representing opportunity cost.
Key statistics

- USA imports c. US$40 million per year
- Australian production (c. 10-20 t/yr) insignificant compared to Japan and Taiwan (c 800-1200 t/yr)
- Costs of production ($2.00-5.75/kg) can be less than farm-gate prices ($4.00-12.00/kg)
- Four mechanised harvesting systems have been developed, facilitating expansion of production

Key messages

- Purchase planting material of a known named variety from a reliable source
- Ensure access to mechanical harvesting and to markets have been established before embarking on large-scale production
- Monitor growth of plants on regular basis (x 3 times weekly) to ensure appropriate water level and freedom from pest/diseases (including wild fowl and herbivores)
Chinese waterchestnuts

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Peter Gersteling has been growing waterchestnuts commercially since 1993 and has pioneered the use of plastic-lined macrophyte ponds for ease of harvesting, minimising water use and controlling weeds. He is largely responsible for establishing the current grading sizes for waterchestnuts, as well as developing a successful venturi-style harvester.

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Culinary bamboo shoots

Steven Keilar and Ray Collins

Acknowledgement is given to David Midmore, the author of this chapter in the first edition of this publication.

Introduction

Bamboo shoots are the actively growing immature culms emanating from buds on the underground rhizome section of the plant. Shoot characteristics vary widely depending on the species. Of the more than 1,500 recognized species less than 100 are commonly grown specifically for their shoots.

Bamboo species are commonly divided into two groups. Sympodial species (clumping bamboos) produce compact clumps, with tightly packed culms or poles (Figure 1). Monopodial species (running bamboos) spread over much larger areas (Figure 2). Clumping species tend to be found in tropical and sub tropical areas, while running species are more cold tolerant. The limiting factor in the distribution of most bamboos is the availability of water.

Clumping species mature more quickly, with the first harvest of shoots usually between 3 and 5 years after planting. Shoots appear from late spring to early autumn.

Running species take longer to establish with the first harvest up to 8 years after planting. They have an earlier and shorter shoot season in early spring.

Australian bamboo shoot growers presently supply the fresh domestic market, but potential export markets include Japan, Singapore, Hong Kong, Taiwan and Korea. Asian markets, in which fresh bamboo shoots are a widely consumed traditional
food, represent an opportunity for counter-seasonal supply by Australian producers. Worldwide, most of the trade is in canned bamboo shoots, with China and Thailand the major suppliers.

**Markets and marketing issues**

Bamboo shoots are considered a healthy, low energy, non-fattening food source. They are used for their crisp texture, their delicate flavours and their ability to take on the flavour of the dish with which they are cooked. As bamboo shoots contain cyanogens, it is important that they be properly prepared (usually by boiling) before consumption.

The worldwide consumption of bamboo shoots is estimated to exceed two million t/yr. China, Japan, Thailand and Taiwan dominate both production and consumption. Most bamboo shoots are processed (canned, dried, pickled) but every country has a market for fresh shoots as well. Consumption of bamboo shoots outside of Asia is minor but the market is thought to be increasing in countries such as Australia, the United States and Canada.

The relatively small Australian domestic market is dominated by imports of 4,000 to 10,000 t annually of canned bamboo shoots (Cusack, 1999; Midmore et al., 1998). However, there is an increasing demand for fresh shoots. Asian markets for fresh Australian bamboo shoots are yet to be developed, but preliminary indications are that counter-seasonal opportunities do exist. Australia’s proximity to these markets is also an advantage.

In 2003 fresh shoots returned between $2.75 and $10.00/kg wholesale on the Australian domestic market while canned shoots sold for $2.00 to $6.00/kg. Consumers of Asian backgrounds were the major purchasers of bamboo shoot products in Australia.

**Production requirements**

The large range of species means that bamboo can be cultivated in most Australian climates. Temperature and precipitation are the most important climatic factors when selecting the best bamboo species for a particular site.

In general, sympodial (clumping) species grow best in warmer tropical climates where the minimum summer temperature does not fall below 15° C, and with rainfall in excess of 1,400 mm annually. In areas where there is not enough rainfall, irrigation is needed.

The high water demand for commercial, high quality bamboo shoot production means that a reliable supply of water such as from a river or bore is usually required.

Monopodial (running) bamboos are considered harder. They tolerate subtropical and temperate areas and can thrive with less water. Both types require most of
Table 1. Characteristics of bamboo species for shoot production

<table>
<thead>
<tr>
<th>Species</th>
<th>Origin</th>
<th>Min Temp (°C)</th>
<th>Shoot Size (kg)</th>
<th>Yield (t/ha)</th>
<th>Plants/ha</th>
<th>Shoot Season</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Dendrocalamus asper</em></td>
<td>Thailand</td>
<td>-3</td>
<td>0.5-4</td>
<td>8-10</td>
<td>100-400</td>
<td>200 Nov -May</td>
</tr>
<tr>
<td><em>Dendrocalamus latiflorus</em></td>
<td>Taiwan, S. China</td>
<td>-4</td>
<td>1-5</td>
<td>10</td>
<td>200-400</td>
<td>270 Nov -May</td>
</tr>
<tr>
<td><em>Bambusa oldhamii</em></td>
<td>Taiwan, S. China</td>
<td>-9</td>
<td>0.5-1</td>
<td>6-10</td>
<td>400-800</td>
<td>625 Oct -March</td>
</tr>
<tr>
<td><em>Phyllostachys heterocyclo pubescens</em></td>
<td>China, Japan, Taiwan</td>
<td>-15</td>
<td>0.3-1.5</td>
<td>10</td>
<td>300-800</td>
<td>625 Sep -Nov</td>
</tr>
</tbody>
</table>

*Dendrocalamus asper* is a sympodial bamboo best suited to tropical climates. Shoot characteristics vary between cultivars, the most common being a Thai cultivar known as Phai Tong Keo. The shoots of *D. asper* are commonly used for canning but are also suitable for fresh consumption.

*Dendrocalamus latiflorus* is a sympodial bamboo adapted to tropical and subtropical environments. It is commonly consumed as preserved shoots and traditional Japanese pickles. It is also consumed fresh in large quantities in Taiwan.

*Bambusa oldhamii*, a sub-tropically adapted sympodial bamboo, is the favoured shoot species in Taiwan, where it is cultivated on a large scale for shoots for fresh consumption and processing. Compared with other sympodial species it is more tolerant of lower temperatures, produces a smaller plant and lower yields per hectare.

*Phyllostachys heterocyclo pubescens* is commonly called “Moso”. Of the four varieties commonly utilised for commercialisation in Australia, Moso is the only monopodial species. It is better suited to temperate climates than sympodial species, but it is highly invasive by nature, requiring intensive management to ensure that it remains contained. In Australia, Moso yields a small winter crop of high quality shoots (around 300 g) from May to August, followed by a crop of larger (1 kg) shoots from September to November. Moso shoots must be dug by hand from under the ground to ensure their quality.

Other species sometimes harvested for shoots in Australia include *Dendrocalamus giganteus*, *Gigantochloa atter*, *Phyllostachys nigra*, *Bambusa vulgaris var. vittata*, *Bambusa balcooa* and *Bambusa arnhemica*.

**Species**

A large number of bamboo species have been introduced into Australia but few have exhibited the desired characteristics for commercial shoot production.

The main species presently grown in Australia for their shoots are *Dendrocalamus asper*, *Dendrocalamus latiflorus*, *Phyllostachys heterocyclo pubescens* “Moso” and *Bambusa oldhamii* (Table 1). These species can be obtained from specialist bamboo nurseries throughout Australia.

**Agronomy**

Many bamboos flower gregariously, that is, a clone of a species flowers at the same time across regions and even countries. Depending on the species, intervals between flowering may vary from a few decades to over a hundred years. The plants of gregariously flowering species typically produce seed and die after flowering. Propagation from this seed is possible but large variation occurs in the resulting plants.

Vegetative propagation of species that are known to have flowered recently is currently the only means to reduce these risks. Techniques of vegetative propagation include layering whole culms, partial and whole culm cuttings, node cuttings, branch cuttings and offset propagation.
Bamboo species can be planted at any time of the year but late winter or early spring is the favoured period. Plants are costly because propagation is slow, but recent advances in tissue culture have reduced prices and improved the availability of superior plant material.

Spacing recommendations (Table 1) need to be adapted to individual properties. When determining the distance between clumps, the size of the mature plant and its nutritional needs must be taken into account, as does the management technique to be employed on the plantation.

In areas with high rainfall and rich soils bamboos can be planted at smaller intervals and still obtain their required nutrients while in poor soils spacing may need to be increased.

After establishment, fertiliser should be applied to cover most of the space between plantings to encourage root growth in clumping species and rhizome growth in running species. Regular small applications are more productive than a single large annual application.

Fertiliser should be broadcast at around 300 kg/ha of complete NPK plus trace elements annually. Smaller amounts of fertiliser should be applied during the shoot season as it can cause soft and dark coloured shoots that are more susceptible to bruising and discolouration. Lime can be added as both a fertiliser and a neutraliser for acid soil.

Bamboo shoots contain 90% water and adequate water supply is essential, especially during the shoot season. The equivalent of 2,000 to 2,500 mm/yr of rainfall is the current recommendation for total annual water requirements. A combination of rainfall and irrigation should supply about 200 mm per month for the period commencing 2-3 months before shoot harvest until the completion of harvest. It is common to install drip irrigation in young plantations, graduating to spray irrigation in mature plantations.

A full canopy will smother weeds but in immature plantations it is important to control weeds as they compete with young bamboo for nutrients. Mulching helps to control weeds and improves water retention, thus shoot quality.

Shoots grown without exposure to sunlight are sweeter and lighter in colour. In the absence of an organic mulch, emerging shoots can be covered with soil or black plastic planter bags.

Bamboos produce numerous culms. It is important that dead culms and the thinnest culms are removed as there is a positive relationship between culm size and the diameter of the next season's shoots. To maximise shoot yield the majority of shoots need to be harvested each year. Depending on species, only 2 to 10 of the larger shoots should be allowed to grow into mature culms in order to maintain clump vigour. A mature clumping bamboo should have 8-12 culms of different ages present after thinning.

Pests and disease

Australia remains relatively free of the large number of bamboo specific pests and diseases, although bamboo mosaic virus (BoMV) is present. This virus attacks leaves, shoots and young culms and causes shoots to harden, resulting in poor eating quality. The virus affects the *Bambusa* and *Dendrocalamus* genera and is spread by mechanical means. Its distribution in Australia is presently very limited.

A number of leaf-biting and sucking insects, including aphids, can cause minor damage, especially to young plants. Scale insects are common but cause no obvious damage and are controllable using white oil.

The leaf rolling caterpillar *Crocidophora pustuliferalis* can colonise bamboo species with smaller leaves. Some problems have been encountered with rats nesting around the base of bamboos and damaging the underground rhizomes of the plant.
Harvesting and marketing

Good quality culinary bamboo shoots need to be crunchy yet non-fibrous. Shoot maturity determines fibre formation – younger shoots are less fibrous. Markets prefer shoots that are light in colour with creamy or white flesh. Dark coloured (brown, black or green) shoots are considered to be of low quality. Light coloured shoots tend have less bitter compounds and more delicate flavours. Premium maturity is indicated by the shoot’s height:base diameter ratio, ideally between 2:1 and 3:1. Mature bamboos may be harvested on a three or four day cycle.

Shoots of clumping species are harvested by severing them at the point where the softer shoot tissue joins the woodier rhizome. This point may be 100 mm to 200 mm below the soil surface. Harvesting running species is similar except that the whole shoot is dug from under the ground and the cutting point can be anywhere between 15 cm and 60 cm below the ground surface.

After harvesting, shoots should be pre-cooled as swiftly as possible using iced water baths or evaporative sprays and forced air cooling. Pre-cooled shoots are then washed or brushed to remove any foreign matter before the base is trimmed and any lose culm leaves removed. Trimming is especially important for forced air-cooled shoots as the cut base will dry out and crack during cooling and by trimming 0.5 – 1 cm of flesh off the base the appearance of the shoots is vastly improved.

Shoots are packed in 10 kg polystyrene boxes or waxed cardboard boxes before dispatch to market. The maintenance of the cold chain between the farm and the end consumer is the most important factor in maintaining product quality. Shoots should be cooled to 2°C and stored as close

Key Messages

- A plentiful supply of water (rainfall/irrigation) is essential before and during the shoot season and plantations should not be established if this cannot be guaranteed
- A labour-intensive crop, especially during the shoot season for harvest and culling of culms
- Most bamboo stock in Australia is unlikely to flower in the next few decades
- Prospective growers should contact the Australian Commercial Bamboo Corporation for advice and guidance

Disclaimer

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Table 2. Set up costs for 1ha of bamboo plantation for shoot production

<table>
<thead>
<tr>
<th>Species</th>
<th>Plants/ha</th>
<th>Price/plant</th>
<th>Plant material/ha</th>
<th>Land preparation</th>
<th>Planting</th>
<th>Irrigation</th>
<th>Labour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dendrocalamus asper</td>
<td>200</td>
<td>$25 - $35</td>
<td>$5000-$7000</td>
<td>$450</td>
<td>$200</td>
<td>$3500</td>
<td>$4000-$6000</td>
</tr>
<tr>
<td>Dendrocalamus latiflorus</td>
<td>270</td>
<td>$25 - $35</td>
<td>$6750- $9450</td>
<td>$450</td>
<td>$300</td>
<td>$3500</td>
<td>$4000-$6000</td>
</tr>
<tr>
<td>Bambusa oldhamii</td>
<td>625</td>
<td>$15 - $25</td>
<td>$9375- $15625</td>
<td>$450</td>
<td>$600</td>
<td>$4000</td>
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</tr>
<tr>
<td>Phyllostachys heterocycla pubescens</td>
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<td>$6000- $8000</td>
</tr>
</tbody>
</table>

Financial information

Table 2 details some of the expected costs for setting up one hectare of bamboo for shoot production. The cost and quality of plants varies widely, but tissue cultured plants are generally more even in quality and less expensive. Given the embryonic stage of development of the industry in Australia, it is impossible to provide anything more than a guide to costs and returns.

The area of commercial bamboo in Australia is small but is increasing, from just over 200 ha in 1999 to over 350 ha in 2002.

The Australian Commercial Bamboo Corporation is Australia’s largest single bamboo producer organisation. It estimates that in 2002 some 60,000 bamboo plants were distributed among its 69 members, representing an annual production exceeding 2,700 t by 2005. Australia’s actual production could be up to double this figure taking into account harvesting from wild stands.

The price obtained for bamboo shoots depends on the time of season with the highest prices achieved at the beginning and end of the season. In 2003 the average farm gate price for shoots was just under $3.00/kg and the cost of production, including post harvest handling and packing, was between $1.80 and $2.40/kg.

If domestic production could substitute for approximately one third of Australia’s annual imports, between 1,500 and 3,500 t of fresh shoots could be sold on the domestic market. While the development of the domestic market for bamboo shoots will be important to the future of the industry in Australia, the size of the market means that it could potentially be supplied by as little as 150 to 350 ha of plantation bamboo. If the Australian bamboo shoot industry is to grow to a substantial size, its future will therefore lie in the development of export markets. Japan, Taiwan and Singapore should be the first targets for market development by the industry.

Key statistics

- Australia imports 4,000-10,000 t of canned bamboo shoots annually
- The worldwide consumption of bamboo shoots is estimated to exceed two million t/yr
- It is estimated that Australia’s annual production will exceed 2,700 t by 2005

Financial information

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<td>$450</td>
<td>$600</td>
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</tr>
</tbody>
</table>

Culinary bamboo shoots
Key references


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About the authors

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Long white radish (Daikon)

Introduction

Long white radish (*Raphanus sativus* L.), or daikon, belongs to the mustard family, Brassicaceae. They have been consumed in China since 400 BC and are still one of the most important vegetables in Asia with a production of approximately 20 million t/year.

The radish plant is erect, with a short, non-branching stem supporting leafy rosettes. It has a swollen tap root with narrow, round petioles and the mid-vein is light green in colour. The radish leaf is rich in carotene (pro-vitamin A) and calcium while the root is a good source of vitamin C and some potassium and dietary fibre. The leaf, root and sprout are consumed as a vegetable. Long white radish, which is one of four types of radishes, is the most extensive vegetable crop grown in Asia. The other types are twenty-day radish, leafy radish and sprout radish.

Markets and marketing issues

Most of Asia would be considered as suitable markets for long white radish even in Australia. Japan, for instance, produced 1.36 million t of radish on 42,500 ha in 2002, valued at ¥109 billion (equivalent to A$1.45 billion [A$ = ¥75]) in wholesale markets. Production of long white radish in Japan was reduced from 2 million t in the 1980s to 1.5 million t in the 1990s, 1.4 million t in the early 2000s, and production now

Japanese daikon grown on the Central Coast of NSW. Green shoulder (neck) daikon is used for the fresh market whilst white shoulder is used for processing.
appears to be declining in most Asian countries as it is a heavy vegetable which brings low prices. However, because of the demand for processing products such as radish pickles, takuan, dried radish and frozen radish, opportunities exist for supplying fresh and processed long white radish to Asia, particularly Japan which, it is believed, imports a large amount of radish in semi-processed forms for the pickle industry.

Long white radish imported into Japan is classified under the code 105 “Salad beetroot, salsify, celeriac, radishes and other similar edible roots (0706.90.090)” which shows that imported quantities of daikon were 3,000-6,000 t of dried daikon per year at approximately ¥190/kg (CIF) during the last seven years from 1995-2002. Japan also imported 1,000-2,000 t of fresh radish mainly from China with very cheap CIF prices at about ¥50 mark in the last three years from 2000-2002. The wholesale and retail prices of daikon in Japan provide an indication of the import prices for daikon (Table 1).

Long white radish can be processed into products such as pickles, dried and frozen radish.

Pickled radish comprised 32% of approximately A$6 billion of the Japanese pickle markets in the 1990s. Of these, takuan is the most popular processed form of pickled radish. The production of takuan has declined from 250,000 t in 1985 to 210,000 t in the 1990s. In 2002 the Japanese pickle market was 1,319,348 t valued at approximately ¥725 billion, equivalent to A$9.7 billion in the wholesale market.

There are four types of takuan available in Japanese markets: pickling radish with rice bran (nakazuke takuan), pickling radish with miso (misozuke takuan), pickling radish with sake lees (kasuzuke takuan) and pickling radish with soy sauce (shozuzuke takuan). One form of pickling in which radish is the major ingredient, referred to as one-night quick pickling (ichiyazuke), has recently become popular in Japan.

Information in Japan on the importation of radish for takuan is unclear, e.g. in 1991 Japan produced 210,157 t of takuan but in the same year produced 1,692 t of dried radish as well as importing 30 t of fresh radish and 7,139 t of salted radish, making approximately 10,000 t of material for the production of takuan. The gap of approximately 200,000 t of takuan has raised a question mark about supply sources. Separate import statistics are not kept for takuan as it would be classified under ‘Materials for other salted & processed materials’ of which Japan imported 201,420 t valued at 30.8 billion (A$410 million) in 2002.

Dried radish is used for cooking, soup, nigiri rice and ‘gobugobu’ pickles. There are three types of dried radish available in Japanese markets, and they are fine sliced (usukiriboshi), long strip or ribboned (kiriboshi) and cross-cut (wagiriboshi).

Production of dried radish in Japan has increased up to nearly 6,000 t in 2000 but CIF import prices have stayed at around ¥190 (A$2.53) mark per kg (Table 1).

Frozen radish is used mainly for Japanese traditional food ‘oden’ (casserole) in which the root is cross-cut approximately 5-6 cm in length, blanched and frozen by Individual Quick Frozen (IQF) technology. Frozen radish might be imported into Japan under ‘Other Frozen Vegetables [Code 490, No. 0710.80.090]’ and has been dramatically increased from 61,953 t valued at approximately ¥11.4 billion in 1993 to

---

Table 1. Production and importation of daikon in Japan, 1985-2002

<table>
<thead>
<tr>
<th>Year</th>
<th>Production</th>
<th>Importation</th>
<th>CIF prices (fresh)</th>
<th>Yen/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area ha</td>
<td>Volume ton</td>
<td>Fresh ton</td>
<td>Dried ton</td>
</tr>
<tr>
<td>1985</td>
<td>66,900</td>
<td>1,856,000</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>1995</td>
<td>53,300</td>
<td>1,609,000</td>
<td>522</td>
<td>2,926</td>
</tr>
<tr>
<td>1997</td>
<td>49,800</td>
<td>1,487,000</td>
<td>138</td>
<td>3,163</td>
</tr>
<tr>
<td>1999</td>
<td>47,700</td>
<td>1,466,000</td>
<td>815</td>
<td>5,576</td>
</tr>
<tr>
<td>2000</td>
<td>45,700</td>
<td>1,419,000</td>
<td>1,018</td>
<td>5,757</td>
</tr>
<tr>
<td>2001</td>
<td>44,100</td>
<td>1,413,000</td>
<td>2,028</td>
<td>4,546</td>
</tr>
<tr>
<td>2002</td>
<td>42,500</td>
<td>1,361,000</td>
<td>1,740</td>
<td>3,765</td>
</tr>
</tbody>
</table>

154,618 t, valued at ¥27.2 billion (A$363 million) in 2002.

**Production requirements**

Long white radish is essentially a cold-season vegetable. However, it can be grown year round in Australia.

Producing high quality radish during mid-summer and winter requires great care as high summer temperatures and strong sunlight prompt the roots to develop rapidly in size, and become pithy soon after maturity.

Low temperatures slow vegetative growth, stimulate the forming flower buds and cause bolting in spring. Bolted radish is not marketable as the roots become woody and pithy. Therefore, the best time to grow long white radish is spring and early autumn.

**Varieties/cultivars**

There are several varieties of long white radish grown in Asia, the main differences between them being size, root shape and root neck colour. The main root shape grown is triangular with a white neck.

When selecting a radish variety, also check shape and colour, since market requirements vary with ethnic groups.

The Chinese and Indo-Chinese require a white-necked (shiro-kubi), thin (5 cm diameter) root growing to 25 cm in length, but the Japanese and Korean fresh market prefers the green-necked (ao-kubi), fat (7-10 cm diameter) radish grown to 30-35 cm in length.

For processing, the root shape is not as important but the flesh must be crunchy, and low in water content for faster drying. It must not be pithy.

Radishes are marketed when the root mass is approximately 300-1000 g, but depending on the type and market, they can be grown to even greater weights; a special Japanese variety called ‘Sakurajima’ (shape 5) can be grown up to 20 kg and a variety called ‘Moriguchi’ (shape 8) can grow up to 120 cm long with a width of 2.5 cm (Figure 1).

There are three other types of radish used in Asia which are:

**Twenty-day radish:** Most commonly cultivated radish in Australia and other Western countries. There are several varieties, differing in size and shape, but they all produce relatively small roots of approximately 30-40 g and are coloured red, white or red/white. They are very fast growing, maturing in approximately 30 days in summer and 45 days in winter.

**Leafy radish:** Grown as a leafy vegetable, this radish has large foliage and small roots. The plant is harvested when it has grown 10-15 leaves, each measuring 25 cm in length. The growing method is similar to twenty-day radish.

**Sprout radish:** A specific variety that grows long, white stems. Seeds are sprouted in moist, dark conditions at approximately 20-25°C and grow to approximately 15 cm over ten days and are marketed after the roots are removed. The Japanese are heavy consumers of sprout radish under the name ‘Kaiware daikon’ with approximately 15,000-20,000

![Figure 1. Root shapes of radishes. Shapes 1 and 2 are fresh market types; the others are mainly for processing.](image)
When the seedlings are established 3–4 weeks after sowing, thin them to 20–25 cm apart, side dressing with potassium nitrate after thinning if necessary. White radish needs to be grown 50–60 days in summer and 70–80 days in winter for the fresh market when the fresh root weighs approximately 0.5–1.0 kg.

Pest and disease control

Weeds are a problem for long white radish as their slow growth in the early stages makes them poor competitors with weeds. Weed control from sowing time onwards is essential, otherwise yield and quality are affected.

Pre-germinate weeds before planting the crop and control them either with knockdown herbicides or by cultivation. It is usually sufficient to hand-weed fast-maturing vegetables like white radish once during their growth.

Radishes are attacked by the same pests as other members of the Brassica family.

The most serious pests found in the New South Wales radish crops are cabbage white butterfly and aphids; nematodes and black beetle sometimes cause root damage.

The most important disease is bacterial soft rot (Edwinia carotovora), which is also found on other Brassica species. The bacteria are commonly found in decaying vegetable matter in the soil. They invade damaged tissue, often following other diseases.

Hot, wet weather favours soft rot. A soft, mushy decay develops from the root ‘neck’ (near the ground) and eventually the entire root is affected by a very smelly soft rot. Soft rot can also be a postharvest problem.
The disease is controlled by avoiding damage to the plant during side dressing or harvest, destroying diseased crop residues, and rotating the crop every three or four years.

Radishes are sometimes attacked by yellows (*Fusarium oxysporum*). The fungus survives for long periods in the soil, infecting the plant through roots and growing in the water-conducting tissues. Warm weather favours the disease.

Affected plants lose vigour and the lower leaves on one side of the plant turn yellow; a brown discolouring develops under the skin of the root. The disease is controlled by using resistant varieties, and rotating crops every three or four years.

**Harvesting and packaging**

Fresh market radish varieties are harvested approximately eight to ten weeks after sowing. The roots are mature when they reach a 5–10 cm diameter at the 'neck'.

Radishes are hand-harvested and tied in bunches of two or three roots, or sold in bulk in cartons of five, ten or fifteen kg, or sold individually. Radishes sold on the market have full foliage or are trimmed to leave 10 cm of foliage.

The root should have smooth white skin without blemishes. Internally, root flesh should be compact with no signs of pitthiness or hollowness.

Like other vegetables, radishes are susceptible to wilting. If possible, harvest them when it is cool, preferably in the early morning, and keep the produce cool and moist until placed in cold storage at a temperature of 0°C and a relative humidity of 90–95%, but do not freeze the produce, as it can suffer extensive damage when thawing.

These precautions should maintain the quality of the radish and increase its storage life. The radish has a short shelf-life if pitthiness develops inside the root.

In hot weather, pre-cool the crop to its optimum storage temperature as soon as possible after harvesting.

This is best done with forced-draught air-cooling. Vacuum cooling benefits produce with a high, surface area-to-volume ratio, where rapid cooling is important, such as leafy vegetables.

Processing radishes are harvested approximately 10–12 weeks after sowing, because processing cultivars need to be grown longer than fresh market types. Roots are thoroughly washed by brush-washer machine or by hand, and are prepared as per market requirements.

To make *takuan*, all plants need to be dried for approximately 3–5 days in shaded areas with good ventilation for the roots to reduce to approximately 50% of their fresh weight.

To make dried sliced radish, the leaf should be trimmed and roots are sliced and dried by either sun or in a drier until they are approximately 10% of their fresh weight. The dried radishes have a strong odour, and packaging them in sealed plastic bags is desirable.

**Precautions with pesticides**

Long white radishes are eaten raw or cooked without peeling, so extreme care must be taken if using pesticides. They must be registered and approved for use and applied according to the directions on the product label. Postharvest chemical treatments are generally unnecessary.

**Quarantine requirements**

A declaration must be provided to the Australian Quarantine and Inspection Service (AQIS) that the daikon crop has been inspected by an authorised person and is free of burrowing nematode (*Radopholus*...
The crop must have been grown on a farm that has been inspected by soil sampling during the growing season and found to be free from *Radopholus similis*. *Radopholus similis* is present along the north–east coast of Australia, especially in banana–producing areas.

**Financial information**

Long white radish can be harvested at different root weights from 300 g to 1,000 g or even up to 1,500–2,000 g depending on the end uses. The production costs therefore vary between time of harvesting, cultivars, seasons, growing locations, packaging and time of consignment. Whilst the break-even for fresh daikon is estimated at around A$0.55/kg (or $0.27 per root), it is understood that break-even for dried daikon is high, estimated at A$5.57/kg (Table 2). This is probably caused by intensively high labour costs.

Exporting of Australian dried daikon to Japan remains possible if the Australian daikon industry reduces its production cost by mechanising production systems, translating its “safe and high quality” vegetables into sales with acceptable margins.

Table 2 shows an enterprise budget for 1.0 ha for Daikon located in Somersby, New South Wales, for a period of 8–10 months.

### Table 2. Gross margin for Diakon growing on the Central Coast of NSW, 2004

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost (A$)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sales</strong></td>
<td>55,000</td>
<td>roots</td>
<td>A$0.40/root</td>
<td>22,000</td>
</tr>
<tr>
<td><strong>A. TOTAL INCOME</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Variable costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>8hrs</td>
<td></td>
<td>18.48/hr</td>
<td>147.84</td>
</tr>
<tr>
<td>Diakon seed</td>
<td>2.5kg</td>
<td></td>
<td>400.00/kg</td>
<td>1,000.00</td>
</tr>
<tr>
<td>Planting labour</td>
<td>4hrs</td>
<td></td>
<td>18.48/hr</td>
<td>73.92</td>
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<tr>
<td><strong>Fertilisers</strong></td>
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<td></td>
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<tr>
<td>Agricultural lime</td>
<td>4.0t/ha</td>
<td></td>
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<td>520.00</td>
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<tr>
<td>Fertilisers Multigro</td>
<td>1.5t/ha</td>
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<td>495/t</td>
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<tr>
<td>Spreader machinery cost</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Labour</td>
<td>2hrs</td>
<td></td>
<td>18.48/hr</td>
<td>36.96</td>
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<tr>
<td><strong>Nematode control</strong></td>
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<tr>
<td><strong>Weed control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hand weed labour (2 times)</td>
<td>10days</td>
<td>8hrs/day</td>
<td>18.48/hr</td>
<td>1,478.40</td>
</tr>
<tr>
<td>Pesticides, machinery, labour</td>
<td></td>
<td></td>
<td></td>
<td>48.14</td>
</tr>
<tr>
<td>Irrigation (water pump &amp; mainten)</td>
<td></td>
<td></td>
<td></td>
<td>219.50</td>
</tr>
<tr>
<td><strong>Harvesting</strong></td>
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</tr>
<tr>
<td>Labour</td>
<td>59.5days</td>
<td></td>
<td>147.84/day</td>
<td>8,796.48</td>
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<td><strong>Transportation &amp; fees</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freight to Sydney</td>
<td>2,291.50 ctns</td>
<td>0.50/ctn</td>
<td>1,145.75</td>
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</tr>
<tr>
<td>Levies</td>
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<td>0.25/ctn</td>
<td>572.87</td>
<td></td>
</tr>
<tr>
<td>Agent commission 10%</td>
<td>2,291.50 ctns</td>
<td>0.10/ctn</td>
<td>229.15</td>
<td></td>
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<tr>
<td><strong>B. TOTAL VARIABLE COSTS</strong></td>
<td></td>
<td></td>
<td></td>
<td>15,100.40</td>
</tr>
<tr>
<td>GROSS MARGIN (A-B)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Break even for Fresh Daikon</td>
<td></td>
<td></td>
<td></td>
<td>6,899.61</td>
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<tr>
<td>Break even for Dried Daikon</td>
<td></td>
<td></td>
<td></td>
<td>0.27</td>
</tr>
<tr>
<td><strong>For Dried Daikon 1)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drying</td>
<td>357 hrs</td>
<td></td>
<td>7.00/hr</td>
<td>2,499.00</td>
</tr>
<tr>
<td>Loading drying trays (1 min/tray)</td>
<td>250 trays/t</td>
<td>0.06/kg</td>
<td>3,000.00</td>
<td></td>
</tr>
<tr>
<td>Unloading trays &amp; packaging</td>
<td>40 hr/ha</td>
<td></td>
<td>12.00/hr</td>
<td>480.00</td>
</tr>
<tr>
<td>Packaging (50t fresh less 20% loss = 4t dry)</td>
<td>0.30/kg</td>
<td>1,200.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>C. TOTAL VARIABLE COSTS</strong></td>
<td></td>
<td></td>
<td></td>
<td>22,279.15</td>
</tr>
<tr>
<td>Break even for Dried Daikon</td>
<td></td>
<td></td>
<td></td>
<td>$5.57</td>
</tr>
</tbody>
</table>

1) Figures in 1997 by Gas drying
Key references


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Key Messages

- Low capital investment but long term commitment required
- Labour intensive
- High returns are possible

Key statistics

- Japan produced 2 million t of daikon in the 1980s but has declined to 1.4 million t in the early 2000s
- There is a potential market in Japan for semi-processed and processed daikon
- The imported CIF prices of processed daikon in Japan are low, at around ¥190 (A$2.53) per kg

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Edamame
(Vegetable green soybean)

Acknowledgement is given to Vong Q. Nguyen, the author of this chapter in the first edition of this publication.

Introduction

Edamame or vegetable soybean (Glycine max [L.] Merr.) is a traditional food of Japan and China that is now consumed throughout East-Asia and elsewhere in the world with expatriate Asian populations. Traditionally, the whole plant is harvested green when the seeds have reached their maximum size but before any yellowing has occurred. The plants are then transported intact to market to assure customers of the freshness of the product. After purchase, pods are removed from the plant, boiled and consumed as a snack food. To do this a person will squeeze the pod between thumb and forefinger to cause the seed to slide out directly into their mouth. Only the seed is eaten as the pod is fibrous and unpalatable. In Japan, the common use for edamame is as a snack consumed with beer in commercial establishments. Boiled salted pods should be blemish-free, bright green and have a sweet flavour with a slight nutty texture. In other parts of Asia and increasingly in western countries, the seeds are shelled from the pod and used in stir-fries.

Edamame has the same health benefits as are reputed for grain soybean. Notably, a reduced risk of cardiovascular diseases, various cancers, osteoporosis and menopausal symptoms associated with soybean consumption. Importantly, edamame is more palatable to the western consumer than many other soy products.

Until recently, production of edamame for the fresh-frozen market for export to Japan...
was focussed in Taiwan where technologies were developed for mechanised harvesting and processing into a consistently high quality product. More recently, production has moved to China, Thailand and Vietnam following investment and technology transfer from Taiwan.

**Markets and marketing issues**

There is a limited but high value market to supply restaurants during the Australian summer and autumn with freshly produced edamame. Expansion beyond this will depend on development of an export market to Japan or increased consumption in Australia. Both these areas show potential, but both require market development.

There is potential for year-round production in Australia using a range of varieties and locations from north Queensland to Victoria. The main period of production is likely to occur during the Australian summer and autumn. Production at this time corresponds with a production gap in Japan and very high prices for fresh product. The Japanese government has recently relaxed quarantine restrictions previously in place to protect against fruit fly.

Current Australian production of edamame is of very small volume and entirely used to supply fresh markets. Most varieties of edamame are poorly adapted to Australian growing conditions. As a result, good quality planting seed is difficult to produce and growers find it difficult to achieve good crop establishment and poor productivity results.

Edamame is marketed in one of three forms:

1. Attached, in which whole plants are transported to market after being lightly trimmed of leaves. Japanese customers believe they are able to better determine the freshness of product of this type. In the initial phases of market development in Australia, this is the form that is most likely to succeed in developing niche markets.

2. Detached, in which pods are marketed after plucking from the plant. Detached pods may be marketed fresh or frozen. Frozen beans of this type are the main type imported by Japan.

3. Shelled, in which the seeds are first shelled from the pods. Product of this form is sometimes sold fresh in Chinese markets, but generally product of this type is sold frozen for inclusion in stir-fries and vegetable blends.

Annual consumption in Japan is in the order of 160-180 000 t/year of which around a third is imported, principally as frozen product. Freshness is important, even for the frozen product. Imports of frozen beans into Taiwan are also substantial but largely controlled by Taiwanese owned processors with frozen production from China, Thailand and Vietnam.

Australian prices of around $6 to $10 /kg for fresh-attached have been quoted at fresh markets in capital cities. However demand can be patchy depending on whether key buyers realise the availability of the product and on its quality.

**Production requirements**

Production of edamame is similar to grain soybean in that time from sowing to flowering of the crop is highly sensitive to daylength and temperature. Time to flower sets the size of the plant as little growth occurs after flowering. It is therefore important to use a variety adapted to the latitude and sowing date to ensure that plants grow to the correct size for the market.

In general, varieties for southern New South Wales and Victoria need to be of early maturity type and are only suited to sowing dates of late October through to early December. Edamame can be sown from November through to January in northern New South Wales and southern Queensland, and could be produced during the winter season in tropical regions.

Maintenance of the crop in a well watered condition from flowering through to harvest maturity is important to ensure that seeds are large and high in sugar content. Water stress results in smaller seeds which are reputed to have tough texture.

Production of high quality planting seed is a key constraint to production. In many Australian cropping environments, traditional

The traditional setting for consumption of edamame is as a snack with beer
(Photograph: Andrew James)
Table 1. Most popular and emerging varieties and cultivars in Australia

<table>
<thead>
<tr>
<th>Variety</th>
<th>Synonyms</th>
<th>Area of adaptation</th>
<th>Key characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSB #1</td>
<td>Vesoy #1</td>
<td>NSW</td>
<td>Good quality for fresh market, pods susceptible to bruising so less suited to mechanical harvest and freezing.</td>
</tr>
<tr>
<td>GSB #4</td>
<td>Vesoy #4, CM #1, Chiang Mai #1</td>
<td>NSW</td>
<td>Good quality for fresh market, pods susceptible to bruising so less suited to mechanical harvest and freezing.</td>
</tr>
<tr>
<td>KS #1</td>
<td>Taisho Shiroge, Kaohsiung #1, and many other local names throughout south east Asia.</td>
<td>central NSW to southern Qld</td>
<td>Good quality for fresh or frozen market.</td>
</tr>
<tr>
<td>C784</td>
<td></td>
<td>Qld</td>
<td>Good quality and improved agronomic characteristics.</td>
</tr>
<tr>
<td>Tanbaguro</td>
<td>northern NSW to central Qld.</td>
<td></td>
<td>Very large black seed with high sugar content and excellent eating quality.</td>
</tr>
</tbody>
</table>

Varieties

Traditionally, cultivars with green seed coat and cotyledon at maturity have been preferred by growers because the harvest period can be extended closer to maturity of the plant without experiencing the yellowing associated with maturity. Seed pods should have sparse grey pubescence and contain three seeds per pod, though two seeded pods are acceptable in the market. There should be an absolute minimum of one seeded pods because they are disliked by the consumer, requiring greater effort to shell them. Four seeds in a pod are not preferred because the

varieties have uneven ripening within a plant and severe shattering of grain. Often pods at the top of the plant shatter while pods lower on the plant are still green. If desiccated and mechanically harvested, large seed with very low moisture content tends to be mechanically damaged, whilst immature seed with high moisture content tends not to be viable after drying or have low vigour. Attempting to establish a crop with seed of low germination or low vigour results in uneven plant stands and highly variable quality.

Edamame seed is large and of epigeal germination, that is the plant lifts cotyledons from the soil during germination. In order to achieve good establishment, it is necessary to start with high germination seed with high vigour and plant it into a friable seedbed. Hard setting or crusting of the seedbed can result in poor establishment because the cotyledons are prone to being trapped under the crust.

Growing vegetable green soybean for Japanese domestic fresh markets and potential export to Japan in frozen form.

Vegetable green soybean for seed production for export to Japan. The average yield of seed is approximately 1.5 t/ha.

Growing vegetable green soybean for Japanese domestic fresh markets and potential export to Japan in frozen form.
number four is considered unlucky in Japanese culture.

**Cultural practices and agronomy**

Cultural practices, fertiliser and herbicide rates are similar to that of grain soybean, except that plant population should only be around 50 000 to 70 000 plants/ha. Plants should be evenly spaced and a higher standard of seedbed preparation, weed and insect control is necessary as edamame seed tends to be more difficult to establish than grain soybean. Inoculation of the seed with rhizobium strain CB1809 is necessary.

For seed crops, plant populations of greater than 250 000 plants/ha are desirable to maximise seed yield as is sowing during the early part of the planting window for soybean in the region of cropping. The crop needs to be well watered at planting, flowering and early pod fill to ensure good growth and pod set. The crop should be maintained substantially free of sucking and chewing insects. Mild water stress during late pod fill is desirable. Some varieties may need to be desiccated prior to harvest at moisture content of 13–14%. The same desiccant and rates as used for soybean seed is appropriate. The aim of this recommended agronomic package is to maximise seed number and minimise seed size, as smaller seed tends to maintain germination and vigour better during harvest, cleaning, storage and planting.

**Pest and disease control**

Generally, little insect control is necessary before early pod fill. The one exception to this is if more than one in ten plants have caterpillar damage to the growing point. Once early pod-fill has been reached it is important to scout the crop for sucking bugs and chewing insects. Economic thresholds for insect numbers in edamame have not been developed, but are likely to be somewhat lower than the recommendations for food grade soybean in the same region. At this stage, the recommendations for food grade soybean should be used as a guide. Only insecticides registered for soybean can be used and withholding periods strictly observed.

**Harvesting/handling/storage/post harvest/processing**

Two techniques for harvesting have been trialed in Australia. The crop may either be hand harvested as intact plants that are then trimmed of excess leaves or machine harvested using a modified green-bean picker. Hand harvested product is generally far superior in quality to the machine harvested, although this machine harvest quality varies dramatically with the skill of the operator and with adjustment and modifications to the equipment. Hand harvesting is however labour-intensive and therefore expensive. Efficiency of hand harvest is improved by having low plant populations and good agronomy which result in larger plants.

Edamame is best harvested early in the day for peak moisture content, flavour and texture. If machine harvested, it is possible to perform the operation during the night whilst conditions are cool. Flavour quality peaks 3–5 days before seed size is maximised. Research is currently underway to determine methods for practical determination of harvest time. Standards for the fresh attached product are absolute minimum of empty and one seeded pods, pods to be longer than 4.5cm and wider than 1.3cm and greater than 350 pods/kg.

In order to supply fresh edamame to markets with produce over a sufficiently long production season to permit market development, production needs to occur over at least a three-month period from any region of production. Australian markets for fresh produce are often up to 2,000 km by road transport from areas of production. Since freshly harvested edamame commands the highest price in the market, techniques were needed to transport fresh edamame to market in good condition. In CSIRO trials, whole plants were harvested at the R6 or R7 stage and transported intact to market using technology similar to that employed for broccoli, ie packing in ice and transport in polystyrene cool boxes. Customers were delighted with the freshness and quality of the product. Blanching, freezing and transport of edamame is a similar operation as freezing of other vegetable crops.

For non-traditional consumers of edamame, previously shelled product is desirable as hand shelling is time consuming.
Mechanised edamame shelling equipment has been produced and should be considered in developing non-traditional markets.

**Financial information**

Yields of around six to nine t/ha have been reported, although it appears possible to substantially exceed this level with good agronomic management. Complete crop failures have occurred because of poor quality planting seed or poor quality of harvested product due to insect damage. At this stage it is difficult to produce gross margins of any validity until improved varieties are trialed in several production areas.

**Future outlook**

Once Australian production is underpinned by good agronomic research and improved varieties, harvest, handling and processing technologies, substantial expansion in supply of fresh-attached product and in frozen detached and shelled product is likely to occur. Japanese trading houses have expressed interest in import of fresh-attached type edamame during the January to May production gap in Japan.

**About the author**

Dr Andrew James is the soybean breeder with CSIRO Plant Industry. He has worked on soybean improvement projects in Australia, Vietnam and Thailand. Dr James currently leads the national soybean improvement program with inputs from state departments of agriculture in Queensland, New South Wales and Victoria, the Rural Industries Research and Development Corporation, the Grains Research and Development Corporation, the Australian Centre for International Agricultural Research, the Sugar Research and Development Corporation and Australian and international industry.

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**Key references**


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Japanese ginger
(Myoga)

Richard Warner

Introduction

*Zingiber mioga*, commonly called myoga or Japanese ginger, is a traditional Japanese vegetable. Myoga is the most cold tolerant species of the ginger family and is widely cultivated throughout Japan. Myoga is a typical ginger plant with a thick rhizomatous but inedible rootstock. Myoga is grown for spring shoots, or more commonly, for sterile flower buds produced during summer.

Myoga ginger is a perennial, woodland plant from Japan. The plant’s top growth is frost tender and senesces in winter. It regenerates in spring from underground rhizomes and produces dense foliage on robust pseudostems 1.5 to 2 m high. Under Australian conditions, myoga pseudostem growth sunburns without shading.

Myoga buds emerging from mulch

The flower buds, which are produced at ground level from underground rhizomes during summer are used fresh as flavouring in a wide range of foods including salads, sushi and soups. The Japanese market consumes approximately 10,000 t annually, grown mainly during the summer months of June to September. Winter production of myoga in Japan is produced in heated glasshouses and is called ‘house myoga’. The opportunity exists for Australian grown myoga to be supplied to the Japanese during the ‘out of season’ months in competition with ‘house myoga’. The Australian market offers the opportunity to supply a product which is not widely known but has significant potential.

Since 1990, myoga has been the subject of intensive research and development activity. Production techniques including annual production protocols in the warm coastal regions of central

Suitable for production
- Coastal areas in Qld from Cairns to Bundaberg
- Albion Park in NSW
- New Norfolk in Tas
Queensland have been proven which enable the harvest period to extend to six months minimum each year. Trial marketing has been completed in Japan and in the major cities of Australia. Product quality has been very well received in Japan and Australia and the supply chain to both has been successfully implemented.

**Markets and marketing issues**

The Japanese and the Australian markets are seen as the principal potential markets for fresh Australian grown myoga. The Japanese market is supplied mainly from summer production with plants grown in soil and in ambient conditions.

House myoga or winter production in Japan is expensive to produce and fresh Australian myoga harvested from November to June is competitive with Japanese house myoga.

Trial commercial shipments of Australian myoga have been successfully airfreighted to Japan and distributed in Tokyo and Osaka using an established supply chain specialising in the distribution of Tasmanian grown salmon. The quality of Australian grown myoga compared highly with local product.

The Australian market has been supplied with myoga grown in New South Wales from January to April. The Sydney market has been the major focus with supplies also going to selected markets in Brisbane, Perth and Melbourne. Apart from Japanese residents, myoga is not widely known in Australia and therefore presents an opportunity to expand its use in western cuisine.

**Production requirements**

Myoga grows naturally in shaded wooded areas in Japan. In Australia, myoga requires shading of 30% to 50% provided by the use of shadecloth. The soils must be free draining preferably alluvial loams or sandy loam.

Plants grown in ambient conditions will produce flower buds for a period of up to six weeks which is not long enough to create a presence in the market or provide continuity of supply to the market. A production method, using forced techniques including chilled root-stock, day length manipulation and minimum night temperatures of 16 degrees, has been proven. The coastal regions of northern New South Wales and central Queensland can provide ideal conditions which allow for sequential plantings to give a lengthened harvest period of at least six months, which both the Japanese and Australian markets require.

Myoga is planted into raised beds of 1.2 metres wide with two rows per bed with 40 cm between the rows and 40 cm between the plants. The beds are covered by an open mulch (pine shavings or similar) to allow the flower buds to emerge from beneath the soil surface into the mulch. The mulch allows diffused light to reach the buds, which produces a pink colour, which the market demands.
Varieties

Myoga varieties from Japan are not named but are identified only as having been grown in a particular region or as early, mid or late season myoga. The Australian research and development program has identified a superior variety which has demonstrated high yields of highly coloured flower buds in a range of production areas extending from Tasmania to Rockhampton in Queensland. The superior variety performs particularly well under forced conditions.

Cultural practices

The soil should be cultivated to a fine tilth and bedded up prior to planting. The plants should be cooled prior to planting either in the soil from a cool climate (Tasmania) or from plants cooled in a store. The plants should weigh at least 100 g each. The plants are planted on raised beds with 0.8 m between the beds for easy access for harvest and other activity. Wood shaving mulch is applied to a depth of 100 mm over the full width of the bed.

Irrigation can be provided by overhead mist sprinklers or drip tube laid on the soil surface but beneath the mulch. Myoga will not tolerate water logging.

Myoga produces a very vigorous and dense canopy of pseudostems early in the growing season and then goes on to produce a vigorous rhizome ‘mat’ and yields of flower buds of up to 10 t/ha. Phosphorus and potassium should be applied as a mix before planting at the rate of approximately 400 kg/ha and regular applications of nitrogen should be made throughout the growing season at approximately 30 kg of N per hectare each four weeks. Leaf analysis will provide more accurate information to determine nitrogen applications. Excess nitrogen will promote vegetative growth at the expense of flower production.

Shade should be provided by the erection of a structure to carry shadecloth of 30% to 50% with vehicle access provided.

Pest and diseases

The most serious fungal diseases, reported in Japanese literature but not found in Australian grown myoga are *Pythium zingiberum* causing root or rhizome rot and a leaf spot caused by *Pyricularia zingiberi*. Myoga is also known to be susceptible to Cucumber Mosaic Virus (CMV). The myoga plants being grown in the Tasmanian foundation nursery have been tested free from CMV.

Some slug damage can occur after periods of rain but is readily controlled using commercially available repellents. No other pests or diseases are reported in literature or observed in Australian grown myoga.

Harvesting and post harvest handling

Flower buds are picked by hand as soon as they emerge through the mulch layer. If harvesting is delayed much beyond this time the flower buds become deep.
Japanese ginger green on their tips and rapidly progress to anthesis. Green buds with emerged flowers are not marketable.

Highest quality buds are large and plump with a distinct pink to crimson colour weighing between 15 and 25 g. Experienced pickers will harvest 10 kg per hour and are able to exercise judgement and only harvest the highest quality flower buds.

Freshly harvested flower buds are transferred to cool rooms as quickly as possible to remove the field heat. The buds are washed in cool water. Washed buds are stored at 4 degrees until they are graded and packed by hand into 75 g or 150 g punnets. Grading is done using Japanese quality standards available on guide charts showing the essential criteria of shape, weight and colour.

Myoga destined for Japan will be inspected for pest contamination by AQIS staff prior to the issue of a phytosanitary certificate that is a requirement of the Japanese import authorities. The myoga packing premises used for export will require AQIS certification.

Packed myoga should be stored at 4°C prior to consolidation in airfreight containers. Myoga destined for the Australian market should also be stored at 4°C prior to delivery.

The graded flower buds are packed into clear clip-top retail packs of 75 to 150 g each and these packs are packed into protective polystyrene outers complete with lids.

### References


### Financial information

A financial model has been prepared to examine the feasibility of production and processing myoga in soil as a perennial crop. In the model, production and processing have been treated as a separate business from marketing, which could be handled by another entity.

The financial model looked at the first ten year life of a one ha plantation complete with shade house and irrigation. Yield of the mature plantation in year three was 10 t and the price was established at $A24.70/kg which was based on the weighted average of the price achieved in Japan and Australia. The total accumulated capital investment cost is $A102,750 and the net operating profit is $A56,920 in year three.

The model shows a net present value of $A250,768 and an internal rate of return of 28% with no allowance made for the sale of second grade buds.
About the author

Richard Warner has been involved in horticultural production and marketing since 1971. He has managed his own business specialising in production of hops, berry fruits and vegetable seeds. He has chaired a number of agricultural related businesses.

In 1990, in association with Mr Peter Shelley, he commenced trial production of myoga. An intensive research and development program was commenced in 1994 into myoga production and marketing which concluded in 2003 when a student completed her doctorate into myoga production issues.

Richard continues to manage his own business specialising in berry fruit production.

Much of the basic research on the myoga growth model was developed in a research higher degree study by Kristen Stirling at the University of Tasmania. Research has been funded by Agrilink Asia Pacific Pty Ltd and the Australian Research Council through an APA (Industry) grant, and by RIRDC.

Key statistics

- Japanese production is approximately 10,000 t annually grown mainly in the summer months of June to September

Key messages

- ‘Out of season’ Australian grown myoga has the competitive advantage of being produced under favourable naturally occurring conditions found in coastal Queensland
- The Australian myoga variety has provided excellent yields of high quality buds

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Japanese taro (Sato-Imo)

David Hicks and Vong Q. Nguyen

Introduction

Sato-Imo, Japanese taro or Japanese potato (Colocasia esculenta var. antiquorum), is a golf-ball size and shaped starchy root crop belonging to the Araceae (Aroid) family of plants. A fleshy herbaceous perennial with large 'elephant ear' like leaves supported on long 1-1.5m petioles, it produces an over-wintering corm mass which includes a large mother corm subtended by a great number of smaller daughter corms. The large numbers of small corms and the 'nuttiness' of the flavour are what distinguish this crop, from other taro varieties that produce much larger mother corms with several daughter corms (Colocasia esculenta var. esculenta, large-corm taro or Pacific taro). The following information refers only to the Sato-imo types known commonly as the antiquorum or small-corm varieties.

Japanese potato can be used similarly to 'Irish' potatoes and can be prepared as a nutritious substitute or interesting replacement. In Japan, sato-imo has cultural significance as a traditional food which is widely consumed. It is an intensive crop, introduced to and produced in the Northern Rivers region of New South Wales, coastal Queensland and the Darwin region, which yields large volumes per unit of land.

Other known producers are China, Japan and Samoa. Production in Japan was 124,000 t in 2002. Japan is the only currently known importer, and, while peak consumption is during the Japanese winter, there is a
continued period of demand which is counter-seasonally conducive to Australian production.

The challenges facing industry development in Australia beyond competitors, such as China, are quality maintenance during shipment and shelf-life, development of the domestic market and cooperative coordination of export activities.

The RIRDC funded project UCQ-13A involving the Northern Rivers Agricultural Development Association (NORADA), and lead by Central Queensland University (CQU) with New South Wales Agriculture, is presently in the advanced stages of identifying market opportunities and addressing production requirements and practices. The following information is an outcome of that project.

**Market and marketing issues**

The principle market for sato-imo, and the focal basis for which the research project was established, is the counter seasonal export market opportunities in its fresh form in Japan (Table 1).

During the months of May through to July inclusive, the volume of supply has an annual sharp decline, whilst the price for this period has a corresponding sharp increase (Table 2). This suggests that there is still a demand during this period. Estimates for fresh imports from Australia into Japan are targeted at 2,000 tonnes based on 10% of Japan's annual import volume.

Processed-fresh products including pre-peeled and packaged sato-imo are also worth exploring. Further, Japan imports 50,000 t of pre-peeled frozen product annually which may have longer term implications for export opportunities.

Significant hurdles remain for developing the export market, particularly guaranteeing a high enough return price to make the venture profitable. Japanese importers are over familiar with cheap imports from China during their production season, even though air-freighted trial shipments of the Australian product have been recognised as superior in quality.

**Technologically, quality parameters for a product that must go via sea-container, are not yet resolved. Included in the quality issues,**

Table 1. Production and importation of Sato-imo in Japan, 1985-2002

<table>
<thead>
<tr>
<th>Year</th>
<th>Production 1)</th>
<th>Importation 2)</th>
<th>CIF Prices (Fresh) 2,3</th>
<th>Yen/Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area, ha</td>
<td>Volume (t)</td>
<td>Fresh (t)</td>
<td>Frozen (t)</td>
</tr>
<tr>
<td>1985</td>
<td>28,500</td>
<td>225,300</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>1995</td>
<td>2,400</td>
<td>147,500</td>
<td>26,863</td>
<td>48,382</td>
</tr>
<tr>
<td>1997</td>
<td>1,400</td>
<td>163,900</td>
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</tr>
<tr>
<td>1999</td>
<td>20,000</td>
<td>148,100</td>
<td>10,322</td>
<td>52,393</td>
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<tr>
<td>2000</td>
<td>18,800</td>
<td>138,300</td>
<td>20,345</td>
<td>56,159</td>
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<tr>
<td>2001</td>
<td>17,800</td>
<td>129,200</td>
<td>20,254</td>
<td>55,425</td>
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<tr>
<td>2002</td>
<td>17,100</td>
<td>123,900</td>
<td>24,887</td>
<td>49,660</td>
</tr>
</tbody>
</table>

2 Shokuhin Seisan Yonju Shohi, 2002.  
3 Yasai Yunyu no Doko, 2002.  
4 Prices of frozen Sato-imo.
Table 2. Consignment and prices of Sato-imo at the Tokyo Central market, Japan (Average of 5 years, 1998-2002)

<table>
<thead>
<tr>
<th>Month</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume, t</td>
<td>1133</td>
<td>1213</td>
<td>1014</td>
<td>826</td>
<td>679</td>
<td>556</td>
<td>550</td>
<td>929</td>
<td>1778</td>
<td>2011</td>
<td>1867</td>
<td>2594</td>
<td>15249</td>
</tr>
<tr>
<td>Price, ¥/kg</td>
<td>182</td>
<td>194</td>
<td>193</td>
<td>179</td>
<td>249</td>
<td>356</td>
<td>326</td>
<td>267</td>
<td>233</td>
<td>196</td>
<td>170</td>
<td>180</td>
<td>209</td>
</tr>
</tbody>
</table>


Due to the morphology of the plant, is the fact that in a crop of small-corm taro, a maximum of approximately 30-40% of corms per plant are suitable as export quality.

For the domestic market, most Japanese sato-imo is sold through niche markets and Asian grocery stores. It has not been seen in the larger mainstream chain-store outlets; which is a problem of marketing. There are suggestions that the product be re-branded for the Australian domestic market as “Japanese potato”, to distinguish it from the large-corm varieties and the term taro altogether.

Production requirements

Temperature and water availability have the most important influence on production. The growing season from germination to corm formation will need to be between 6 and 9 months, with an average temperature during growth of between 25-30°C. Sato-imo is frost sensitive, however, lower temperatures after corm formation are favourable to suppress shoot growth from the new corms.

A full sun aspect with protection from wind via windbreaks is an advantage, this is a species that readily transpires water and in strong winds can be damaged. Water will be the major limiting factor to production and any naturally occurring precipitation should be augmented with irrigation.

Preliminary observations indicate good water management practices will provide optimum yields.

Sato-imo will accommodate a wide range of soil types, though it thrives best in soils with high fertility and good structure. It will tolerate waterlogging, though higher yields have been observed in soils with good drainage. A longer growing season is necessary for poorly draining soils. Soil pH should be in the range of 5.5–7.5.

Varieties/cultivars

Considerable attention has been given to nomenclature. Based on more recent genetic and morphological variation studies, proponents of a revision of taro classification argue that the use of the two varietal taxonomic sub-groups, var. antiquorum and var. esculentum, is unreliable, and that the preference is to treat Colocasia esculenta as a single polymorphic species, differing at the cultivar level only. However, the debate

is currently unresolved and to prevent confusion the prevailing commercially-accepted taxonomic breakdown into *antiquorum* and *esculenta* will be recognised here.

An alternative grouping convention is to refer to small-corm and large-corm cultivars. This is a way of referring to relative corm size and morphology and is not based on taxonomic or genetic relatedness.

The only recognised *antiquorum* cultivar currently available in Australia is thought to be *Ishikawa wase*. Confirmation by DNA fingerprinting, of the varietal identification is an objective of the current research project.

There are 10 other cultivars, favoured by different markets within Japan, in the process of importation into Australia. These include *Dodare*, *Tono-imo* and *Takenoko-imo*. The strict quarantine measures imposed upon importers require a laborious route; any new varieties may require up to 2-3 years before release.

### Cultura practises/ agronomy

Preparation of land should begin with deep ripping the soil followed by ploughing and mound formation. The use of double or single beds or mounds, 1.5 m in width or one standard tractor wheel width, will assist in harvest and alleviate any drainage problems on heavier soils. Incorporation of half the nitrogen, all the phosphorous, and one quarter of the potassium requirement is recommended prior to mounding. Any minor nutrient, trace element or pH adjustment, recognised by a soil test, should also be addressed at this stage.

Any corms in good condition can be used as propagation material. Mother corms or quarter-cut mother corms, sealed with dolomite or ash and allowed to dry, have provided the highest yields. Planting in single or staggered double rows, within the mound 30 cm apart and 10 cm deep, on central coast and in northern NSW, is from September to November.

Sato-imo is a gross feeder of nutrients; they should be applied as 3-4 split applications. Initially, nitrogen is required for shoot growth at a rate of 150 kg/ha, phosphorous at 80 kg/ha and potassium 100 kg/ha. Subsequent side dressings should be at the rate of 75 kg/ha nitrogen and 100 kg/ha potassium. A final application of potassium at 50-100 kg/ha as potassium sulphate, is required for corm formation. Too much nitrogen at this stage can result in elongated corms and promotion of new shoots from developing corms. Logically, the absolute quantities will depend upon data from prior soil analyses.

Weeds are a severe problem to the taro grower during the early stages of growth before canopy cover over the soil is achieved. Glyphosate can be used between mounds and rows using a hand-held backpack type sprayer. Care should be taken to avoid spray drift onto crop plants. Cultural practices such as using hay mulches, hilling-up and weedimg are also effective. A number of chemical herbicides are currently under test for registration application.

Rotation practices should be observed. It is preferable to use a site once only; many very small corms will be missed during the harvest and will sprout during the following season. Effectively acting as weeds, these invaders will compete for available resources and compromise the quality and quantity of yield.

A maximum of two yearly rotations is recommended, as yields have been observed to be lower in subsequent plantings.

### Pest and disease control

This is a crop relatively free of pests. *Heliothis* sp. and cluster caterpillars can cause minor damage to leaves and emerging shoot tips. Chemical control at this stage cannot be recommended, as no products are registered for use. Soil borne larvae such as cane grubs and African black beetles, which can attack and spoil corms, can be kept in check using cultural measures and rotation.

The most serious problem of the taro family of plants is the fungal organism *Phytophthora colocasia*, which causes the disease taro leaf

### Table 3. Classification of sato-imo in the Japanese market

<table>
<thead>
<tr>
<th>Corm Size</th>
<th>Early cultivars</th>
<th>Normal cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt;60g</td>
<td>&gt;90g</td>
</tr>
<tr>
<td>2L</td>
<td>60g – 40g</td>
<td>90g – 60g</td>
</tr>
<tr>
<td>L</td>
<td>40g – 20g</td>
<td>60g – 30g</td>
</tr>
</tbody>
</table>

Note: Early cultivars such as Ishikawa Wase and the same are produced and delivered to the market from May to August. The normal cultivars are other sato-imo varieties that are supplied to the market in another period of time from September to April.

blight (TLB). This fungus has not yet been officially recorded in Australia, though symptoms which superficially resemble TLB on some plants, have been observed.

**Harvesting and packaging**

Corms are harvested when the shoots die back over winter, usually from mid-May through to July. Corms should not be stored in the ground as re-shooting and quality problems can occur. A slasher can be used to remove standing canopy in areas where it is still present at harvest time. A potato digger is used to lift the corms and initially separate the clump. Yields of between 10-100 t/ha have been reported, though on average 18 t of marketable export quality corms have been reported by growers.

It is necessary to perform the first of two gradings in the field to reduce labour inputs. All mother corms, misshapen, damaged and very small corms are separated from the marketable product. The marketable product is then washed and any remaining roots and soil debris removed. This process may be undertaken on 2-3 occasions. A second and third grading based upon size and then shape is performed. [Note that the grading in Table 3 is the standard for the Japanese domestic fresh market. Individual import companies may have different specifications depending on their clients’ requirements].

Three size grades *viz.* small, mid, and large ranging from golf-ball to small tennis ball are acceptable. The shape must be either evenly

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost (A$)</th>
<th>Total</th>
</tr>
</thead>
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<tr>
<td><strong>A. TOTAL INCOME</strong></td>
<td></td>
<td></td>
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<td>67,500</td>
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<tr>
<td><strong>Variable costs</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>Cash</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>8hrs</td>
<td></td>
<td>18.48/hr</td>
<td>207.58</td>
</tr>
<tr>
<td>Taro corm</td>
<td>20-25 onion bags</td>
<td></td>
<td>50.00/bag</td>
<td>1,250.00</td>
</tr>
<tr>
<td>Planting labour</td>
<td>32hrs</td>
<td></td>
<td>18.48/hr</td>
<td>591.36</td>
</tr>
<tr>
<td><strong>Fertilisers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agricultural lime</td>
<td>2.5/ha</td>
<td></td>
<td>130/t</td>
<td>325.00</td>
</tr>
<tr>
<td>Fertilisers CK44</td>
<td>24bags</td>
<td>40kg/bag</td>
<td>0.53/kg</td>
<td>508.80</td>
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<tr>
<td>Spreader machinery cost</td>
<td></td>
<td></td>
<td></td>
<td>3.88</td>
</tr>
<tr>
<td>Labour</td>
<td>2hrs</td>
<td></td>
<td>18.48/hr</td>
<td>36.96</td>
</tr>
<tr>
<td><strong>Nematode control</strong></td>
<td></td>
<td></td>
<td></td>
<td>85.00</td>
</tr>
<tr>
<td><strong>Weed control</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tractor cultivation (6-8x / season)</td>
<td>25hrs</td>
<td></td>
<td>18.48/hr</td>
<td>462.00</td>
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<tr>
<td>Tractor cultivation machinery cost</td>
<td>6 times</td>
<td></td>
<td>5.50</td>
<td>33.00</td>
</tr>
<tr>
<td>Hand weeding labour</td>
<td>5days</td>
<td>8hrs/day</td>
<td>18.48/hr</td>
<td>739.20</td>
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<tr>
<td>Pesticides, machinery, labour</td>
<td></td>
<td></td>
<td></td>
<td>48.14</td>
</tr>
<tr>
<td>Irrigation (water pump &amp; maintenance)</td>
<td></td>
<td></td>
<td></td>
<td>219.50</td>
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<tr>
<td><strong>Harvesting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carton 10kg</td>
<td>2,500</td>
<td></td>
<td>2.00/ctn</td>
<td>5,000.00</td>
</tr>
<tr>
<td>Slashing tops machinery cost</td>
<td>2hrs</td>
<td></td>
<td>10.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Slashing labour cost</td>
<td>2hrs</td>
<td></td>
<td>18.48/hr</td>
<td>36.96</td>
</tr>
<tr>
<td>Per carton cost for all harvesting</td>
<td>2,500</td>
<td></td>
<td>15.00</td>
<td>37,500.00</td>
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<td><strong>Transportation &amp; fees</strong></td>
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<td></td>
<td></td>
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<tr>
<td>Freights to Sydney/Melbourne</td>
<td>2,500</td>
<td></td>
<td>1.00/ctn</td>
<td>2,500.00</td>
</tr>
<tr>
<td>Levies</td>
<td>2,500</td>
<td></td>
<td>0.25/ctn</td>
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<td>Agent commission 10%</td>
<td>2,500</td>
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<td>0.10/ctn</td>
<td>250.00</td>
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<tr>
<td><strong>B. TOTAL VARIABLE COSTS</strong></td>
<td></td>
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<td></td>
<td>50,442.38</td>
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<tr>
<td><strong>GROSS MARGIN (A-B)</strong></td>
<td></td>
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<td>17,057.62</td>
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<tr>
<td><strong>Break even</strong></td>
<td></td>
<td></td>
<td>$/ha</td>
<td>52.02</td>
</tr>
</tbody>
</table>

---

1 Phillip Wilk & David Hicks, 2004. Small –Corn Taro growing in New South Wales (Agfact, in press)
round or oval. Mixing of the six grades is unacceptable. No cut surfaces should be present, although a single scar from an adjoining smaller corm is acceptable. Corms should be surface-dried, before marketing in sturdy 10 kg cartons.

Storage of corms is possible at between 7–15°C in a dark well-ventilated room for up to 8 weeks without quality compromise. It is essential that corms be surface dry before storage to reduce the incidence of fungal infection.

Attention must be given to ensure propagation material is retained for the following season. Conditions for storage would be similar and the material should have been semi-washed and cleaned of soil and roots prior to storage.

Quarantine requirements

The prospective exporter of sato-imo to Japan is required to provide a phytosanitary certificate for the absence of the nematode Radopholus similis.

The volume of waste corms which are unmarketable and surplus to the propagation material requirement must be adequately disposed of.

These corms have the potential to become an invasive weed species. Current disposal methods have been burial, or as cattle stock feed.

Concerns remain over the longer term effects on stock of the calcium oxalate residues in the uncooked corms.

Other investigations are being undertaken for value adding processes to utilise product that does not meet fresh export quality standards.

Financial information

The high labour inputs required for postharvest practices determine a high variable cost per hectare. Based on the averages of a minimal machinery and a machinery assisted operation, the gross margin for 1ha of sato-imo is restricted to $17,057.62 for 1,800 cartons sold at a seasonal mean of $27 per 10 kg carton (Table 4). With a greater understanding of the production system, there is scope for improving the efficiencies of postharvest processes and reducing labour inputs through mechanisation and recognised techniques. Further, experimentation has revealed that yields can be increased through adoption of the production requirements.

However, the limited size of the underdeveloped domestic market demonstrated a sensitivity to oversupply in the 2003 season. Initial returns of $35 per carton were reduced to $19 per carton during peak supplies. Confounding the analysis of the market returns was a poor understanding of the quality requirements for this product by a large number of growers.

Export shipments would require a greater return to cover the costs of transport and logistics. A 12 t container trial shipment during 2003 received positive responses on the quality compared with Chinese imports and locally grown product. However, the high cost of airfreight made the product uncompetitive from a price perspective.

Further trial shipments via sea-container during 2004 will be a critical factor to the development of a Sato-imo industry.

Table 4 (on previous page) shows an enterprise budget for 1.0 ha for Sato-imo Ishikawa-Wase located in North Coast, NSW, for a period of 7–8 months.

Key messages

- Export demand in Japan
- Domestic market development potential

Key statistics

- Market volume estimated at 5000–7000 t annually

References


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Kabocha

Melinda Gosbee

Introduction

Kabocha (Cucurbita maxima), and Japanese pumpkin (Cucurbita moschata) are members of the cucurbit or pumpkin family. They are small (1.5 to 2.0 kg), generally dark skinned pumpkins with strongly coloured flesh and nutty flavour. Kabocha is grown in Australia for the domestic market, and small amounts are exported fresh (from Tasmania) and processed (from the Australian mainland) to Japan. Within Australia, kabocha is also known as Buttercup Squash, Ebisu, Delica and Early Potkin. In Japan, kabocha is known as Kuri Kabocha, or nutty pumpkin.

Kabocha and Japanese Pumpkin in Australia (Morgan and Midmore 2003) gives a comprehensive summary of current knowledge and reports of varietal trials conducted across Australia from 1998 to 2000. It includes descriptions of varieties, production methods used in those regions where the trials took place and yields of kabocha. It concluded that kabocha can be grown around Australia throughout the year.

Markets

Japan is the largest importer of fresh kabocha with 154,183 tonnes imported in 2002 (Figure 1, JETRO 2003). Japan requires kabocha between September and April to supply its off season. 60% of its total kabocha import is supplied from New Zealand (NZ) during this period. Tasmania has exported 1000 tonnes per annum over recent years, which is less...
than 1% of Japan’s total kabocha imports. Tasmanian kabocha is exported between March and May. The price is set by kabocha imported from NZ, however quality Tasmanian imports have received higher than average prices. DPIF Tasmania has estimated that exports of 10 000 tonnes are achievable. Other exporting countries include Mexico, Tonga/Fiji and New Caledonia.

Japanese quarantine regulations with regard to fruit fly prevent fresh kabocha being imported from mainland Australia. Frozen pumpkin pieces and purees have been exported from the mainland, and kabocha is currently being processed. Fresh kabocha is also consumed domestically. Average prices for fresh kabocha are $0.40 per kg.

Production requirements

Kabocha has been grown commercially around Kununurra and Carnavon, WA; on the North West coast of Tasmania, north of the Great Dividing Range in Victoria, in various locations in Queensland and in Griffith, NSW. It has been successfully trialled in several other locations. A summary of approximate harvest dates in various locations around Australia is given in Table 1.

Kabocha grows best in mild to warm conditions, with 20 to 30°C days and 15 to 20°C nights. Soil temperature should be greater than 10°C, and frosts cause severe damage. Optimal pH is 6.0 to 6.4, although kabocha will grow between pH 5.5 and 7.2. Kabocha will grow in a range of soils from fine sandy loam to light clay. Irrigation is generally required for growing kabocha. Kabocha requires a 90 to 130 day growing season.

Varieties

Delica and Pacifica are two of the better known hybrids of kabocha. Delica is also known as Ebisu. It is a flat globe shape, deep green in skin colour and with thick yellow flesh.

Tetsukabuto is thought to be an inter-specific cross of C. moschata and C. maxima. It is darker skinned, nearly round in shape and has darker orange flesh. It yields more highly and also has better quality than the traditional varieties Delica and Pacifica. However, Tetsukabuto needs to be planted near C. moschata or C. maxima to set fruit.

Ken’s Special is an Australian selection of C. moschata, or Japanese pumpkin, which yields similarly to Delica. Orange skinned kabocha varieties Golden

Table 1. Seasonal harvesting dates for kabocha and Japanese pumpkin production around Australia. From Morgan and Midmore, 2003

<table>
<thead>
<tr>
<th>Location</th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
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</thead>
<tbody>
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<td>+</td>
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<tr>
<td>Central Qld</td>
<td>+</td>
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<td>E</td>
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<td>L</td>
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<tr>
<td>South Qld</td>
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<td>+</td>
<td>L</td>
<td>+</td>
<td>+</td>
<td></td>
</tr>
</tbody>
</table>

E: early; M: mid; L: late; +: all varieties.
Debut, Golden Orbit and Uchiki Kuri are also available.

South Pacific Seeds and Yates stock some of the better known varieties. Fairbank's Selected Seed Co currently stocks Kurijiman and Uchiki Kuri. Tetsukabuto is a release of Takii Seed Company, Japan. Tasmanian production is mainly Delica and Kurijiman, and the seed is imported from Japan.

**Agronomy**

Requirements are similar, but not identical to pumpkins traditionally grown in Australia. Seeds geminate within 5 to 7 days, and can be transplanted at the first true leaf stage 6 to 14 days after emergence. Direct seeding is preferable if conditions are suitable. Irrigation is required if rainfall is inadequate. Drip tape is preferred as kabocha is sensitive to powdery and downy mildew, which thrive in humid conditions. Generally, raised beds with black plastic mulch and drip tape are used for production.

Crop densities of approximately 1.1 plants/m² have been reported to give greatest yields of marketable sized fruit. This is equivalent to 1.5 to 1.8 m spacing between rows and 0.3 to 0.8 m between rows. At higher densities, total yields increase mainly due to a larger number of smaller fruit. High levels of nitrogen are required early for plant growth, up to 180 kg N/ha. High calcium is applied later in the crop growth to improve fruit quality. Actual requirements will depend on the soil type and history.

Average marketable yields have been estimated at 15 to 22 t/ha, but yields from 10 to 50 t/ha have been reported. Yields vary greatly between varieties. Minimum weight of kabocha for processing is 0.5 kg and fruit must be sound. Skin blemishes and sunburn can result in up to 30% of the harvested crop to be rejected for fresh export. Sunburn was a problem for fruit harvested late summer in south Queensland, and it can also result when the canopy is destroyed by disease.

**Pest and disease control**

Several insect pests of kabocha have been reported in the various locations that it is grown. These include pumpkin beetle, cabbage moth, cutworm, mites, and melon thrips. Kabocha is also a host of Mediterranean fruit fly. Disinfestation protocols have not been established for export of kabocha from mainland Australia to Japan.

Powdery and downy mildew are significant diseases of kabocha, and careful management of these is required for a successful crop. Kabocha trials in the humid conditions of the north coast of New South Wales were a failure due to these diseases. Kabocha is also susceptible to mosaic viruses, so aphids, which may transmit the virus, should be carefully controlled. Nematodes can also reduce yield, planting kabocha after a resistant crop or cover cropping between kabocha crops will reduce the build up of nematodes in the soil. Other diseases which may affect kabocha include bacterial spot, brown etch and gummy stem blight.

Integrated pest management programs of agriculture and primary industry have been developed for most of these pests. Check with the local state department for current permits for biological and chemical control of these pests and diseases.

**Harvest and postharvest**

More than one harvest is usually required commercially. Fruit are mature when the stem dries and splits. Skin hardness and growing degree days can also be used as indicators of maturity. The stem should be carefully cut to minimise damage and access by stem rots. Good quality kabocha has dark skin of an even colour, with little evidence of the earth mark. This is the pale area where the fruit sits on the ground. Skin blemishes such as warts also detract from Kabocha 'Delica' (Photo: Murat Top)
quality. Dark orange flesh is also preferred.

Kabocha should be stored between 10 and 15°C at low humidity and with adequate ventilation. Chilling injury will occur if the fruit are stored at less than 10°C for a few days.

Kabocha harvested from warm climates such as Queensland are more susceptible to chilling injury than those grown in Tasmania. Kabocha should keep between 3 and 4, and sometimes up to 6 months. Postharvest rots are predominantly caused by Fusarium spp. Curing at 30°C and high humidity for 2 to 3 days before storage reduces rots.

Washing fruits in sodium hypochlorite reduces incidence of rots, as does careful handling to minimise wounding. Sunburn has also been correlated with increased rots.

Processed kabocha is cut into small pieces of varying sizes, with or without the skin and frozen. The processed flesh can also be sold as a paste or puree.

### Key references


### Financial information

Establishment costs for kabocha include tractors with appropriate soil preparation equipment, bed formers, irrigation and spray equipment.

Depending on the market being used, curing equipment may be required.

Production costs include fertiliser and irrigation costs, and pest and disease control plus the labour required to carry out these activities.

Estimates of yield at 15 t/ha and price $400/t put gross sales at $6,000/ha (Hassall and Associates 2003).

Gross margins calculated in 1998 have been reported for Tasmania at 15 t/ha yield; they were $1,351/ha at $250/t, and $2,101/ha at $300/t (in Morgan and Midmore, 2003).

More recent figures are not available. It is prudent to establish markets and potential prices at the time of harvest for the desired location before planting.

### Key messages

- Kabocha can be grown around Australia
- New varieties have higher yields
- Tasmania exports fresh kabocha to Japan

### Key statistics

- Japan imports 140,000 t of fresh kabocha yearly
- Average yields are 15 to 22 t/ha
- Australian domestic price for fresh kabocha is 40c/kg
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Introduction

Lotus (Nelumbo nucifera GAERTN.; Nelumbium speciosum Willd.), also called Sacred Lotus and/or Indian Lotus, originates in Asia, Persia, India to China and in North Eastern areas of Australia.

Lotus is one of the oldest plants in the world. Archaeologists in China found seeds of the Lotus with estimated ages of 7,000 years. Seeds, 1288±271 years-old found in China have been germinated, one of the oldest demonstrably viable and directly dated seed germinations recorded.

Lotus is a perennial aquatic crop that is grown and consumed throughout Asia. The young flower stalks, seeds and rhizomes are all edible. The flower is used in religious ceremonies and the flower receptacles (pods) are used for ornamental purposes. However, the largest market exists for rhizomes which are a vegetable with enormous potential for a large-scale production in Australian horticulture to supply domestic and overseas markets. Lotus rhizomes form from the terminal roots of the lotus root system. One rhizome carries usually three “sausages” and is creamy-white in colour.

Lotus is cultivated in many countries in the world, especially in Asia, such as India, China, Japan, Korea, South-East Asia, Russia and some countries in Africa. Lotus grown in Europe and America is mainly for ornamental purposes, rarely for foods.
In China, the growing area of lotus is estimated at more than 133,400 hectares with an average yield of 22.5 t/ha. China has a capacity to produce up to 3 million tonnes of lotus rhizomes per annum. In Japan, lotus is grown throughout the country mostly for ornamental purposes, particularly in the Buddhist temples and/or national parks.

Production of lotus rhizomes is however concentrated in few prefectures on the Central and Southern parts of Japan such as Ibaragi, Tokushima, Aichi, Saga, Yamaguchi, Niigata and Okayama. In 1985 Japan produced 73,800 t lotus rhizome on an area of 6,090 ha but reduced to 56,900 t on 4,490 ha in 2002 (Table 1).

Lotus is currently an infant industry in Australia. The industry needs to put more effort into research on variety, growing techniques, post-harvest storage and handling and market development.

The Australian lotus industry can penetrate into overseas markets, particularly Japanese, if we can open up a trading system directly with supermarket chains.

A case study of lotus rhizomes in the Asian market including Taiwan and Japan, has shown that the Japanese market appears to be more favourable for Australian lotus during June, July and August, which coincides with the lotus rhizome harvest period in Australia. If Australia could provide just 1% of the Japanese wholesale market, we would earn A$8 million for our horticultural industry.

A research project on lotus has been implemented at the New South Wales Agriculture’s Gosford Horticultural Institute, in cooperation with the University of Western Sydney, Hawkesbury to research and develop this new crop for Australia domestic and export markets.

Growers intending to access Japanese markets will be required to provide a phytosanitary certificate for the nematode *Radopholus similis*.

**Markets and marketing issues**

From 1995, Japan imported, 1,347 t fresh and 14,887 t salted Lotus rhizomes for the first time, mainly from China.

In 2002, Japan imported only 11,504 t salted lotus rhizomes from China, worth 739 million Yen (A$10 million). There was however, no importation of fresh lotus rhizomes both in 2001 and 2002.

Production of lotus in Taiwan has declined over seven years to about 550 t in 1993. This may reflect the arduous nature of competition with China in Japanese markets where almost all Taiwanese lotus is destined. South Korea produced 9,261 t of lotus rhizomes on 291 ha in 1995. It is the fourth largest crop area in this country.

Lotus rhizome is a new crop to Australia. It is estimated that domestic demand for lotus rhizomes is approximately 1,000 t annually and valued at approximately A$6 million. At present, Australia is able to provide only 100 t in the fresh form, the rest being imported mainly in frozen and dried forms. Requirements for flowers and pods are unknown, but thought to be potentially high.

Of the several countries in Asia where lotus is cultivated and consumed, the Japanese market offers the best opportunities for the Australian lotus industry. Japan has a market of approximately 70,000 t of lotus rhizomes annually, valued at approximately A$800 million. Domestic production in Japan is still falling due to increased pressure on agricultural land, which has resulted in importation of up to 18,000 t of lotus rhizomes valued at more than A$18 million in the mid ‘90s. In 2002, although production was only 56,900 t, no fresh lotus was imported and Japan was forced to reduce its importation of salted lotus from China because of a problem with chemical residues (Marubeni, pers. comm.) (Table 1).
Table 1. Production and importation of lotus in Japan, 1985-2002

<table>
<thead>
<tr>
<th>Year</th>
<th>Production 1</th>
<th>Importation 2</th>
<th>CIF Prices (Fresh) 2,3, Yen/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area, ha</td>
<td>Volume, ton</td>
<td>Fresh, ton</td>
</tr>
<tr>
<td>1985</td>
<td>6,090</td>
<td>73,800</td>
<td>Nil</td>
</tr>
<tr>
<td>1995</td>
<td>5,360</td>
<td>65,100</td>
<td>1,347</td>
</tr>
<tr>
<td>1997</td>
<td>4,920</td>
<td>53,300</td>
<td>2,007</td>
</tr>
<tr>
<td>1999</td>
<td>4,790</td>
<td>58,100</td>
<td>1,260</td>
</tr>
<tr>
<td>2000</td>
<td>4,660</td>
<td>58,900</td>
<td>1,425</td>
</tr>
<tr>
<td>2001</td>
<td>4,560</td>
<td>58,800</td>
<td>nil</td>
</tr>
<tr>
<td>2002</td>
<td>4,490</td>
<td>56,900</td>
<td>nil</td>
</tr>
</tbody>
</table>

2) Shokuhin Seisan Yunyu Shohi, 2002. 
3) Yasai Yunyu no Doko, 2002. 
4) Prices (CIF) for Salted lotus.

Production requirements

A high degree of dedication from the grower, and commitment of utilised resources make lotus a relatively difficult crop to grow. Growing lotus should be thought of as a system. This includes positioning of ponds in relation to water storage, movement and recycling. Determination of harvest method and soil type in use prior to any pond design would also be an advantage. Considerable capital investment is essential for the construction of ponds. Potential growers should consult an earth working organisation and the incumbent local council before any commitment is arranged.

The site for ponds needs to be relatively flat, expansive, and close to a reliable source of large volumes of fresh water. Farm dams are not suited to lotus production, though can be utilised as a water reservoir for production pond requirements.

Lotus requires a warm temperate to sub-tropical environment with average day time temperatures of 20-30°C. However, a temperate climate produces better quality rhizomes than a tropical climate (Marubeni, pers. comm.). A high incidence of solar radiation providing intense sunlight and long day hours are needed for successful growth. Protection from wind is recommended. Appropriate soil can be transported into the ponds if the on-site soil is unsuitable. Optimal soil is a soft silty loam, free from particulate matter. Attention to soil will assist in harvesting ease. Lotus is highly frost resistant.

Varieties/cultivars

There are many lotus varieties available in the world but they have been classified into three categories according to use, namely flowers, fruits (seeds) and rhizomes. They are different in flower colour, starch content and growing water levels. Some varieties may exhibit one or more of the three characteristics but generally each is classified by the strongest feature. Often, rhizome varieties will have relatively few flowers, which are generally white, and flowering and seed types have no appreciable rhizome, if at all. Many tropical varieties do not form a significant rhizome due to the absence of a cold period in which the plant must produce a storage organ for survival. In China, at the Wuhan Institute of Botany alone, 124 lotus cultivars are available for research. Cultivars currently grown in Australia and distributed through domestic markets include Quangdong, Brisbane, Vietnam Red, Paradise and Green Jade. Of these, only Quangdong is moderately acceptable for rhizome production, the other four being better suited to flower production.

Cultural practices/agronomy

Lotus is grown in specialised shallow ponds with a soil depth of 1m and surface water of 10-20cm. The size or number of ponds will depend upon amount of available water and land in the grower’s operation. Planting is conducted in September to October by using seed or rhizomes. The propagation by seed is unusual since seeds are highly heterozygous and the progeny may not be true to the original variety. If propagating by seed, the best and most simple method is to make a small hole on the seed skin and soak in water at 25°C, with 12 hours light. Change the water daily until the seed germinates 5-8 days later. Transplanting occurs
6-8 weeks from sowing when the seedlings have 2-3 leaves and a few roots. If propagation is by rhizome, there needs to be care about the rhizome sections with at least 2-3 intact nodes. The section is planted on a 15° angle to horizontal and spaced 1.5-2 m apart within 2.5-3 m spaced rows. The direction of the growing tip should be along the longer axis within the row. The water level during planting should be 5 cm and increased with leaf emergence and rising temperatures.

Fertiliser requirements are high. Nitrogen (N) at a rate of 300 kg/ha, phosphorous (P) at 80 kg/ha and potassium (K) at 350 kg/ha is applied as split applications. The total amount of P is incorporated into the dry pond, with half the N and K, prior to planting. The additional side dressings, applied at 2, 4, and 6 months after planting, will have a high to low concentration gradient for N and low to high for K. Fertiliser should be of technical grade to assist in solubility. The E.C. can range from 2.5-3.2 µS/cm as the plants develop, pH is optimal between 5.8-6.5 though higher and lower pH is tolerated.

Weed control is difficult within the closed pond system, treatments to weeds will often affect the crop plants. Most weed control will require physical removal, this should be practiced prior to planting, especially for soil rooted aquatic weeds. Floating weeds should only be a problem during the initial month of growth before a canopy of lotus leaves is achieved. Salvinia (Salvinia molesta) and alligator weed (Alternanthera philoxeroides) infestations should be removed immediately. Some weeds, such as the Azolla sp. are not considered a weed in parts of Asia. The fern fixes nitrogen, which is passed onto the plant when the fern dies, and it has a thermoregulating effect on pond water temperature by creating a blanket across the pond surface. Fertiliser requirements may have to be adjusted to compensate for the load of any weeds present.

**Pest and disease control**

Lotus is host to a number of minor pests, most of which do not occur in Australia. The most important pest is *Heliotris* sp. caterpillars which skeletonise leaves. Aphids, two-spotted mites and mealy bugs will also be a minor pest on under-canopy emerging leaves. Control recommendations can only be cultural and biological until registration of appropriate control measures is established.

Diseases of lotus are few. Leaf spotting organisms have been identified as powdery mildew (*Erysiphe polygoni*), *Cercospora* sp., and *Ovularia* sp. Control is achieved using copper based fungicides. Lotus streak virus produces streaks on roots and chlorotic ringspots on leaves and requires removal of infected plants. Rhizome specific diseases are caused by *Fusarium oxysporum* ssp. nelumbicola and *Pythium elongatum*. Correct water management by adjusting water levels should help to control *Fusarium*, the disease incidence is attributed to high temperatures and low rainfall. An infected pond should be rotated in the following season.

Lotus also produces excellent flowers which could be of high value for the Australian ornamental flower industry.
Harvesting and packaging

Harvest is performed 7–9 months after planting, during winter months, after leaves have died off. Rhizomes are removed from the soil by either drying the pond and using a backhoe with a modified fork appendage, or manual removal assisted by recirculating pond water with a high pressure portable pump/canon. The first method is quick but with high waste and quality compromises. The second is labour intensive, performed in cold ponds and requires a soft enough soil to be conducive. The quality of the second and third methods is very high and waste is low. Yields are expected to be in the range of 8–12 t/ha and will be dependent upon variety, location and cultivation practices.

Lotus requires laborious preparation prior to marketing conducted within a shed set-up for this purpose. Rhizomes should be even in size and colour (unblemished cream) with a distinct constriction between rhizome flesh and internode. Select rhizomes are cut to length on the 4th segment of a rhizome chain. Optimum segment sizes are between 15–20 cm long and 5–8 cm in diameter. Side shoots, petiole remains and ‘daughter’ rhizomes should be removed. The chain is then washed with detergent to remove soil residues prior to removal of roots and side meristem buds followed by another rinsing wash. Rhizomes should be surface dried before grading according to size, and storage at temperatures between 3–7°C or marketing in 5 or 10 kg styrofoam boxes.

A cool-storage area proportionally sized to the operation scale is essential.

Postharvest losses are high due to rhizome sensitivity to damage. Discolouration is immediate upon physical damage and the probability of disease infestation to damaged tissue is increased. Postharvest diseases include grey mould, Anthracnose and black spot caused by the fungal organisms Botrytis cinerea, Colletotrichum sp and the bacteria Pseudomonas sp. There are no known control measures for these diseases on this crop other than prevention.

Financial information

Working in field trials at Gosford Horticultural Institute and, in discussions with Tai-Cheung Agricultural Development Pty. Ltd., it is understood that high gross margins for Australian lotus rhizomes, estimated at A$2.76/kg (Table 2), would never be competitive with China, whose CIF prices have only ever achieved 30–35% of the Japanese wholesale market prices (Table 1). The possibility of exporting Australian lotus to Japan remains to be seen. There could be interest from Japan because of low chemical residues if Australian lotus are sold at a lower acceptable price.

Table 2 shows an enterprise budget for 1.0 ha for lotus rhizome located in Gosford, NSW, for a period of 9–10 months.

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity</th>
<th>Unit</th>
<th>Cost (A$)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales</td>
<td>10,000</td>
<td></td>
<td>4.00</td>
<td>40,000</td>
</tr>
<tr>
<td>Less commission</td>
<td>12%</td>
<td></td>
<td></td>
<td>4,800</td>
</tr>
<tr>
<td><strong>A. TOTAL INCOME</strong></td>
<td></td>
<td></td>
<td></td>
<td>35,200</td>
</tr>
<tr>
<td>Variable costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Certified rhizomes</td>
<td>650kg a)</td>
<td>6kg</td>
<td></td>
<td>3,900.00</td>
</tr>
<tr>
<td>Compost</td>
<td>10t</td>
<td></td>
<td>$200/t</td>
<td>2,000.00</td>
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<tr>
<td>Pine bark (fine)</td>
<td>15m3 a)</td>
<td></td>
<td>$55/m3</td>
<td>825.00</td>
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<tr>
<td>Fertiliser (G5)</td>
<td>2000kg</td>
<td></td>
<td>$376.85/t</td>
<td>753.70</td>
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<tr>
<td>Pesticides</td>
<td></td>
<td></td>
<td></td>
<td>200.00</td>
</tr>
<tr>
<td>Machinery</td>
<td>10hr d)</td>
<td></td>
<td>$50/hr</td>
<td>500.00</td>
</tr>
<tr>
<td>Contract harvest (hand pick)</td>
<td></td>
<td></td>
<td>$20/15kg</td>
<td>13,333.33</td>
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<tr>
<td>Carton</td>
<td>666</td>
<td></td>
<td>$1/ctn</td>
<td>666.00</td>
</tr>
<tr>
<td>Water</td>
<td>1500kl a)</td>
<td></td>
<td>$0.3/litre</td>
<td>450.00</td>
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<tr>
<td>Cash (sub total)</td>
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<td></td>
<td>22,628.03</td>
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<tr>
<td>Non Cash</td>
<td></td>
<td></td>
<td></td>
<td>5,000.00</td>
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<tr>
<td>Family labour</td>
<td>50 days</td>
<td></td>
<td>$100/day</td>
<td>5,000.00</td>
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<tr>
<td>Non cash (sub total)</td>
<td></td>
<td></td>
<td></td>
<td>5,000.00</td>
</tr>
<tr>
<td><strong>B. TOTAL VARIABLE COSTS</strong></td>
<td></td>
<td></td>
<td></td>
<td>27,628.03</td>
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<tr>
<td>GROSS MARGIN (A-B)</td>
<td></td>
<td></td>
<td></td>
<td>7,571.97</td>
</tr>
<tr>
<td>Break even</td>
<td></td>
<td></td>
<td></td>
<td>2.76</td>
</tr>
</tbody>
</table>

a) Less from the 2nd year
b) Family labour not included in gross margin calculation but is important
c) Cost of packaging, transportation and family labour are not included
Lotus

Key messages

• High capital investment and long term commitment required
• Labour intensive
• High returns are possible

Key statistics

• A potential market estimated volume requirement of 2000 t annually
• Japan has a market of 70,000 t/year. It produces about 57,000 t and imports about 13,000 t per annum

References


Suggestions

• Potential market
• Export opportunities

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Dr Vong Nguyen is a Special Research Horticulturist with NSW Agriculture at the Gosford Horticultural Institute (see Key contact for address). Born in Vietnam, he studied in Japan and received his PhD from the University of Tokyo, Japan in 1977. He is currently involved in research into the development of Asian vegetables for domestic consumption and export to Asian markets.
Luffas, Asian melons and snake beans

Acknowledgement is given to T. K. Lim, the author of this chapter in the first edition of this publication.

Introduction

Luffas, Asian melons and snake beans are tropical or sub tropical Asian vegetables. The term Asian is used in the sense that they are used widely and traditionally in Asian cuisine. The Asian melons and snake beans are yet to be widely adopted in the diet of Australians of European descent. The melons and snake beans are consumed as immature fruits, either in stir fry, soups or curry. Mature smooth luffa can also be dried and the remaining fibres used as a luffa sponge, however the production of sponges is not discussed here.

There is a lot of variation in the naming of these vegetables, particularly the types of *Benincasa hispida* (Table 1). This is due to different local and cultural names for the vegetables, and the fact that some melons are harvested immature (weight about 1 kg) and mature (about 4 kg).

The words ‘gourd’ and ‘melon’ are used almost interchangeably. It is important to establish the correct identity of the product under discussion, preferably with a picture.

These vegetables are mainly produced in the Northern Territory (NT) during the winter months, and other states in warmer seasons, and are marketed domestically. The luffas, long melon and hairy melon have similar production techniques on trellises, and will generally be discussed together. Snake beans also grow on a trellis; however winter melon is grown on the ground. Bitter melon, the most commonly grown Asian melon, is presented in a separate chapter of this volume.
Table 1. Common names of the luffas, Asian melons and snake beans.
The names used in this chapter are underlined.

<table>
<thead>
<tr>
<th>Common names</th>
<th>Scientific names</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinqua, angled luffa/loofah, ridged luffa</td>
<td>Luffa acutangula (L.)</td>
</tr>
<tr>
<td>Smooth luffa, loofah, dishcloth gourd</td>
<td>Luffa aegyptiaca (L.) Syn. Luffa cylindrica.</td>
</tr>
<tr>
<td>Winter melon, wax melon, dong gwa, tung gwa</td>
<td>Benincasa hispida cv. group Unridged Winter Melon</td>
</tr>
<tr>
<td>Hairy melon, fuzzy melon, winter melon (NT), mo gwa</td>
<td>Benincasa hispida cv. group Fuzzy Gourd</td>
</tr>
<tr>
<td>Long melon, wax gourd</td>
<td>Benincasa hispida cv. group Wax gourd</td>
</tr>
<tr>
<td>Snake bean, Long bean, Yard long bean</td>
<td>Vigna unguiculata cv. Group Sesquipedalis</td>
</tr>
</tbody>
</table>

**Markets and marketing issues**

Within Australia, most Asian vegetables are sold in Sydney and Melbourne. This is largely due to the greater population of Australians of Asian descent in these cities. Distribution is both within and outside the major produce markets. Domestically, prices of the melons and luffa vary between $1.00 and $3.00/kg, the average being approximately $2.00 (Table 2). Prices are lowest during the winter months when supply from the NT is high. Average snake bean prices are higher at $2.50, and winter melon somewhat lower.

These vegetables are widely consumed and produced by Asian nations. Currently, they are not exported from or imported into Australia. Any product exported from Australia would compete with low prices from locally grown produce, making the available margin for transport costs small. In addition, snake beans are highly perishable, and a tightly controlled cool handling chain would be necessary.

**Production requirements**

All of these vegetables are sub tropical or tropical in nature, and are sensitive to frost and water logging. The main production area is around Darwin during the dry season, with harvesting from May to October. They are also grown in northern Western Australia, and in the Northern Rivers district of New South Wales from January to April. Some production of snake beans occurs around Sydney, Melbourne and Brisbane over the summer months. Considerable areas of the East and West Coasts with a sub tropical or tropical climate and available water would be suitable for production of these vegetables.

Optimum temperatures for growth of 25 to 27 °C have been recorded. These plants tolerate higher temperatures well, however growth is slowed when temperatures drop below 18 °C. Irrigation during the dry season is essential in the NT. Regular irrigation during dry periods in other climates would likewise be necessary. Snake beans also require warm temperatures above 25 °C for production, and growth slows markedly at temperatures lower than 15°C.

These vegetables can be grown on a wide variety of soil types, however production is better on well-drained soils rich in organic matter. A pH of 6.5 is commonly reported.

Table 2. Northern Territory production of selected Asian vegetables in 2001 and 2002, and price range.

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>2001</th>
<th>2002</th>
<th>Price range</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tonnes</td>
<td>Value ($’000)</td>
<td>Tonnes</td>
<td>Value ($’000)</td>
</tr>
<tr>
<td>Luffa (smooth and angled)</td>
<td>72</td>
<td>130</td>
<td>115</td>
<td>208</td>
</tr>
<tr>
<td>Winter melon*</td>
<td>0.50 – 2.00</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Long melon</td>
<td>218</td>
<td>435</td>
<td>285</td>
<td>570</td>
</tr>
<tr>
<td>Hairy melon</td>
<td>125</td>
<td>188</td>
<td>122</td>
<td>182</td>
</tr>
<tr>
<td>Snake bean</td>
<td>483</td>
<td>1207</td>
<td>253</td>
<td>696</td>
</tr>
</tbody>
</table>

*The 4 kg winter melon is rarely grown in the NT. Prices vary greatly depending on quality of the product and seasonality of supply. These figures should be taken only as an indication.

**Varieties**

Sinqua is 20 to 50 cm long, and 5 to 8 cm diameter, slightly tapered and dark green. Several ribs or ‘angles’ run the length of the fruit. Smooth luffa has no angles, and a much more fragile skin. It is mid green in colour with longitudinal darker stripes. It is shorter than sinqua with a maximum length of 40 cm. Luffa varieties are different for vegetable or sponge production, it is important that the right one is selected. Luffa varieties imported from Asia may be daylength sensitive. Luffas weigh approximately 0.5 to 1.0 kg.

Hairy melon are cylindrical light green fruit, 20 to 25 cm long and 8 cm wide, and are covered with a layer of fine hairs. Long melon is a similar colour and also finely haired, but is 30 to 40 cm long with a slightly narrowed neck. Its skin is more delicate than hairy melon, and must be grown on a trellis. Long and hairy melon weigh 1 to 1.5 kg. Winter melon, or wax melon, is round to oval shaped, 20 to 30 cm wide and 30 to 40 cm long, green with a whitish waxy bloom. It weighs 4 to 6 kg.

Snake beans look like a slim round bean but are 30 to 40 cm long. A purple tipped variety called Green Pod Kaohsiung has been used in the Darwin area, but other varieties are also grown. Quarantine regulations prevent bean seed being imported into Australia.

It can be difficult to source the seeds of these vegetables from within Australia. Local seed companies may source seed from Asian seed companies on inquiry. Known-You Seed Company, Taiwan and East-West Seed Company, Thailand are two which have seed for these type of vegetables. Market agents may also be able to source the type of seed for the product they require.

**Agronomy**

The luffas, hairy, long melon and snake bean are grown on trellises, which are in turn placed on raised beds or ridges. These can be covered in mulch to improve growth where necessary. Trellises are usually 2 m high, with wires at 50 cm from the ground and then 20 cm intervals, with 100 mm nylon netting. Overhead trellises are commonly used for the melons, particularly sinqua, to prevent wind rub damage to the fruit. These are similar in construction but have additional horizontal spans.

Row spacing is generally between 1.5 to 2.0 m, depending on the row spacing required for machinery access. Sinqua and luffa are planted 0.4 to 0.6 m apart, while hairy melon and long melon are slightly further apart at 0.6 to 0.8 m between plants. Snake beans are planted 0.4 m between plants. Winter melon is grown on the ground, using a raised bed prevents water logging. Spacing is again 1.5 to 2.0 m between rows, and 0.6 to 0.8 m between plants.

Seed can be sown directly into the ground, although transplanting seedlings can be more efficient. Irrigation is necessary.
for all these crops. The use of drip tape, micro sprinklers or drippers under the trellis is more efficient than overhead watering, which may increase fungal disease. Fertiliser application should be determined depending on the soil type and history. Adequate basal fertiliser is essential to establish vigorous vine growth prior to flowering. Nitrogen application is reduced during fruit set to promote flowering and fruit development.

Reported yields of these vegetables vary, and should be interpreted with caution (Table 3). This variation can be due to the stage of harvest, variety, climate and skills of the farmer. It should also be remembered that these crops are generally grown in small areas, less that 0.5 ha, and that this harvest is over several weeks.

### Table 3. Estimated yield range of Asian melons and snake bean

<table>
<thead>
<tr>
<th>Vegetable</th>
<th>Yield range (t/ha)</th>
<th>Average yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luffa (smooth and angled)</td>
<td>4 to 12</td>
<td>7</td>
</tr>
<tr>
<td>Winter melon</td>
<td>18 to 22</td>
<td>20</td>
</tr>
<tr>
<td>Long or hairy melon</td>
<td>8 to 10</td>
<td>9</td>
</tr>
<tr>
<td>Snake bean</td>
<td>6 to 30</td>
<td>8</td>
</tr>
</tbody>
</table>


### Pest and diseases

Pests of the melons can include leaf feeding beetles, mites, cucumber moth, Helicoverpa spp., aphids and thrips. However, pest damage to these crops is relatively minor. Fruit fly and whitefly can be a problem, and the cucurbits are susceptible to virus, so aphid control is important. Common diseases include powdery mildew and downy mildew.

Nematodes, particularly root knot nematode (Meloidogyne spp.) can affect all these crops. Use of an off-season green manure crop, such as sorghum, reduces the population of nematodes in the soil and provides some control. Crop rotation with non-susceptible crops also prevents the build up of nematodes in the soil.

Bean fly is the major pest of snake beans in the NT. Other pests include thrips, caterpillars and mites. Fusarium root rot of snake bean vines is a major disease concern. Control of this disease is through using clean planting material, increasing the organic matter in the soil and preventing spread of the disease through farm hygiene. Snake bean can also be grafted onto a resistant cowpea rootstock. The Department of Business, Industry and Resource Development, NT is currently evaluating snake bean varieties for resistance to Fusarium. Parrots can also be a serious pest of snake beans.

Pesticides are rarely registered specifically for Asian vegetables within Australia, however some off-label permits are available. Check with the local state department of agriculture and primary industry for current permits. Biological and ‘soft’ insecticides such as potassium soap are also available to control some pests.

### Harvesting and storage

Sinqua and luffa are harvested 9 to 13 weeks after sowing. Winter melons are slow growing and are harvested at a more mature stage 90 to 100 days after sowing. Hairy melon is harvested 3 to 4 weeks after fruit set, which is about 90 to 100 days after sowing. Harvest for snake beans commences at 6 to 8 weeks after sowing. Snake beans are harvested while immature, before the seeds within the pods are fully developed. Beans need to be harvested several times a week, if not daily, over the production period. Depending on the health of the vines, beans can be harvested for up to 8 weeks from first production.

Most of the melons can be stored at 12°C for up to 3 weeks,
however sinqua stored at 5°C has been found to have a longer shelf life. Mature winter melon can be stored below 12°C for up to six months. Smooth luffa is quite sensitive to water damage, so care should be taken with washing and drying. The melons are sold in 10 kg cartons with no liners. Sinqua is often packed in a longer carton because of its greater length.

Snake beans need to be cooled rapidly after harvest to 8 to 10°C and stored at this temperature. Packaging to prevent water loss is necessary for beans to remain crisp. Generally, beans are packed in 10 kg cartons with a plastic or perforated plastic liner. Beans will last up to 2.5 weeks when stored at 5 to 10 °C. Snake beans, like all beans, have a very high respiration rate and heat will build up in packaged beans if they are not adequately cooled.

Financial information

The major risks for growing the Asian melons are associated with learning a new crop. Firstly, getting the right seed is vital and can be easily mistaken owing to the confusion with names. Harvesting at the right stage and correct postharvest handling for each type of melon is also critical.

Diseases such as Fusarium can also dramatically reduce yield of snake bean. Marketing any of these products is also an area where inexperienced growers can flounder, so be certain of the market and requirements before planting. Prices can vary greatly within and between seasons depending on supply. Most growers produce several types of vegetables to minimise that risk.

Equipment requirements include land, a tractor and some type of bed former, trellis materials, irrigation and spray equipment, and some sort of cooling and storage facility after harvest. Production costs include fertiliser, pesticides, irrigation and labour for these activities. Harvest and packing costs, including both labour and materials, are also a large proportion of production costs.

References


About the author

Melinda Gosbee (B. Sc. (Agr.), PhD) worked as Senior Horticulturist with the Northern Territory Department of Business, Industry and Resource Development. She worked with the Asian vegetable growers around Darwin and studied postharvest problems of Asian vegetables and other produce.
Key messages

- Establish a market before planting
- Get the right vegetable!
- Cool beans after harvest

Key statistics

- Average yield of luffas: 7 t/ha
- Snake bean average price $2.50/kg
- Long melon and snake beans are produced in greatest quantities
- Supply, and price, varies greatly between seasons

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Introduction

Taro (Colocasia esculenta L. Schott) belongs to the monocotyledonous family Araceae, which includes the well known ornamental plants Philodendron, Dieffenbachia, Caladium and Anthurium. This taro species has two forms, the 'large corm' taro which is the subject of this chapter and 'small corm' taro (Colocasia esculenta L. Schott var. antiquorum) also known as Japanese taro which is dealt with in another chapter. Large corm taro is characterised by a larger central or main corm and usually 5-10 smaller side cormels or suckers. Small corm taro has a relatively smaller central corm and very numerous (>50) well developed side cormels. Other plants referred to as taro include White Taro (Xanthosoma sp.), Giant Taro (Alocasia sp.) and Giant Swamp Taro (Cyrtosperma sp.).

Taro is an ancient crop grown throughout the humid tropics and parts of the subtropics for its edible corms and leaves (blade and petiole). The corms are usually boiled, steamed or baked but they may also be fried to make...
chips – both fries and crisps. The leaves and corms must be cooked properly before consumption otherwise the calcium oxalate present can cause irritation. The same is true for other crop plants such as rhubarb.

Large corm taro has been growing in Australia for about 100 years but it is only in last 10 years or so that a significant industry has emerged which is based mainly on the wet tropical coast of north Queensland. Smaller production areas are located near Darwin, the Atherton Tableland, central and southern Queensland and northern New South Wales. The rise in importance of taro can be partly attributed to the very large increase over the last 20 years or so in the ethnic Asian and Pacific Islander population, who are the main consumers (Table 1). Pioneer taro growers, the Rural Industries Research and Development Corporation, the Queensland Department of Primary Industries and Fisheries and Central Queensland University and have also fostered the development of the taro industry. Recently the favourable nutritional properties of taro have been raising a lot of interest with non-traditional consumers.

Australian production is conservatively estimated at 1,000 t/yr with a wholesale value of about $3.5 million to the 150 or so growers. Thus at yields of 20 t/ha Australian production could be achieved off just 50 ha. A further 3,000 t or so is imported – mostly from Fiji. Small quantities of frozen peeled taro pieces are also imported from several countries including Thailand, Malaysia and Fiji.

Growing taro is currently physically demanding but as mechanisation of cultural and harvesting practices increases, the challenge for Australian producers is to significantly improve their efficiencies of production so that they can be more competitive with imports in the domestic marketplace and increase their prospects for export to New Zealand.

Marketing issues

The main taro product traded is whole fresh corms. Sale of fresh leaves is of very minor importance currently in Australia. Much of the north Queensland production is marketed in Sydney...
and Melbourne with some being shipped as far away as Perth. The volume that goes through the Brisbane wholesale market is quite small due to the existence of taro locally grown by Vietnamese and Pacific Islanders in backyards in the Brisbane region. This taro is sold directly to both the public and to Asian retail outlets.

Currently there are three main exporters of taro from Fiji to Australia. Each sends one shipping container every two weeks. These exporters have their own supply chain to distribute the taro which bypasses the central markets. Some smaller exporters send taro whenever it is available but they do not have an efficient distribution network with a considerable amount finding its way to the central markets where it creates havoc with sales of domestic product.

We believe that the future is positive for taro in Australia. However, much will depend upon putting in place a strong supply chain and a sound marketing strategy. Taro is consumed as a staple starchy food by the Asian and Pacific Islander ethnic communities in Australia. Thus consistent year-round supply is desirable – not just when it is easiest to grow (over the wet season). Merchants in the central markets have indicated that they could sell a great deal more taro (3-4 times has been quoted) if growers could deliver consistent supply (volume) and consistent quality (grade standards). Thus coordination of supply of product to the marketplace would appear to be crucial to achieve significant increases in sales. In particular, the Australian industry must ensure that they do not oversupply the market from April-July when imports from the Pacific Islands are greatest. Profits are not necessarily just made by getting high yields relative to inputs but by matching good yields with good market prices.

It is interesting to note that in the Pacific, the Australian market is not seen to be assured in the long term. Indeed Australia is seen as a potential future rival in the New Zealand market which currently takes about 6,000 t/yr. Under the existing circumstances, costs of production in Australia are still too high compared to Fiji but an event such as an outbreak of taro leaf blight in Fiji and enhanced industry mechanisation in Australia could tip the balance.

About 400 million people around the world include taro in their diet and in much of the Pacific, West Africa and the Caribbean it is a staple food crop (Table 2). However, in Australia most of the consumption is by Asian and Pacific Islander communities which represent less than 7% of the population. Thus per capita consumption is only 0.2 kg/yr compared with about 60 kg for potato (Solanum tuberosum). One key to an expanding Australian industry is to increase consumption by the remainder of the population. Capturing these new markets will partly involve the interaction of producers and researchers with hotels and restaurants to promote and create awareness with the public. Special features of taro that could be exploited are:

- taro chips (fries and crisps) are better for you than potato chips because taro absorbs a great deal less cooking oil during the frying process
- taro has a low glycemic index (GI factor) i.e. it provides slow sustained release of energy to the body. Thus it is a desirable food in the treatment and prevention of the blood sugar disorders diabetes and hypoglycemia which are rampant in the western world
- most importantly it is very delicious when properly prepared.

Taro is a major staple food crop in much of the Pacific. Both corms on the left and young leaf on the right are consumed.
Table 2. Proportion of world production of 9 million t of taro among regions and countries and consumption statistics 2001.

<table>
<thead>
<tr>
<th>Region</th>
<th>Country</th>
<th>% total world production</th>
<th>Taro consumption (kg/person/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>Nigeria</td>
<td>43.6</td>
<td>33.4</td>
</tr>
<tr>
<td></td>
<td>Ghana</td>
<td>18.8</td>
<td>85.5</td>
</tr>
<tr>
<td></td>
<td>Cote d’Ivoire</td>
<td>4.1</td>
<td>22.6</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>8.8</td>
<td></td>
</tr>
<tr>
<td>Asia</td>
<td>China</td>
<td>17.2</td>
<td>1.1</td>
</tr>
<tr>
<td></td>
<td>Japan</td>
<td>2.4</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Oceania</td>
<td>Papua New Guinea</td>
<td>1.9</td>
<td>35.0</td>
</tr>
<tr>
<td></td>
<td>Fiji Islands</td>
<td>0.4</td>
<td>38.1</td>
</tr>
<tr>
<td></td>
<td>Samoa</td>
<td>0.2</td>
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<td>0.2</td>
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<tr>
<td></td>
<td>Other</td>
<td>0.48</td>
<td></td>
</tr>
<tr>
<td>Americas</td>
<td></td>
<td>0.2</td>
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</table>

Source: FAO

Wholesale prices received for Australian taro in the central markets range from $2-$6/kg but are generally $3-$4 – the price received being largely governed by supply. Imported fresh taro usually retails from $4-$6/kg. It is interesting to note that when the wholesale price falls below about $2/kg virtually any amount of taro can be sold. Thus consumption could be greatly increased without substantial damage to grower returns if lower cost efficient production could be implemented.

**Production requirements**

Taro can be grown over a range of climatic conditions but is best adapted to a warm humid environment. Cooler temperatures, water stress and overcast conditions will lead to delays in the crop reaching maturity. Best growth occurs at daily maximum temperatures of 25–35°C. It can be grown in subtropical environments with average temperatures of 20°C, but must be frost-free during the growing cycle. Excessive wind can cause damage to the large leaves. Highest yields for taro are obtained under full intensity sunlight but taro is more shade tolerant than most other crops. Taro can be grown on a wide range of soils but best results are obtained on deep, well-drained friable loams with pH 5.5–6.5. Soils with high water holding capacity are advantageous during dry weather. Taro is a water loving plant and is very sensitive to water stress which causes drastic effects on yield. Irrigation is essential for high yields of quality corms. Taro can withstand prolonged waterlogging and in certain parts of the world some varieties are actually grown like paddy rice.

**Varieties**

The main variety grown in Australia is Bun Long. This variety is a soft cooking type which is favoured and mostly consumed by the ethnic Asian community. Smaller quantities are also produced of ‘Pacific’ taros such as Pink Samoan and Taro Niue (Tausala ni Samoa) which retain a firmer texture after cooking and are preferred by Pacific Islanders. Imports to Australia are mostly firm textured varieties and largely Pink Samoan and Taro Niue. There are no fresh corm imports of Bun Long. Fresh ‘Pacific’ taro grown in north Queensland is superior in quality to imported taro from Fiji because:

- it is fresher
- it does not require fumigation
- it is carefully handled to minimise mechanical damage.

Thus if ‘Pacific’ taro could be produced at a competitive price then an Australian market three times greater than for Bun Long would open up to producers.

There are several thousand varieties of taro existing around the world and each country has its favoured varieties. Thus there

Dirt and roots are removed from individual corms prior to packing.
are opportunities to further develop niche markets. The best varieties for expanding the non-ethnic market in Australia may not necessarily be the main ones currently grown. Producers must also realise that each variety will have its own particular set of advantages and disadvantages e.g. Taro Niue is more tolerant of dry conditions and suffers less damage from rats compared to Bun Long but the crop cycle is longer and yields are lower. The calcium oxalate content also varies with different varieties.

Commercially produced varieties in Australia have been demonstrated to be susceptible to taro leaf blight overseas, so it would be advisable to begin a program of importation of taro leaf blight resistant germplasm to examine agronomic characteristics and potential marketability. A gene pool reserve of resistant varieties in the possession of growers will prevent the overnight collapse of the industry and long lead-time to re-establish should the disease enter and become rampant.

Taro farms have abundant quantities of planting material. Contact Taro Growers Australia (07 40672078) for potential suppliers.

**Agronomy**

Taro is grown as an ‘upland’ crop in Australia, not as a paddy crop. Land preparation usually consists of weed removal and cultivation to obtain a friable soil texture with deep ripping usually beneficial. Mounding of rows is recommended on the wet tropical coast. In tropical locations field planting can occur at any time of the year so long as the ground is dry enough for land preparation.

Provided there is an ample supply of irrigation, production and harvest can be scheduled for most of the year. However, on the wet tropical coast plantings are mostly made prior to the wet season which extends from January to June so that the crop is largely rainfed. The crop duration in north Queensland is from 7-12 months depending upon time of planting and variety grown. Subtropical regions must grow the crop over the warmer part of the year, usually establishing plantings in early spring and harvesting in the autumn and winter months.

Taro is propagated vegetatively by setts which consist of the lower 30-40 cm of the leaf stalks together with the top 1-3 cm of the corm. Suckers (side cormels) including their attached undeveloped corm may also be used as planting material. However, larger setts give higher yields. Plantings are often made by hand in planting holes 10-15 cm deep but mechanical planting or at least opening furrows with a tractor greatly speeds up the planting operation. The corm that will eventually be harvested grows upward from the corm portion of the planting piece. If plantings are too shallow this will result in corms developing above the ground surface which are more likely to be damaged by insect pests and rodents. This can be partly overcome by hilling up the rows as part of the weed control strategy.

Planting densities are from 12,000 to 25,000 plants/ha either arranged in single or double rows (e.g. 1.5 m x 0.6 m in single rows → 12,000 plants/ha and 1.5 m x 0.50 m x 0.50 m in double rows → 25,000 plants/ha). Irrigation is essential for optimum yields and is usually delivered by solid set sprinklers above the crop or by drip irrigation.
Fertiliser requirement will depend upon the particular soil conditions. Soil testing prior to planting is recommended to reduce some of the guesswork of rates of fertiliser to apply. Likewise plant analysis of leaf tissue comparing levels to tentative optimal levels will help fine-tune fertiliser requirements. The usual experience is that taro responds to regular applications of nitrogen and potassium fertiliser. Sugar mill byproducts such as mill mud are useful sources of nutrients for the taro crop. Mill mud should be incorporated well prior to planting at rates from 15 to 40 t/ha. Otherwise a basal dressing of a balanced fertiliser should be incorporated in the bottom of the planting furrow. Cover crops of forage sorghum grown during the fallow period and then incorporated before planting have been very beneficial to growth of taro crops. As well as contributing organic matter to the soil they can also help break some pest, disease and weed cycles.

Weeds can take over and substantially reduce yields if not controlled during early crop development. Ensuring strong healthy growth of the taro plants to improve competitiveness is a key. Weeds are generally not a problem once the taro’s leaf canopy has closed. Weeds are usually controlled by cultivation, mulch, mowing/slashing or combinations of these. Some herbicides are used but the crop is very sensitive to several herbicides. Weeds may re-establish in a mature crop but this is not really an issue if hand-harvesting. However, weeds must be controlled during this latter stage if the crop is to be mechanically harvested or ratooned.

Taro is most commonly produced as a single plant crop but it may also be ratooned for a second crop. Such ratoons have lower costs of production compared to the first crop but management, particularly weed control, crop nutrition and plant density must be just right. However, the size of ratoon corms is seldom as large as the plant crop. Also if a ratoon crop is desired, mechanical harvest will not be possible in the plant crop.

**Pest and disease control**

Taro is a crop with generally few pest and disease problems in Australia. This makes it one of the easiest crops to grow organically. However, because taro is only a niche market there is no particular consumer demand for taro grown organically. Nevertheless as the non-ethnic market grows this may be a useful marketing angle.

Various species of rats cause the most damage in taro crops by feeding on the corms. This can lead to downgrading of a large percentage of corms because rather than eating the whole corm they nibble on many. Rats are best controlled by good farm hygiene as well as controlling surrounding vegetation and weeds to reduce their other food sources and shelter. Strategic baiting and trapping is also practised. Feral pigs and wallabies can also cause significant plant damage if not controlled.

Outbreaks of cluster caterpillar (*Spodoptera litura*) and hawk moth larvae (*Spingidae*) are common but they are readily controlled with the use of sprays such as Dipel® (*Bacillus thuringiensis*). Various grasshoppers and cane grubs cause damage to leaves and corms respectively from time to time.

Taro also suffers at times from bacterial corm rots. There is still much to be learnt on this subject but it appears that crop stress such as foliar damage and leaving the crop in the ground for too long once maturity has been reached tends to increase the problems experienced. The virus, dasheen mosaic virus is present in plantings but it is not known just what impact it has on yield.

A particular concern to the industry is the threat of taro leaf...
blight, taro beetle and exotic virus diseases entering Australia via illegal imports of taro planting material and via insufficient enforcement of AQIS guidelines for the import of taro corms for sale/consumption in Australia. There is evidence of shipments being contaminated with soil and the corms having viable ‘eyes’ that can be propagated from. By comparison no imports of new varieties via quarantine have been permitted in recent years because of the possible incursion of exotic virus diseases.

**Harvesting and postharvest handling**

The crop is mature for harvest when the leaves become smaller, the leaf stalks shorten and the main harvestable corm pushes out above the soil surface and is about half exposed. If the crop is left in the ground too long after this stage the eating quality of the corms can deteriorate and as mentioned there is more likelihood of rots occurring.

Harvesting is a very laborious task with mature corms usually pulled out by hand. Some mechanical harvesters have been developed but these are not yet in common use. The corms are then transported to the packing shed where the tops are trimmed and roots and dirt removed from the corm. Corms are usually graded according to size or weight. Taro Growers Australia has recently prepared a set of grading and packing standards. Corm weight of 1-2 kg is preferred for Bun Long. ‘Pacific’ taros are best in the 1.5-2.5 kg range. Corms are then packed into fibreboard cartons holding 15-20 kg, palletised and freighted by road or rail to the capital cities which can take 2-3 days from north Queensland. Harvested corms should not be stored for lengthy periods at ambient temperatures as deterioration occurs. Cool storage can be used to extend storage life.

Crop yields are extremely variable with the full yield potential seldom reached which is partly due to grower inexperience. Yields >50 t/ha have been reported from Hawaii but in north Queensland yields are more usually 15-25 t/ha.

A taro chip (crisp) factory is about to be established at Babinda, north Queensland. Projected product sales from this venture forecast a need for about 100 t/yr of fresh corms of Bun Long by the fourth year of operation which is 10% of current Australian production.

Tender young taro leaves are usually prepared for market by packing in low density polyethylene bags. They can then be stored at 10°C for up to two weeks without discolouration and major weight loss.

**Financial information**

Taro is a relatively new crop to Australia hence there is limited market, production and economic information available. Growers of taro usually have plantings of between 0.5 and 2.5 ha. Also taro is usually grown in conjunction with other crops to spread risk. Taro is a good complementary crop for an orchard which can ensure positive cash flow between fruit harvests.

The costs of producing and marketing an average yield of 20 t/ha are $40,000 with labour costs comprising 50% of the costs while gross incomes amount to approximately $70,000/ha.

**Key references**

CTAHR (1997) Taro – Mauka to Makai. College of Tropical Agriculture & Human Resources University of Hawaii at Manoa


**Key messages**

- Main market – Asian and Pacific Islander communities
- Easy to grow organically
- Very labour intensive crop
- Irrigation essential
- Improved competitiveness by enhancing production efficiencies
- Market growth via consistent quality, supply and promotion

**Key statistics**

- Australian production 1,000 t/yr
- Imports 3,000 t/yr
- Exports nil

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Wasabi

Angela Sparrow

Acknowledgement is given to Melanie Barber and Michele Buntain, the authors of this chapter in the first edition of this publication.

Introduction

Wasabi (*Wasabia japonica* Matsumara) is a perennial herb belonging to the Brassica family, which includes broccoli, cabbage and mustards. The plant grows naturally alongside mountain streams in the highlands of Japan.

Wasabi paste is prepared by grating the fresh stem of the wasabi plant, to form a hot, spicy green condiment served with traditional Japanese dishes such as sushi, sashimi and soba noodles. Ready-to-use wasabi pastes are also popular and dried powder is used to flavour foods ranging from rice crackers to ice cream.

Wasabi is in short supply in Japan due to a decline in traditional farm labour, urban encroachment on production sites and pollution of some rivers and streams. Wasabi is becoming increasingly popular in many other countries with the inclusion of Asian food in cultures formally dominated by European cuisine.

Wasabi is grown commercially in gravel beds filled with fast-flowing water or in soil, in a manner similar to other Brassica crops. The requirement for shade and cool growing conditions determines the suitability of a site for wasabi production.

The major advantage of producing wasabi in Australia is the ability to supply product year round. Mild summer and winter temperatures

Freshly grated wasabi stems

Current wasabi production

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in the cool temperate zones of Tasmania and southern Victoria mean that there is no constraint to production caused by extreme temperatures.

**Markets and marketing issues**

In Australia, there is potential not only to supplement the demand for wasabi in Japan, but also to provide fresh wasabi for the increasing number of people enjoying Japanese cuisine throughout the Asia-Pacific region.

Markets in Australia, south-east Asia and the Pacific islands will be targeted initially, while increased product volume will provide the opportunity to export to Japan. Current Japanese production is around 5000 tonnes fresh weight per annum, but fresh product is unavailable in the coldest months (December-February).

Fresh wasabi was not available in Australia prior to 2000. Processed products imported to Australia often contain European horseradish. Evaluation of wasabi from trial wasabi crops grown in Tasmania has confirmed a large domestic market based in Sydney and Melbourne, and export opportunities to south-east Asian and Pacific regions with expatriate Japanese populations keen to obtain fresh and processed pure wasabi products.

Since 2000, a supply of fresh Tasmanian wasabi with a farm gate value of $AUD 100/kg has been available to selected clients in Sydney, Melbourne and Hobart. Fresh stems are airfreighted either directly to the restaurant or to a distributor servicing a number of Japanese restaurants.

Yields of 10 t/ha have been realised and are estimated to double, in line with those achieved in Japan, as crop husbandry practices improve. Fresh Tasmanian wasabi is currently a soil-grown product, traditionally considered suitable only for processing. Market evaluation indicates that discerning domestic consumers are willing to pay up to $AUD 380/kg for water-grown wasabi. Consequently, the introduction of water-grown wasabi production systems, and improvements in the quality of planting stock, have been development priorities for the industry in the last 3 years.

While there is a high demand for fresh quality stems, a major market also exists for processed product in the form of pastes, pickles and powder. Wasabi-flavoured cheese produced in Tasmania uses dried wasabi powder from Tasmanian crops and has met with great success in Australia, USA and Japan. This is the first in a range of value added wasabi products to be produced in Tasmania.

**Production requirements**

Wasabi is a cool climate crop requiring shaded conditions, plentiful irrigation water and readily available oxygen at the root system. The ideal root temperature range of 12-15°C may be a constraint when choosing a site to grow the crop. While wasabi tolerates air temperatures ranging from mild frosts to 30°C, root temperatures below 12°C cause declining growth rate. Growth ceases altogether at 5°C. The plants exhibit signs of stress and become more susceptible to disease if the root temperature exceeds 18°C.

In Japan, shade is provided from deciduous trees complemented by temporary shade structures during the summer months. In Tasmania, permanent structures, built to withstand windy conditions and using 80% shade cloth, have been constructed. While crops have been produced successfully under black shade cloth, light colours have the advantage of reflecting light, thereby keeping the internal environment of the shade house cooler.

For soil grown crops, excellent drainage is essential. Soils with an open friable structure, such as sands or light loams, are preferred. Raised beds assist with drainage and soil pH should be in the range 6.5 - 7.5. Soil preparation includes the incorporation of base nutrients.
similar to those required for other leafy vegetables. Foliar boron and sulphur sprays may be beneficial during the second year of growth.

For water grown crops, the semi-aquatic plants are anchored in gravel beds through which fresh water flows continually. Water must be free of pollutants and have an oxygen concentration of 10-12 mg/L. A delivery volume of 180 L/sec/ha is recommended. Plants generally scavenge nutrient requirements from the fast-moving water while foliar sprays provide supplements.

Areas most suitable to wasabi production in Australia are those with a maximum summer temperature below 30°C and access to abundant water. This confines production to isolated pockets in the southern-most part of the continent (see map).

**Varieties**

‘Daruma’ variety has been selected for soil-grown wasabi crops in Tasmania. Its rhizome is thick and green, and has excellent flavour. Leaves are heart-shaped and deep green in colour. ‘Daruma’ produces many side-shoots, lending itself to vegetative propagation. This practice should be continued for a maximum of 2 - 3 generations to prevent build up of disease.

‘Mazuma’ is the preferred variety for semi-aquatic production. Plants produce short, thick rhizomes with excellent flavour. Mature leaves are round and dark green while emerging leaves and petioles have a distinct reddish colouration. The use of tissue-cultured plants of ‘Mazuma’ variety in Tasmania aims to minimise disease risk.

‘Midori’ variety is also suited to semi-aquatic production. By comparison with other cultivars, the rhizome grows quickly and is pale green in colour. The leaves are heart-shaped and bright green. Growers in Victoria have conducted trials with this variety.

The use of high quality planting stock is essential to minimising disease risk in wasabi production. Although Japan continues to provide the largest gene pool for wasabi varieties, it is anticipated that local production of disease-free tissue-cultured plants will replace the need to import commercial quantities of planting stock from Japan.

**Agronomy**

Tasmania’s temperate climate allows wasabi to be planted and harvested year round, providing a distinct advantage for supplying fresh wasabi to the market. Mature stems are harvested 18 – 24 months after planting.

**Soil Culture.** Soil preparation includes application of a base fertiliser N:P:K (12:12:12). Application rates are determined by paddock history but should be similar to those for other Brassica vegetables. Boron must be included pre-planting with additional foliar applications made one year after planting. Beds can be prepared by building ‘potato mounds’ along which plants are sown in zigzag manner. Alternately, raised beds 1 m wide are prepared with plants spaced at 300 mm intervals.

A shade house structure is required to provide 80% shade in the summer months. The shade structure must be sufficiently robust to withstand windy conditions in the local environment. Extension of the shade cloth down the walls to the ground protects plants from wind and grazing predators and ventilation openings reduce the incidence of mildew. Light colour shade cloth is beneficial in keeping the shade house cool.

Rainfall should be supplemented during dry summer months with irrigation water applied gently from overhead micro-sprinklers or drippers at a rate of 30 mm/week.

**Water culture:** Bed preparation is determined by the topography of the site and the water source available. Bed types for stream and spring fed systems have a finished slope of 1-2% and require 80% shade in the summer.
(1) Stream fed sites consist of gravel-filled terraces through which water is diverted from an adjacent watercourse. The topography of the site will determine the depth and length of the terraced beds. Bed depth may range from 400 – 900 mm. Drainage pipes incorporated into a coarse gravel layer at the base of the beds ensure that water moves downward throughout the whole root zone of the plant allowing fresh water to rapidly replace that depleted of oxygen and nutrients. A layer of fine gravel overlays the coarse gravel layer to a depth of 100 – 200 mm. This provides anchorage for both the plant and water borne nutrients. The gravel beds are filled with water covering the gravel to a depth of 10 mm. Water should be delivered at a rate of 180L/sec/ha and plants spaced at 300 mm intervals.

(2) Spring fed sites are usually identified by the occurrence of coarse gravel or sand from which spring water seeps. The rate of delivery of the spring water will determine the size of the wasabi beds at these locations. A flattened area is prepared at the spring source with gravel mounded in rows running parallel to the flow of water. Plants are placed at 300 mm intervals along the water’s edge. The water flow rate should be controlled to provide a surface speed of 120 – 150 mm/sec.

Pest and disease control
Maintaining cool temperatures for wasabi culture is a valuable tool for controlling pest and disease problems.
Insect pests that attack Brassica vegetables such as Diamond Back Moth and White Cabbage Butterfly are occasional visitors to wasabi production sites. The most detrimental organisms in Japan are fungi, such as Phoma species, Fusarium species, Pythium species, and bacteria such as Corynebacterium species.
Black streaks on the leaf stalk and dark brown circular spots on the leaves are indicative of Phoma infection. Chronic wilt symptoms and rotting at the base of the plant are indicative of Fusarium.
The effects of these organisms can be minimised by taking precautions such as the use of disease-free planting material when establishing new production sites, maintaining good plant nutrition and immediately removing and destroying plants displaying disease symptoms.
Copper sprays can be used as a protective fungicide in the summer months to control Fusarium, though care must be taken to avoid run-off to streams and rivers. Trials are currently being conducted in Tasmania to identify fungicides suited to a pre-planting control treatment for other fungal organisms.

Harvesting, handling and post harvest treatments
Wasabi stems reach a marketable size of 80 - 150 mm long, weighing 60 – 180g approximately two years after planting. As side shoots develop from the main stem following flowering, harvest should commence prior to flowering in the second year.
Whilst mature stems may be harvested individually, more often the whole plant is harvested and graded as:
- premium stems suitable for the fresh market (farm gate price $100/kg)
- smaller stems, leaves and petioles suitable for processing as prepared wasabi paste or dried powder (farm gate price $20/kg)
- fresh leaves (wholesale price $75/kg).
An individual plant weighs approximately 3 kg and can produce 4 - 14 stems for the fresh market, 2 kg of smaller stems, leaves and petioles and 100 g of premium quality fresh leaves.
Wasabi stems should be bright green in colour and evenly tapered,
narrowing at the root. Uneven taper indicates that the plant has been subject to environmental stress during growth.

Trimming is a critical part of wasabi stem presentation. Excessive trimming suggests that soil or diseased material has been present. Stems should be trimmed immediately above the root and petioles trimmed to a length approximately one third the length of the stem. Wasabi stems are cleaned under cool running water. This procedure is considerably easier for wasabi grown in water culture.

Stems for the fresh market should be kept moist, cooled to 4°C immediately after harvest, packaged in chilled polystyrene boxes and delivered to the market within 24 hours. Restaurants and households can keep wasabi stems fresh for up to two weeks by wrapping in a moist towel and storing in the refrigerator.

Stems weighing less than 60 g, or those that are bent or broken, are used for processing. These should be kept chilled prior to mincing or drying. Leaves that are not suitable for the fresh market may also be dried and ground to add authentic colour and flavour to processed wasabi products. Leaf petioles can be made into wasabi pickles.

Leaves 100 - 150 mm in diameter are suitable for the fresh market. Premium leaves should have no discolouration or physical damage and be packed in breathable plastic bags, cooled to 4°C and delivered to the market within 24 hours.

**Financial information**

A crop of wasabi becomes commercially viable with 0.5 ha under production, half of which is planted and harvested each year.

**Soil culture.** To date the average yield of fresh stems for a Tasmanian wasabi crop is 10 t/ha, with secondary stem leaves and petioles contributing a further 20 t/ha. An average price of $35/kg is estimated for the different component products of the plant. The crop production cycle is between 18 months and 2 years. This calculates to a gross income per crop cycle of $262,500 (30,000 kg/ha x $35/kg x 0.25 ha), or equivalent annual gross income of between $131,250 - $175,000 per 0.25 ha.

Establishment costs for a wasabi crop in soil culture including planting stock, soil preparation, irrigation and shade-house construction are estimated at $90,000/0.25 ha. These costs are incurred for each 2-year crop cycle as the site is relocated to provide a rotational break. Access to a suitable shade tolerant, disease breaking crop would allow a reduction in establishment costs as the same site could be reused without the need to re-locate the shade house. A 0.25 ha site is estimated to require a basic packing shed ($15,000) and harvest and processing costs of $10,000 per cycle. Sharing with nearby growers could reduce overhead costs for packing shed facilities and harvest times could be coordinated to ensure continuity of supply to markets.

**Water culture.** Although the yields are similar for soil and water grown wasabi, market evaluation indicates that water-grown wasabi for the fresh stem market has a value three times that of soil grown stems, bringing the gross income for 0.25 ha to $393,750 for a 2-year rotation. Establishment costs are higher for this type of system when the recommended disease-free, tissue-cultured planting stock is used ($170,000). However, because the site is permanent, the capital costs of shade house, gravel bed and drainage can be amortised over more production cycles. Capital costs can be reduced by linking shade houses on adjacent sites. Variable establishment costs can be reduced for subsequent crops by using side-shoots for crop establishment.

Once established, variable costs of production, including gravel bed restoration, replanting, foliar fertiliser application and harvest costs are estimated to be approximately $30,000 per 2-year crop cycle. However, actual costs may be significantly different as there are no Australian figures currently available.
Key references


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Angela is project leader for the jointly sponsored DPIWE and RIRDC Tasmanian wasabi project and has travelled to Japan and the USA to compare methods of traditional and modern wasabi cultivation systems. The project aims to establish wasabi production and marketing in Tasmania as a sustainable agricultural enterprise.

Key statistics

- Japanese market demand exceeds supply
- Potential market for Japanese cuisine in Asia Pacific region
- Australian market evaluation predicts $100-380/kg for fresh stems from Tasmania
- Current Tasmanian production of 0.2t/ha projected to increase 500-fold by 2015

Key messages

- Requires water, shade and cool temperatures
- High value, low input crop
- High initial capital investment
- Two-year production cycle

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Rob McEldowney

**Introduction**

An extract for use in flavours and fragrances can be extracted from the dormant buds of the blackcurrant bush *Ribes nigrum* L. It has a distinctive aroma with fresh top notes and an intense catty characteristic overlying a strong fruity background.

The extract can be obtained through solvent extraction using either a purified hydrocarbon solvent like hexane or liquid CO₂. The product is generally traded as a ‘concrete’ which is solid at room temperature due to the presence of plant waxes, or refined to an alcohol soluble product known as an ‘absolute’, which is liquid at room temperature.

The buds required for extraction have traditionally been sourced from the annual prunings from fruit plantations with the buds stripped by hand. Consequently the availability of buds has largely depended on the fortunes of the fruit industry at any given time, resulting in severe supply and price fluctuations.

In the mid 1980’s a group of Tasmanian producers, in response to difficulties with their local fruit market, turned to bud production, establishing dedicated high density blackcurrant plantings set up for mechanical harvesting.

**Markets and marketing issues**

The principal market for blackcurrant bud extract has been in flavouring where it is used to reinforce and modify natural or artificial blackcurrant flavours, but it has also found applications in perfumery and cosmetics. The product has been marketed since the early 1960’s as Bourgeons de Cassis, reflecting the traditional production area, the Grasse region of France.

Buds were also imported from other European sources for extraction by a small number of specialised facilities. However, since the supply of buds was only ever a sideline to fruit production, volumes generally fell short of demand. This market opportunity was identified by the School of Agricultural Science at the University of Tasmania and Essential Oils of Tasmania Pty Ltd (EOT) who worked with Tasmanian producers to pioneer economic production systems using mechanical harvesting.

More recently, similar systems have been established in France, under contract to the main suppliers.

As with all essential oil products the quality of the oil, as defined by composition and organoleptic criteria, is critical. Tasmanian production is based on different cultivars and unique extraction systems, giving a product which is different to the established quality. While this invariably makes the marketing process more difficult initially, it does provide a competitive advantage in terms of...
future sales, if the new quality can become established. The market dynamics are expected to change in the near future as new plantings set up for mechanical harvesting come online in France.

Production requirements

Blackcurrants require very specific conditions in terms of microclimate and soil type. Production is most likely to be in the temperate areas of Australia where long days and cool nights favour accumulation of essential oil. However, it would be possible to produce in other specific regions such as highland sub-tropical and tropical areas.

A wide range of soil types can be used provided drainage is good. This is important both for plant performance and longevity, but also to enable access for mechanical harvesters during winter. A neutral pH is ideal but crops can be successfully grown on soils down to pH 5.

Blackcurrants are not deep rooted and have a reasonably high irrigation requirement during the vegetative growth period through summer. Vigorous extension growth has to be maintained to give the necessary bud numbers for economic oil production and the right structure for mechanical harvesting.

Topography limitations are largely dictated by machinery requirements with mechanical harvesters limited to slopes of less than about 10%.

Aspect is not critical - although the crop needs full sun, bud production does not require the same level of sun penetration as a ripening fruit crop.

Varieties/cultivars

Tasmanian bud production has been based on the variety White Bud, a local selection of the English variety Baldwin. More recently selections with particular oil chemotypes have been isolated from the general White Bud population and cultivated to enable different quality criteria to be met. White Bud is not the normal variety used for bud oil in Europe resulting in the Tasmanian product differing from traditional sources.

Cultural practices/agronomy

Blackcurrant plantations for bud production are established at about 4 times the density of fruit plantings. A total of around 50,000 cuttings per hectare are mechanically planted during the dormant period. The cuttings are generally 150-200 mm long, with 6 buds and the cuttings are placed so that no more than 2 buds remain above ground level. Cuttings should be prepared from one year old canes and planted at row spacings to suit the equipment required to manage and harvest the crop.

Good soil moisture must be maintained until the cuttings strike roots – the period after bud burst is the most critical because it generally precedes root development by several weeks.

Irrigation requirements remain reasonably high throughout the growth period. As a guide, approximately 30 mm per week should be budgeted on for the period from bud burst in September until leaf drop starts in April.

A high nutrient status must also be maintained to ensure constant, rapid extension growth. Recommendations for basal fertilisers should be based on soil analyses but on reasonably fertile soils an annual application of around 35 kg/ha of P and 80 kg of K can be expected. Crops in Tasmania have shown responses to additional potash applications around November (100 kg/ha of muriate of potash).

Regular nitrogen side dressings are vital with at least 100 units of N generally recommended in the period through to early autumn. Sulphur is also an important nutrient and it has implications in terms of the chemical composition of the oils produced.

At the end of the growth cycle, a well grown bud plantation will have canes at least 80-100 cm long with up to 30 buds per cane. Recycling of nutrients is encouraged as much as possible – only a relatively small weight of buds is removed from the field at harvest with all the remaining growth mulched and returned. Production can be expected to steadily increase for the first 3-4 years, as the cane density builds up to mature levels, starting with about 50 kg of buds/ha in the first year and levelling out at about 250 kg of buds/ha at full plantation density. Crops on well-selected sites with good management can be expected to produce for at least

Key messages

- Careful market analysis required
- Determine product quality criteria
- Select cultivars and extraction technologies
10 years. Some rejuvenation may be required to counter excessive cane density and soil compaction as crops age.

Good weed control is extremely important to avoid competition and from harvesting and quality considerations. Since propagation is via unrooted cuttings, establishment is relatively slow and poor weed control in the first season will result in crop failure. Depending on the weed spectrum, sites should go through an extensive weed control program before planting, including broad range knock-down herbicides, cereal cover crops and fallow periods. Even after that, follow-up spot spraying is often required after the crop has been planted. There is an opportunity for further perennial weed control during the dormant period in winter after the crop has been harvested.

There are few herbicides registered for blackcurrant plantations and all relate to fruit production situations. Minor use permits are required from the Australian Pesticides and Veterinary Medicine Authority (APVMA) for any non-label chemical use.

**Pests and diseases**

The main disease of blackcurrants in Tasmania is Septoria leaf spot (*Septoria ribisi*), which can cause premature leaf drop, greatly reducing vigour and bud development. It is evident as angular light coloured spots with a greyish centre and purplish margins. Gooseberry mildew (*Sphaerotheca murs-uvae*) can also cause problems sporadically, particularly when conditions have been warm and humid after the crop canopy has closed over. The symptoms of mildew appear as pale yellow patches on the upper surfaces of young leaves with areas of powdery white fungus on the underside. This can develop into a powdery white covering over the whole leaf with subsequent leaf breakdown and stunting of growth.

Insect pests include aphids and mites. Outbreaks of the Sow Thistle Aphid (*Hyperomyzus lactuca*) can occur in spring and early summer causing distortion of the growing tip. The Two Spotted Mite (*Tetranychus urticae*) causes bronzing of the leaves and premature leaf drop during severe infestations, resulting in a loss of vigour and reduced yield.

The Currant Borer Moth (*Synathedon tipuliformis*) which can cause severe damage to fruit plantations can be present in bud crops but does not have any economic impact.

**Harvest/storage/processing requirements**

Development of mechanical harvesters has been crucial to the success of the Tasmanian blackcurrant bud industry, allowing it to become established against competition based on hand harvesting. The equipment used by EOT was designed locally and developed over a number of years. This machine cuts the canes, strips the buds and then chops the canes to a fine mulch in a single pass. Buds are frozen to –20°C for storage until they are extracted.

EOT extracts the buds using highly refined hydrocarbon solvents, with most production sold as an absolute. The extraction process has a strong bearing on the yield and composition of the end product.

**Financial information**

It is not possible to give precise financial details for production of blackcurrant bud extracts because of the diverse nature of systems and circumstances. Indicative costs for field operations can be quoted but the major financial considerations relate to harvest and extraction infrastructure.

With field production costs, the Tasmanian experience has been that establishment, including land preparation, preparation of cuttings and planting, amounts to about $2,000/ha, provided planting material is available at cost. Thereafter, annual growing costs are of the order of $1,500/ha. As already noted, bud production can be expected to start at around 50kg per hectare in the first year increasing to 250 kg/ha in year 3-4 when the plantation reaches a mature density.

Figures relating to the cost of developing and operating proprietary harvesting equipment cannot be quoted. Similarly with extraction, a major component is the capital cost of equipment. Various forms of solvent extraction are used and the equipment required is expensive and needs specific expertise to operate. Since the market for blackcurrant bud extracts is limited it is unlikely that a dedicated plant could be economical. It is likely that any new blackcurrant bud producers would need to have access to a suitable solvent extraction facility processing other commodities as well.

**Key references**

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**Introduction**

*Boronia megastigma* Nees. is endemic to Western Australia and is found in the south-west of that State where it grows as a woody under-storey shrub one to two metres in height on moist or seasonally wet sandy soils of acid to neutral pH. The genetic resources of *B. megastigma* for essential oil product have been investigated by Plummer and Considine (1997).

Flowers are initiated in autumn and continue to differentiate and develop during the winter, bearing a profusion of strongly scented brown, purple and yellow flowers in early spring. Flowers contain the oil or extract which is used in commerce.

The purified extract is known as Boronia absolute and has been available on the world market since the 1920’s (Geunther 1949). Since the mid 80’s the largest volume of commercial production has been produced in Tasmania and a small volume in New Zealand. In the late 90’s a small area of intensive commercial production commenced in Western Australia. Prior to this, flowers were collected from wild stands in Western Australia. The product has application in scales through increased production may accommodate the price decrease required for fragrance application.

The major application for the product is in flavours, for example in beverages and dairy products at low concentrations it imparts the character of fruit, esters, tutti frutti and honey. Other applications include the enhancement of natural flavours in fruit essences such as raspberry, strawberry, plum, peach and meat products such as salmon.

The product is purchased by end users, dealers/traders and flavour and fragrance companies. This latter group may compound a

**Markets and marketing issues**

The principal markets are in Europe and the United States of America with potential in Japan, South Korea and South East Asia. Where the product is used in natural perfumes, it has a distinctive powerful odour which is typical of the fresh flower and makes an excellent addition to quality bouquet perfumes. The odour is strongly persistent with natural green freshness and floral undertones of rose, jasmine and freesias and a character of ripening hay and a woody tea like background. The use of boronia absolute in perfumery is restricted because of price. Economies of scale through increased production may accommodate the price decrease required for fragrance application.

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**Key messages**

- Composition and organoleptic profile are highly specific for particular applications
- Do not plant without a production contract
- Plant material, extraction and harvesting will be supplied with the contract

**Key statistics**

- World production approx 200kg
- Tasmania is the major producer
- Western Australia is a minor producer
particular essence or fragrance to apply to end use products.

The current world production is approximately 200 kg of absolute and the price ranges from $3,000 – 6,000/kg depending on sample size and purchase contract. There is a steady increase in demand which is essentially associated with new applications for the product.

Production requirements

General
Suitable climates exist in parts of Western Australia, Victoria, Tasmania and New Zealand. The current limitation to production is the rate of expansion of market opportunities.

Climate requirements for flowering (Roberts 1989)
Boronia will survive a range of climatic conditions from its native environment on the edges of swamps, to the extremes of dryness associated with a Mediterranean climate. In Tasmania, the plant has survived periods of heavy frost and snow. However best production occurs in a maritime climate in the South West of Western Australia, North, North East and East coast of Tasmania and Southern coastal regions in Victoria.

Boronia remains vegetative at temperatures in the high 20°C. Competition from young developing leaves for available assimilates is the likely cause of flower abortion. In autumn ideal weather conditions for maximum flower number are approximately 10°C night temperature, day temperature 15°C with 10 hour day length and full to 50% sunlight. It appears that prevailing temperatures may restrict the climatic range for commercial boronia flower production.

Boronia flower buds that initiate and develop under non optimal conditions may eventually reach maturity, the structures being a transition between buds and leaves.

Flower initiation and development of flowers in boronia is sensitive to photon flux density, night temperature and photosynthetically active day length. There is no single obligatory stimulus for induction. For example, lowering the night temperature from 15°C to 6°C has a greater promoting effect on flower initiation than the effect of decreasing the day length from 16 h to 10 h. The combination of low night temperatures, short days and full sunlight results in the highest number of flower buds. The conditions that produce the highest number of flower buds are also the most suitable for their differentiation and development. [Roberts and Menary (1994) a]

Soil
Boronia has reasonably specific soil requirements. The soil should have a pH of between 4 and 5, however trials have shown the plant will grow in soil with a pH of as low as 3.5 and as high as 6.5. The soil should have a high organic, low clay content with high production being obtained on well drained acid sands. The natural vegetation on this soil is usually a coastal heath or bracken fern. A previously uncultivated area is preferred. It is recommended that a total soil analysis be undertaken prior to planting to measure pH and levels of macro and micro nutrients.

Two methods of soil preparation are practised. One involves minimum tillage the other normal seedbed preparation with deep ripping to remove old roots which may be a source of Armillaria infection.

Varieties
Current commercial varieties grow to a maximum height of approximately 1.5 m. The leaves are linear, shiny, 10–20 mm long and usually with three leaflets, up to 5 leaflets may occur if the nitrogen supply is high. Buds are usually initiated on the current laterals, these can be distinguished
from that of previous season’s growth by the lack of rough bark and from the general light reddish brown to green appearance of the stem.

Both flower and vegetative buds are formed in the axils of leaves. These flower initials may continue to develop under ideal conditions or revert to vegetative structures if adverse conditions prevail. The maximum number of flowers per node is three.

A typical timetable of visual events during flowering in *B. megastigma* under flower inducing conditions in autumn is given in Table 1. This means that flowers can take 4-6 months to develop, the time being directly related to temperature and sunlight.

Propagation of commercial plant material can be undertaken from short lateral cuttings and through tissue culture. Cutting material is collected in summer from rapidly growing plants and these produce roots quite readily under mist with a rooting medium of bark and coarse sand. Tissue culture plants can be produced from sterile meristems grown in shoot proliferation medium. Shoots are subsequently transferred to a rooting medium. The latter technique is used to produce mother plants from which cuttings can be taken for mist propagation.

Commercial varieties for oil production have been selected from seed populations. They have been selected for agronomic, oil bearing and disease resistance characteristics. These improved varieties are only available through a licence agreement with current owners.

### Cultural information

**Shelter**

Until 2 years of age, the young bushes are very prone to wind damage. Adequate shelter should be provided through the planting of trees as shelter belts.

**Irrigation**

Irrigation is not essential but is recommended for high productivity. Boronia is able to withstand long periods of drought. Once established the plant appears to be able to produce flowers without summer watering.

However trials have indicated that on young plants, a high survival, better establishment and better growth rates are achieved if irrigation is applied. Drip systems using low volumes of water at around 8 to 10 L/plant/week have been successful.

**Cultivation and weed control**

Mowing between the rows to reduce competing vegetation is important. For particular weed problems it may be necessary to seek minor use permits from the Australian Pesticides and Veterinary Medicines Authority (APVMA). It should be emphasised that the use of herbicides increases the danger of chemical contamination in the oil. Their use is minimised through careful land preparation prior to planting and careful sanitation during the production phase.

A plant density of 1 - 3 plants/m² has been used depending on cultivation, site and harvesting methods employed.

**Pruning**

Heavy pruning is practised after harvest to stimulate new growth or potential sites for flower production in the following autumn. The pruning cut should be 2-3 nodes above the previous year’s growth.

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**Table 1. Time taken to flower development in B. megastigma**

<table>
<thead>
<tr>
<th>Event</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days from initiation to appearance of buds</td>
<td>30-40</td>
</tr>
<tr>
<td>Days to flower stalk elongation</td>
<td>55</td>
</tr>
<tr>
<td>Days to flower stalk curvature</td>
<td>75</td>
</tr>
<tr>
<td>Days to petal exposure</td>
<td>125</td>
</tr>
<tr>
<td>Days to flower opening</td>
<td>160</td>
</tr>
</tbody>
</table>

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Flowering boronia shoot

Boronia oil
Fertiliser

Preliminary trials on fertiliser responses have shown that slow release fertiliser such as IBDU and Osmocote are appropriate for boronia to prevent high concentrations of nutrients in the root environment. The nutrient combination used should be high in nitrogen, low in phosphorous and moderate in potassium. Applications of fertiliser should occur after harvest to stimulate summer extension growth.

Nitrogen should be applied at rates between 15 and 80 kg/ha depending on soil type and variety.

Recent trials [Roberts and Menary (1994)a] have shown that ammonium nitrate is a suitable nitrogen source to keep a balance between the two forms of nitrogen, NH₄ and N⁰₃, and so prevent major pH changes.

Nitrogen is normally applied in October/November and the level of total nitrogen in January/February should be 1.5%. Samples should be taken in early January to check these levels and if necessary apply nitrogen to rectify any deficiency. Magnesium, sulphur and molybdenum deficiencies have occurred and these elements should be present in the fertiliser. It is preferable to apply molybdenum as a foliar spray where the soil pH is below 5.5.

Yield and composition

A yield of 2t of flowers/ha can be expected from selected varieties. The extract yield from fresh flowers varies between 0.3 and 0.6% depending on variety. The conversion from crude extract to absolute yield is approximately 50%.

The major chemical components in the absolute are β-ionone, dodecylacetate, methyl jasminate and heptadec-8-ene. (Davies & Menary 1984 and Weyerstahl et al 1995)

Pests

Psyllids (Mensah 1990)

Psyllid (Ctenarytaina thyssana) insects were first identified on boronia plants in 1932 in New Zealand and have been a major problem in the Tasmanian boronia industry. Infestation will kill boronia seedlings or lead to reduced vegetative growth and flower and oil yields. An economic analysis of insect control to benefits achieved established a cost benefit ratio of 1:9. Known insect control programs were therefore regarded as ineffective and expensive.

Damage

Psyllid feeding leads to a reduction in the number of new nodes formed by the plant and eventually growth ceases and the tip of the terminal bud is killed.

The psyllid produces honey dew in the course of feeding and this honey dew settles on the plant causing the development of sooty mould which lowers the photosynthetic ability of the plant.

Their feeding causes yellowing of leaves and consequently leaf loss, and in young plants the whole plant may die while in mature plants it leads to stunted growth and loss of flower yield.

The percentage of oil extracted from the flower is reduced as much as 30% as the psyllid feeding affects the accumulation of oil in the glandular cells.

Population dynamics

The insect lays its eggs in the leaf axil of the terminal shoots of boronia plants but in winter, most of the eggs are laid in the flower bracts, sepals and petals.

Population sampling of insects over a number of generations revealed that natural enemies such as parasites were responsible for mortality at certain stages in the life cycle of the insect.

Integrated pest management program

Application of a systemic insecticide when there are 10 or more adults in young leaves will reduce the numbers of psyllids without affecting the parasites.

Nuvacron 40® (monocrataphos) was used @ 0.02% ai. until 1999. However, registration has now been cancelled and the product withdrawn from sale. No registered insecticide is currently available for the control of psyllids.

About the author

Bob Menary is a Visiting Research Professor, School of Agricultural Science, within the University of Tasmania and has 20 years research experience in developing boronia as a commercial crop. This includes detailed investigations of physiology and development, cultivar development and propagation, nutrition, harvesting, processing and marketing.
Black scale (Enggar 1995) and brown scale

Black scale insects (Saissetia oleae) and brown soft scale insects (Coccus hesperidum) have become serious pests to some boronia plantations in Tasmania. Black scale has only one generation per year, commencing in January.

The immature insects settle on both sides of the leaves and stems over the entire boronia bush, and migrate to the woody stems in late autumn and winter, before reaching adult stage. Adult scales are rarely found on leaves.

Black scale is most vulnerable at the immature stage (first stage nymphs) to attack by parasites, insecticides and also high temperatures during summer.

Brown soft scale has three generations per year, appearing in summer, autumn and spring.

The distribution of the scale, both immature and adult, tend to be on the top half of the boronia plant on leaves and stems although, in spring and summer, the scale prefers to settle on leaves rather than stems.

Parasitism of brown soft scale populations only reaches 19% but does contribute to keeping the population at low levels.

Factors influencing scale populations

Plants damaged through cultural operations are more susceptible to infestation because the bark forms a wound callus which provides an ideal establishment site for scale. The callus also protects the scale from white (summer) oil.

Some weeds act as alternative hosts to immature black scale insects, such as Rumex acetosella (sorrel), Trifolium repens (white clover), Stylidium graminifolium (trigger plant), Leontodon taraxacoides (hawkbit), Hypochaeris radiata (flat weed or cat’s ear) and Solanum nigrum (black nightshade). These should be controlled to reduce infestation.

Pruning reduces scale insect populations but prunings must be destroyed to avoid reinfestation.

Results and recommendations for a successful pest control program

White oil (summer or petroleum oil) is the most effective agent in the control of both types of scale insects. Apply to the entire plant (both tops and sides) at the immature stage of the insects’ life cycles in the last two weeks in February and repeat four weeks later. Apply white oil to run-off in large volumes at low concentrations (1.0% - 1.2%) and at low tractor speed (eg. at 4 km/h rather than 8 km/h).

Browsers

Sound cultural practices should ensure adequate fencing is provided to restrain animals, such as rabbits, bandicoots, sheep and cattle.

Cutworms

Cutworms will ringbark young seedlings during the first few months. Successful control can be achieved if the ground to be planted is cultivated 12 months in advance and left to fallow.
Diseases

General
Sanitation is the best form of control. Ensure disease free stock is purchased, production and handling areas are clean, machine and foot sterilisation is maintained. These and other common methods of sanitation are stressed as a means of preventing infections. Boronia is seriously affected by root rotting diseases. Phytophthora and Armillaria root rots appear most damaging to boronia when grown in contaminated areas. Rust is a problem if commercial varieties are not resistant to the disease. Boronia clones are resistant to Phytophthora but may succumb under unfavourable water logged soil conditions.

Boronia rust
Boronia rust (Puccinae boroniae) is a major problem in the field. Tilt® is registered for control of the disease.

Harvest, handling, storage, post harvest treatments and processing

General considerations
Harvesting is carried out between late August and late October. Localised climatic influences will either produce a compact flowering period or a lengthier flowering period depending on day/night temperatures, day length and sunlight. During years 1 and 2 harvesting is carried out by hand or with a mechanical aid. Hand pickers are unlikely to harvest more than 1 kg/hour under these conditions. Hand held combs are used to rake the flowers into containers.

Mechanical harvesting
Mechanical harvesting is practised in Tasmania. The equipment is solely owned and operated by Essential Oils of Tasmania. The mechanical aids used for harvesting in Western Australia are owner operated. There is also one such operator in Tasmania.

Flowers are harvested when 80% of the flower buds are open. (McTavish & Menary 1997)

Very strict requirements are placed on the levels of leaf matter contained in the harvested product. The leaf contains waxes and impurities which change the composition of the floral extract.

Flower handling
Freshly harvested boronia flowers will remain in a chemically stable condition if the field heat is removed by refrigeration and flowers are then stored at -18°C.

Extraction
Flowers may be extracted with liquid CO₂ or a hydrocarbon solvent (such as hexane). The initial crude extract is then converted to an absolute which is the alcohol soluble fraction.

Financial information
The cost of establishment of boronia is approximately $20-$22,000/ha.

Boronia crops are established from nursery speedlings which are produced by vegetative propagation. Planting material is the major cost of establishment as plant densities of 1 to 3 plants/m² are practised. Each unit may vary in price from 50¢ to $1.00.

On farm costs are fertilisers, pesticides, irrigation, slashing or mowing, pruning, harvesting and cold storage. A total average cost of production is $10,000/ha. Flowers may be purchased by a processing company with solvent extraction facilities.

Gross income to growers for flowers is approximately $24,000/ha. The gross margin for boronia flower production would compare favorably with some vegetable crops, eg. potatoes, or poppies and pyrethrum.

The yield, cost of establishment and maintenance can vary widely depending on location, associated farm activities and previous land use history. Virgin land is the preferred option to minimize disease, encourage biological control of insects, minimize weed infection and improve longevity. Under these conditions a commercial life span of at least 10 years could be anticipated.

No plantings should be undertaken unless a production contract is in place with a reputable company involved in the international essential oils trade and preferably a member of the International Federation of Essential Oils and Aroma Trade.
Key references


Nitrogen and Water Relations in Boronia (RIRDC publication number 00/34 UT-5A)

Boronia Extracts, Increasing Yield and Quality (RIRDC publication number 99/178 UT-10A)


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Chamomile
(German chamomile)

Linda Falzari

Introduction
The common name chamomile covers many species from many genera. In particular it covers two different crop types: English, Russian or Roman chamomile (*Chamaemelum nobile* (L.) All., formerly *Anthemis nobilis* L.) and German or Hungarian chamomile (*Matricaria recutita* (L.) Rauschert., formerly *Matricaria chamomilla* L.). Both belong to the daisy family, Asteraceae and are native to Europe. The latter species is the subject of this chapter.

German Chamomile is a herb producing small, white daisy flowers. It has been used in folk medicine throughout history and its flowers are currently used in the production of three commodities: a) a medicinal tea that is renowned for its calming properties, b) steam-distilled essential oil which is used in the flavour, fragrance, pharmaceutical and cosmetic industries and c) a solvent extract of the flowers used primarily in the cosmetic and pharmaceutical industries.

Growers wishing to diversify into German chamomile production should first forge links with wholesalers of these products. To be successful, potential growers will need to give detailed attention to producing a quality product over many seasons, thereby establishing a reputation for consistency in quality and reliability of supply.

Perhaps the major constraint for the industry is the small size of the local market. Although both the local and export markets are expanding, there is a significant risk that oversupply will greatly reduce the price received for the products, in turn greatly reducing the return to individual growers.

An additional risk is that chamomile is a prolific seed producer. Its weed potential both in other crops and the environment should be considered before chamomile is sown.

Markets and marketing issues
Markets consuming significant quantities of chamomile products are in Europe, Latin America and USA. The oil of *Matricaria chamomilla* is registered with FEMA (Flavor and Extract Manufacturer’s Association) as
GRAS (Generally Recognised as Safe) and therefore can be traded as a flavour compound in the USA.

All three chamomile products, i.e. dried flowers, oil and extracts, are both imported and traded within Australia. Increased production of chamomile in Australia has potential both for import replacement and for export.

Products will generally be traded through an agent or wholesaler who will pool together the supply from a number of small producers. In Tasmania, a collective growers’ group trades directly with a production company which pools and packages the products and in turn distributes the products via agents to the manufacturing companies. By forming regional co-operatives, growers are able to smooth out some of the fluctuations in supply caused by environmental events. As a region, they then gain the reputation for reliability that is critical to trading such products on the world market.

The dried flowers are used to produce herbal teas both alone and in mixed blends. The market requires that these flowers have specified levels of the pharmaceutically active compounds (principally α-bisabolol and chamazulene) and that the product is free from weeds and other debris, including insects and insect parts.

The essential oil is a deep blue or bluish green liquid, which turns green and finally brown upon exposure to air and light. The blue colour is caused by the chemical component chamazulene. Chamazulene is not present in the intact flowers but is produced by the distillation process. The blue essential oil is used primarily in the pharmaceutical and cosmetic industries, although a small amount is used in flavouring. Again, the two important pharmacological components are chamazulene and the bisaboloids.

Chamomile is cultivated in Europe, particularly Germany, Slovakia, Hungary, Czech Republic, northern Africa, Asia, Argentina and USA. Within Australia, there is established production in localised regions from Victoria through to southern Queensland, and the beginnings of an industry in Tasmania. The Australian market will have to compete with the low wage conditions from some of these producers.

The major risk to the Australian chamomile industry is oversupply of the small local market.
yields and dry weather at harvest, particularly for the production of dried flowers. Free water on the surface of the crop will both decrease the efficiency of harvest and increase the cost of drying the flowers. Free water on the surface of the crop also reduces the efficiency of distillation and solvent extraction.

**Varieties/cultivars**

As detailed in the introduction German chamomile is of the species *Matricaria recutita* (L.) Rauschert. Within this species are several chemotypes, which are defined by the ratios of the pharmalogically active components in their essential oil. For example there are those which produce chamazulene (blue colour) upon distillation and those which are chamazulene-free. The other important group of compounds are the bisaboloids. Chemotypes are defined by the relative concentrations of \( \alpha \)-bisabolol, \( \alpha \)-bisabolol oxide A and \( \alpha \)-bisabolol oxide B. Each end user will have different requirements for these active ingredients and an appropriate variety for any new producer will need to be selected after consultation with the proposed wholesaler or agent.

Two cultivars appropriate for use in the production of medicinal dried flowers are Bona and New Bona. These produce essential oil of similar chemical composition. Both were developed through a breeding program conducted by Dr. I. Salamon, Institute of Agroecology, Michalovce, Slovakia. Seed of these varieties is available from Dr Salamon. Other available seed varieties include Bodegold which may be obtained through Johnny’s Selected Seeds, Maine, USA and Goral which is a tetraploid variety.

**Cultural practices/agronomy**

The first step for a new producer should be to establish contact with a wholesaler or agent. Next is to locate the facilities required for processing the raw product. This may involve procuring private facilities or access to a regional facility. Such facilities include screening and drying equipment and/or a distillation or extraction plant. Suitable storage should be organised in advance. Oil and extract products are of small volume but dried flowers are bulky and require a substantial storage facility.

Good site preparation prior to sowing is essential. Chamomile, having extremely small seed, needs a well-worked stale seedbed with a fine surface texture. A Cambridge roller will create a sheltered microclimate for the seed as it germinates.

Chamomile needs to be sown early in the spring to ensure optimum germination and crop establishment. This also allows adequate vegetative growth before flowering. Late sowing restricts the ultimate size of the individual plants and therefore the yield of flowers produced, which in turn restricts the volume of oil. Autumn sowing should be considered if the area is adequately drained through the winter. Established chamomile crops are tolerant of light frosts.

Recommended seeding rates vary considerably, from rates of 320g/ha in the USA literature to 1kg/ha in Slovakia. Seed in Australia is expensive and the lower seeding rate of 300g/ha is recommended in the first year. In the following season, the same site may be re-sown at half this rate due to the establishment of self-sown plants. In subsequent years, chamomile may continue to be produced on the same site entirely through self-

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**Key statistics**

- Price is highly elastic
- World market small but increasing
- Establishment costs are high

**Key messages**

- Requires short spring days for maximum yield
- End-users require specific chemotypes
- Oversupply of small market is a significant risk
- Potential growers must forge links with wholesalers

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**About the author**

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seeded plants. Eventually weed control becomes too difficult and the crop must be moved to a clean site.

The seed is sown directly onto the soil surface, hence the value of the Cambridge roller. After sowing chamomile requires irrigation every two days, even if sown into a moist seedbed.

The surface layer must not be allowed to dry out until the plants are established. Germination and establishment takes between 14 and 21 days. After this, small rosettes should become apparent and irrigation can be reduced.

Crop growth in the early stages is particularly slow and a herbicide regimen aiming for early weed control is best.

Herbicide application can cease once canopy closure is achieved, since mature chamomile plants are very competitive and will smother most weeds. Rogue weeding may be necessary, just prior to harvest.

The fertiliser regimen will be dependent upon the prior nutrient status of the site. The aim should be to apply a complete, balanced fertiliser, including micronutrients, at the rosette stage. Nitrogen application will improve yields of both flowers and oil, but care needs to be taken that the crop does not become too soft and vigorous. This would encourage lodging, making harvest more difficult.

The aim is to manage the crop to produce a low canopy, with short straight plants, minimal branching and strong stems. This will improve mechanical harvesting.

Optimum harvest time is determined by a combination of observation of the crop and repeated sampling of the flowers for chemical composition.

The optimum harvest time is when the flowers are fully open, with the white ray petals fully extended and the small, tubular florets of the yellow disc just beginning to open. At this stage, the crop appears white. Pre-harvest sampling should be conducted to ensure that the oil composition is of sufficient quality and that yield is sufficient to warrant commencement of harvest.

Chamomile has a continuous flowering habit and several harvests will produce better yields than a single harvest at mid flowering. These harvests will be spaced about 10 days apart, depending on the weather conditions. The final flowers are left to self-sow the crop for the following season.

**Pest and disease control**

Chamomile is relatively pest and disease free in Tasmania but snails and slugs can be a problem in the very young crop, particularly with autumn sowings.

Weeds are the most serious hygiene issue as contaminants in the final product, be it flowers, oil or extract will detract from the product quality.

Overseas experience shows the following chemicals to be useful, but none are registered for use on chamomile in Australia. Potential growers should seek advice on Minor Use Permits from the Australian Pesticides and Veterinary Medicines Authority (APVMA).

Sprayseed, glyphosate and trifluralin are potential, suitable pre-emergent herbicides. Trifluralin must be applied at least 2-3 days prior to sowing so that it is deactivated before coming into contact with the chamomile seed. Post-emergent herbicides should not be applied until the crop has reached the rosette stage. Those that may be of use are ethofumesate, MCPA, prometryne and chlorthal.
Harvest/handling/storage/post harvest treatments/processing requirements

Flower maturity is a guide to harvest time. The optimum time is approximately when the majority of flowers present are in full bloom i.e. the ligulate florets (white petals) are fully open and 50% of the disc florets (orange centre flowers) are open. Ideally, pre-harvest serial sampling and small-scale distillation or solvent extraction will be used to observe changes in oil yield and composition. Chamazulene will not be present in solvent extracts but the precursor of chamazulene i.e. matricarin may be monitored. Harvest can then be scheduled to maximise yield and optimise oil composition.

Chamomile has a continuous flowering habit and will produce higher yields from multiple harvests rather than a single harvest, provided that the harvester can selectively pick the mature flowers whilst leaving the developing buds behind. The first harvest should be scheduled to remove the first open flowers and harvest repeated at intervals designed to remove later flowers as they open. Three to four harvests can be expected, although each successive harvest will be somewhat smaller than the previous one. Further harvests should be scheduled until the yield falls below the cost of harvesting. The final harvest may be left to self-seed the following season’s crop.

In countries where labour is inexpensive, chamomile is hand-harvested. This permits grading of the flowers during picking, resulting in a high quality product and facilitating multiple harvests. Hand-harvesting is not economical in Australia, except in very small niche markets for organically produced crops. Large-scale mechanical harvest in Tasmania utilises a header with fingers that comb through the crop and a vacuum system for transferring the flowers to a storage bin. A similar system is used in Slovakia.

The harvest is screened to separate uniform flowers of high quality, which are dried for tea. Lower-grade flowers are distilled to produce blue chamomile essential oil or are extracted with solvent. The flowers may be distilled either fresh or dried. Drying adds a further cost to production but will improve the efficiency of distillation. It also allows the crop to be stored and multiple harvests pooled and distilled together.

Drying may take place in the field but the risk of weather damage is often great. Drying facilities usually consist of a shed with a raised, perforated or slotted platform and a fan to circulate dry air from below. This air may or may not be heated. Care must be taken to keep the depth of flowers low to prevent overheating and/or rotting of the flowers as they dry. On-farm bagging of the dried tea is possible, but usually not economical due to economies of scale.

Distillation of chamomile using low-pressure steam is relatively inefficient and relative to other essential oil crops, a long duration of distillation is required to obtain the bulk of the oil. It is recommended that high-pressure steam be used. However, this adds substantially to the costs of setting up the distillation plant and to the skills and training of the plant operator.

Large-scale chamomile production is relatively new in Australia and attainable yields are still difficult to predict. From Tasmanian trials, yields of one tonne of dry flowers per hectare can be expected. Yields quoted in the literature can be as high as seven tonnes of dry flowers per hectare.

Oil yields are even more difficult to predict. Oil yield depends not only on the quantity of oil produced in the plant but also on the efficiency and duration of distillation. Tasmanian trials indicated that oil yields of Bonanza from 3kg/ha to 4.5kg/ha and Bodegold 1kg/ha to 2.4kg/ha could be expected. Oil yields of up to 15kg/ha are reported in the literature but potential growers would be wise to treat these figures sceptically.

The distilled essential oil of chamomile is relatively stable when stored in full bottles, at 5°C, in the dark.

Dry flowers need to be stored in a dry, rodent and insect free environment.

Financial information

Basic general farming equipment for the establishment of crops is required for the production of chamomile. This includes equipment for cultivating, sowing and application of herbicides and pesticides. In addition, a Cambridge roller is of benefit. A suitable irrigation system, capable of applying low volume of water at frequent intervals is necessary in the establishment phase of crop production.

Chamomile seed is a relatively expensive commodity and adds significantly to the gross margin in the first two years of production. This expense is reduced in subsequent years by allowing the crop to self-seed.

Capital outlay for the post-harvest processing equipment is significant.
and usually is best undertaken by a group of growers in order to take advantage of economies of scale. In Tasmania, there is a significant, established essential oils industry. Potential growers in this state may be able to tap into the current infrastructure, significantly reducing the expense of entry to the industry. Without the benefit of an existing facility the cost of a regional distillation plant is in the order of $150,000 – $200,000. If high-pressure steam is required, this expense will rise.

A tentative gross margin is provided in Table 1, however, the price of chamomile commodities is extremely elastic and strongly depends upon supply. The price range for dried flowers may vary from $5/kg to $20/kg. The price of chamomile oil may fluctuate in a similar fashion from $200/kg to $1200/kg. Costs of production are relatively stable.

**Table 1. Gross margin analysis**

The following gross margin is based upon the following assumptions:

1) Flower production = 1000kg/ha dry weight.
2) The harvest is split 50:50 between dried herb and oil.
3) Average oil yield = 0.45% D.W.
4) Harvest x 2 passes x 8 hours/ha each @ $100/hour.
5) Screening for dried herb production - 5 hours/ha @ $20/hour.
6) Distillation - 2 batches x 6 hours each at $25/hour steaming cost.
7) Drying @ $1.25/kg dry herb weight.

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**Key references**

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Eucalyptus oil

Richard Davis and John Bartle

Introduction

Australia is the home of the eucalypt. All the commercial oil-bearing species of *Eucalyptus* are indigenous. Therefore, the raw material for the production of eucalyptus oil is available, and the soil and climate are suitable for the establishment of plantations of oil-bearing species.

Eucalyptus oil has been produced and traded for over 150 years. Although several different types of oil can be produced, it is only the oils rich in cineole that are now produced in quantity. Eucalyptus oil is used in a wide range of pharmaceuticals, cleansers, flavours, and to a small extent, as an insect repellent. Demand for the oil is currently stable.

The oil is easily produced, but the cost of production in Australia is high compared with other countries, even when produced from natural stands thereby avoiding the cost of establishing the crop.

While the demand is static, the production of eucalyptus oil in other countries, particularly China, has increased to a point where the world demand can be met by countries where labour is cheaper. Furthermore, in China the oil is produced as a by-product of the timber industry, thus also avoiding the cost of establishing the crop.
Key statistics

- World demand for cineole-rich eucalyptus oil—approx. 3,000 t/year
- World production potential from existing trees—over 4,000 t/year
- Australian production is currently approx. 120 t/year. But from 2005 this may increase to 320 t as the pilot plant at Narrogin begins production
- Potential production from WA is 1,000 t/yr

Key messages

- Eucalyptus oil is overproduced
- China can supply world demand
- New use for oil essential

Markets

There are two market categories for eucalyptus oil:

- one for supply of straight oil to the ultimate consumer
- one for oil that will be incorporated in other products.

Eucalyptus oil is sold world-wide. Most oil sold in Europe and North America is used in pharmaceuticals—in a variety of preparations for the alleviation of the symptoms of colds such as inhalations, rubs and cough lozenges. It is also used in mouth-wash, toothpaste and embrocations, in confectionery and in the cosmetics and toiletry industry. Much of the oil sold in Australia and Asia, is used as a pure oil in household products, in inhalations, to alleviate cold symptoms, and as a cleaner, spot remover, massage oil, etc.

The crude oil produced on the farm or in the forest, is sent or sold to a refiner, who redistsils, blends to customers requirements, packages and ships to manufacturers or bottlers. The oil is then exported or distributed through the appropriate chain to the retailer. Nowadays, the straight oil is retailed through pharmacies and supermarktes.

Estimated global demand for cineole-type eucalyptus oil is 3,000-3,500 t/yr. Australian production is about 120 t. However, the Australian production is from a variety of eucalypts, particularly E. polybractea and E. radiata ssp. radiata (cineole variant) (syn. E. Australiana), while almost all the cineole-type oil produced in other countries is from E. globulus. While all the oils conform to the same standards, the Australian oils are more varied in composition, exhibiting more complex aroma and taste. This enables Australian oils to retain their niche position at the premium end of the market.

World market price for the standard grade E. globulus oil is now about US$5.50/kg in container lots (15 t). The price, while varying to some extent, is now fairly stable after a steady decline. The price is now less than it was 15 years ago. Because of static demand and over-production in China, the price is likely to stay low in the foreseeable future, unless a new large-scale use for the oil is found. Although the higher quality Australian oil commands a higher price, the demand is strictly limited.

Production requirements

Oil-bearing eucalypts will grow well in many parts of Australia, but work to date shows that E. polybractea, the major source of oil, thrives best on the light sandy soils of the western plains of NSW and just west of Bendigo in Victoria. It grows quite well in rainfall down to 350 mm/yr, but would probably do better in slightly higher rainfall areas.

While irrigation would enhance growth, the potential return does not warrant the cost.

E. radiata grows naturally on the Great Dividing Range and the south coast of NSW. It thrives in steep country on a wide range of soil types.

Because it is now essential to mechanise production to be able to produce oil at a saleable price, production from natural stands of E. radiata is unlikely. For mechanical harvesting, level to no more than gently sloping land is necessary. Natural forest areas of this type, with good oil-bearing trees as the dominant species, are now rare. This means that plantations, such as those currently being established in WA for salinity control, are required.
Agronomy

Although all the oil-bearing eucalypts occur naturally in Australia, there are now virtually no remaining areas of natural bush suitable for development for oil production. Therefore, future production must be based on plantations of the desired species, or on harvesting of the leaves of trees grown for other purposes, such as salinity control.

The following information on establishment and silviculture relates to mallees in the semi-arid zone of Australia. Other techniques, eg mounding and fertilising, may be essential for the successful establishment of other species in other areas.

Since it is essential to mechanically harvest plantations, planting in straight rows is desirable. For ease of pest and weed control, sufficient space should be left between the rows for machinery access. Thus, site preparation calls for clearing land that slopes no more than gently, and laying out straight rows, across the slope where possible. The rows should then be ripped as deeply as is practicable and, just before planting, the surface layer to about 25 cm on both sides of the rip broken down to allow the use of planting machines. One or two passes with a chisel plough or cultivator should be sufficient to achieve this. Into this ground, 10-20 cm seedlings are planted.

To protect the young seedlings from dehydration, watering at or immediately after planting is essential and watering must continue until the first effective rainfall. In the first few months, the seedlings also need to be protected from livestock.

The equipment required for planting and establishing the young trees is thus:

- a powerful tractor, or preferably bulldozer, with a ripper
- a cultivator
- a planting machine
- either an irrigation system, or a water tanker with an appropriate water delivery and pump and motor filling systems.

A good source of water is essential.

Depending on cost, seedlings can be bought from a commercial nursery or raised on site. If they are raised on site, it will require the usual nursery facilities of tubes, trays, watering bays, plastic greenhouses and a watering system. Once planted the trees need to be kept weed free for at least 12 months and protected from insect attack.

Most of the oil-bearing eucalypts do not respond well to fertiliser and thrive in reasonable weather conditions without additional nutrients.
Large-scale eucalyptus oil production in WA

WA has the most advanced salinity problem of any of the Australian states – 10% of all agricultural land has been degraded and this is projected to rise to 30% over the next 50 years; virtually every creek and river across the 15 million ha of agricultural land with <900 mm rainfall has become saline. This dire situation has given rise to an ambitious project to develop mallee eucalypts as a farm tree crop, to produce commercial return from oil and wood products, and to help control salinity.

Mallee industry development is based on recognition that the scale on which tree crops will need to be used to make a useful contribution to salinity control is very large (up to 20% of all farm land). To achieve adoption on this scale, tree crops will need to be seen to be economically competitive on their own account.

Mallee industry development was initiated by the Department of Conservation and Land Management (CALM) in 1993. It quickly attracted support from farmers who formed the Oil Mallee Association (OMA) in 1995. This body assumed leadership of the project in 1997. Large scale planting commenced in 1994 and by 2003 more than 10,000 ha had been planted. Operational planting was used to explore establishment and management techniques and a substantial body of knowledge and experience has been built up. Planting is on good quality cropland in unfenced belt layouts designed to better capture surplus water from adjacent crops. CALM and OMA undertook R&D in important aspects such as species selection, genetic improvement, yield prediction, harvest and handling systems and economic analysis.

The early hope was that economies of scale and innovative harvest and extraction systems might make a single product eucalyptus oil industry viable. Preliminary analysis had shown that with such advances, considerable reduction in cost of oil production should be achievable, that this could stimulate development of new large scale industrial products and markets for eucalyptus oil, and therefore provide a feasible basis for a large scale industry. By 1996 it was clear that this industry scenario was not likely to be feasible. R&D turned to finding uses for mallee wood and residues.

In 1998 the new Oil Mallee Company assembled a group of parties to conduct a feasibility investigation of ‘integrated processing’ where mallee feedstocks would be converted within a single processing plant to eucalyptus oil, activated carbon and electricity. The study was funded by Western Power Corporation and RIRDC, and managed by Enecon, a Melbourne based engineering company that holds licences for use of CSIRO activated carbon technology. The study showed that integrated processing should be commercially viable. The report by Enecon is on the RIRDC website (http://www.rirdc.gov.au/reports/AFT/01-160.pdf).

A 20% scale demonstration plant has now been constructed at a cost of $9 million at Narrogin, a district with extensive mallee plantings, 200 km south east of Perth. It will test integrated processing on an operational scale. Plant commissioning has been delayed by budget problems but is now expected to commence in late 2004. If testing is successful there is potential to construct some 9 full-scale plants each with the following attributes:

- plant construction cost of $25 million, plants to be located within regional towns
- processing volume of 100,000 green t/year requiring 10,000 ha of mallee crop
- annual production: 1,000 t eucalyptus oil, 3,500 tonne activated carbon and 5 MW electricity capacity
- plant viability was based on a sale price of $A3/kg for oil and payment of a competitive price to growers.

The development of mallee indicates a structural shift emerging in Australian dryland agriculture. It will become imperative to better manage salinity and several new large-scale woody crop industries will be required. Major new research capability is being assembled to address this problem, e.g. the CRC for Plant-based Management of Dryland Salinity (http://www1.crcsalinity.com/index.asp).
Harvesting for eucalyptus oil

First harvest will depend on time of planting and weather, but except during drought the first harvest can be made 18-24 months after planting. Thereafter harvests are at about 18-month intervals. Over-frequent harvesting will adversely affect the trees.

Because the trees are harvested at ground level, soil will be prone to water and wind erosion. This can be prevented by planting pasture or a crop of some sort between the rows but not close to the trees, or by mulching with leaves from which the oil has been extracted. A machine will be needed to spread the leaves.

Pest and disease control

Control of weeds in the early planting and regrowth phases is essential. Cultivation is effective in a well laid out plantation where implements can be used very close to the trees. There are also effective herbicides which can be applied close to, or in some cases over, the trees and which do not suppress tree growth.

Livestock, feral pigs and kangaroos can cause damage in the early stages of plantations.

The main insect pests of the mallee species such as *E. polybractea* are sawflies and case moths. Case moths in particular can spread very rapidly and defoliate the trees. This tends to occur when there is a substantial amount of leaf, but not in the early stages of growth or regrowth. A good means of control is to harvest the affected area even if it is not due for harvest.

Experience from trial plots indicates that insects and diseases may be a greater problem in establishing plantations in higher rainfall areas, than in the dry areas where *E. polybractea* and other oil-bearing mallees occur naturally.

*E. polybractea* has not responded well to more fertile soil in higher rainfall areas. Although it is likely that some suitable areas could be found, improved leaf growth would be offset to some extent by the increased cost of insect and disease control.

Harvest and processing

Eucalyptus oil is extracted by steam distillation. While there are other methods of extracting the oil, this is the accepted method, stipulated by national and international standards. It is a simple and cheap method.

The oil is confined to the leaves which, after harvest, are placed in a container (still) through which steam can be passed. To produce oil economically, these processes must be mechanised. The mallee type eucalypts, with their capacity to coppice vigorously, are ideal for mechanised harvesting as the whole of the aerial part of the tree can be cut off and placed in the still. The amount of non-oil-bearing stem so harvested is insufficient to warrant separation of leaf and stem and so harvesting requires only simple machinery.

By passing steam through the leaf mass in the still, the oil is vaporised; oil and water vapour are ducted to a condenser and there condensed to liquid oil and water which can be separated by flotation. The oil, being of lower density and, for practical purposes, immiscible with water, floats on the top of the water from which it can be separated easily.

The oil can be stored in drums made of high density plastic or steel (preferably but not necessarily galvanised). Although the oil is `wet' at this stage, it can be stored without deterioration for several weeks before further processing.

For most uses, the oil needs to be refined, and this is best done by redistillation under reduced pressure. Thus vacuum stills and pumps will be needed.

The initial steam distillation of the oil from the leaves needs to be done close to the harvest area as
the cost of transporting leaf more than a few kilometres is too high. Vacuum redistillation is generally not carried out on farm as the cost of the apparatus needed will be too high, unless production on the farm is large or a number of farms share the equipment.

If the crude oil is to be sent on for refining, all that is necessary is to pack it into suitable containers for transport to the refinery. If the crude oil is to be sold as crude oil it should first be dried and filtered.

Steam has to be generated for the distillation of oil from the leaf and because of the low value of the oil at present, the cost of steam production must be kept low. The leaf, after the oil has been extracted, is suitable for this purpose. About 20% of extracted leaf is required as fuel, the rest should be returned to the harvested area to minimise erosion and to retain moisture.

Most oil entering the market must conform to the appropriate national standard. Refining ensures that this is so.

**Financial information**

At this stage of the industry’s development it is not feasible to set up a viable operation if land and all equipment has to be purchased. However, if land and some standard items of agricultural equipment are already owned, and the cost of establishment of trees is covered by some other project, e.g. trees planted for salinity control, a profitable operation might eventually be possible. The key to success is the market price. If it remains at its present level it will be impossible to produce oil in Australia at competitive prices.

Establishment costs on cleared land, assuming a heavy tractor or bulldozer is already owned, consist of the cost of laying out the plantation, deep ripping and surface cultivation of the rows, planting, watering and weed control. If, as suggested above, these costs are not borne by the eucalyptus oil production, then the specific costs to be covered to enable production are: acquisition of a heavy forage harvester, at least three mobile distilling vessels, a boiler, lids, a condenser and oil separator, a pump and motor for circulating the cooling water plus housing for the apparatus if it is not already there. A good water supply is essential. The cost of these items, not new, would exceed $100,000 for a modest plant capable of producing about 15 t of oil per annum. At present prices, oil production is not a profitable enterprise if the oil is to be sold to the wholesale market. If retail marketing or a new oil use is being considered, margins may be greater and therefore justify the establishment of a distillation plant.

The world market price is set by China. China is moving towards a market economy and the availability of extremely cheap labour might end. However, unless a substantial new use is found for eucalyptus oil, China can more than supply the world demand, and consequently a dramatic price rise is unlikely.

### Table 1. Gross margin analysis

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<td><strong>Annual gross margin /ha</strong></td>
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1. Yield at 200kg per harvest on an 18 month rotation.

2. Establishment costs for a perennial crop need to be spread over several years – in this gross margin 8 years has been used.

3. Harvest and distillation cost based on theoretical plant producing approximately 15 t/yr. Such a plant is smaller than current commercial plants but represents a minimum sized economic unit. Plant cost approx. $150,000 if mainly second hand equipment used.
**Key references**


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Richard Davis is Managing Director of G.R. Davis Pty Ltd (see Key contacts for address), the major producer of eucalyptus oil in Australia.
Acknowledgement is given to Lee Peterson the author of this chapter in the first edition of this publication.

**Introduction**

Fennel (*Foeniculum vulgare* (L.) Mill.) is a member of the Apiaceae (Umbelliferae) family. It is native to southern Europe and the Mediterranean region. Other cultivated crops of this family include parsley, coriander, dill, parsnip and carrot.

Fennel is a deep-rooted perennial crop, cultivated for the production of essential oil. The essential oil is produced in canal-like structures formed by glandular cells throughout the plant but the most prominent canals are present in the seed coat. The seeds produce approximately 60% of the oil and 90% of the anethole that is produced in the whole fennel plant.

Since fennel is fundamentally a seed crop, simple grain harvesting and handling equipment can be modified and used for harvest. The crop can be direct headed or forage harvested, depending on the type of oil required and the transportation arrangements available. Post-harvest, the crop...
is steam distilled to release the essential oil.

Australian production of fennel for its essential oil has been limited to Tasmania where production began in 1982. It was first produced for the compound anethole, which was used in many aniseed-flavoured beverages popular in European countries. The original alternative source of anethole was star anise, a member of the magnolia family. Cropping fennel enabled broad- acre production of anethole.

Recently aniseed-flavoured beverages have lost favour with consumers and fennel is now produced for fennel oil in its own right.

**Markets and marketing issues**

World production of anethole is about 1000t/annum. Most anethole is extracted from star anise, with China and Vietnam being the dominant producers. The production of anethole from fennel oil requires specialised rectification equipment to produce the 99% pure product that the market requires. Unfortunately, Australia was not able to remain competitive with Chinese and Vietnamese production of anethole due to improvements in the continuity and quality of the Asian supply, combined with price reductions and world-wide trends towards decreased consumption of aniseed based beverages.

Tasmanian production of fennel oil declined to about one tonne per annum in the late 1990’s compared with a high of 40t in 1992. Production has now risen to approximately ten tonnes of oil per annum. The present market for fennel oil is the flavour industry where the balance of anethole with other important flavour components is vital. Fennel is now also used in aromatherapy.

Other countries currently producing fennel oil include India, China, Egypt, Argentina, Indonesia and Pakistan.

While anethole sales in the past have been direct with end-users, fennel oil sales are generally handled through the normal essential oil marketing chain of grower via trader, to flavour and fragrance house and finally to end user or manufacturer.

**Production requirements**

Fennel has been grown successfully on a variety of soil types, from sandy loam to black cracking clay. Although it prefers alkaline soils it will tolerate soil pH’s ranging from 5 to 8.5. Soils must be free draining, particularly during winter, as fennel is a perennial crop. If the ground lies wet for any length of time, root disease and plant death will lead to a patchy crop in subsequent seasons.

The site must be open and sunny, in a cool temperate climate, ideally with an average daily temperature of approximately 20°C.

An advantage of growing fennel is its ability to improve soil structure due to the large amounts of vegetable matter that it returns to the soil and its aggressive deep rooting habit. In addition, in a mixed farming enterprise, fennel provides valuable forage as it can be grazed by stock over winter.

Once established, a fennel plant may grow to over 2m and the volume of vegetative material produced can be considerable. It is crucial to maintain cultural practices during the early development of the crop since accessibility will become very difficult later in the season. Late applications of fertiliser or pesticides must be applied from the air.

Recently production techniques have been modified to reduce the height and bulk of the crop, though this does not negate the need for aerial application of chemicals should they be
needed post-bolting. The new management strategies include grazing the crop for an extended period coming into spring and withholding fertiliser application until after flower initiation. Flower initiation is triggered by day lengths exceeding 13.5 hours when the plant has reached a minimum size of 7-8 adult leaves. At this point nitrogen-based fertiliser is applied and the crop goes on to produce a full yield of seed, carrying the full complement of oil as the traditional growing system. However, this oil is produced from distillation of 60% of the traditional quantity of plant material, significantly reducing the distillation costs.

Irrigation is essential, particularly during flowering and seed development. Flood irrigation is not recommended as this is said to cause root disease problems.

Fennel can be harvested with forage harvesting machinery similar to that used for peppermint. However, the crop does not have to be wilted and is cut at a height that mainly removes seed heads. Direct heading, using regular combine harvesters is also successful. Direct heading of the seed significantly reduces the volume of crop to be processed.

The fennel oil is extracted by steam distillation, a technique requiring specialised equipment and expertise.

**Varieties/cultivars**

The classification of fennel has been disputed by many researches, but the general agreement today is that there is only one species, *Foeniculum vulgare* Mill. with two sub-species, *piperitum* (Bitter Fennel) and *capillaceum*, which has two varieties, Sweet Fennel and Bulb Fennel. Recurrent selection programs have been undertaken in India and France to increase seed yield, oil content, oil quality, pest and disease resistance.

The varieties commercially grown in Tasmania are the result of a joint program by the Pernod-Ricard company and the University of Tasmania. The program was initiated by Pernod-Richard in the quest for higher yields of anethole per hectare. A wide range of selections and oil characters is available. The flavour market, in general, demands an oil with a low concentration of the intensely bitter agent fenchone.

**Cultural practices/agronomy**

Fennel crops can be established easily by direct seeding in the spring. The target density is 10 plants/square metre. Because the seed is small, best results have been obtained using some form of precision seeder. Seeding rates vary with seed size and germination rates but are generally in the order of 2-2.5kg/ha. Seed must be sown deeply, (20-30mm) as germination is inhibited by light. Good seed to soil contact is essential for uniform germination. In general, germination takes 14 to 21 days and initial development of the seedling is slow. No herbicides can be used until the plant has developed at least three pairs of true leaves.

Fennel is a typical long day plant and will remain vegetative until the day-length exceeds 13.5 hours, after which the plant initiates flowers and bolts very rapidly.

Fennel can reach maximum yields in the first year of growth and, with careful maintenance, under Australian conditions can maintain that yield for 6-7 years. Productive crops in excess of 10 years of age exist in Tasmania. Australia is lucky in this respect, since, in many other countries, the severity of *Phomopsis* disease outbreaks means that fennel must be grown as an annual crop.

Fennel is a particularly vigorous crop and can produce biomass yields of 40-60t/ha. Fertiliser requirements are therefore relatively high and annual soil analysis is required to monitor changes. Nitrogen applications are critical, especially during flowering. Actual fertiliser rates required depend upon the initial soil fertility but typically 350-400kg/ha N:P:K (3:6:8) is incorporated prior to sowing and followed up with bi-annual side dressings of 50-75kg/ha ammonium nitrate. To date, no major trace element deficiencies have developed over a 5-year life span.

After two years the crop benefits from deep ripping. This alleviates soil compaction, promotes new adventitious root growth, and lowers shoot density. If the shoot density is not checked, yield can decrease in later years.

Fennel growing at Cressy, Tasmania
Agronomic practices are aimed at promoting maximum seed yield and maximum seed size. Crop uniformity is also important. Harvest date prediction is not as critical as with some essential oil crops since oil composition is largely determined by variety. The more important factor is the minimisation of seed loss. The umbels on fennel mature at different rates and it is important not to leave the crop too late as the seed set on the earliest maturing umbels will shatter. Forage harvested fennel crops can be harvested earlier than direct heading which requires a lower moisture content for successful seed removal and oil extraction.

Pest and disease control

The major disease problem in fennel is a Cercosporidium fungus. This can be managed with early preventative fungicide applications to reduce the level of inoculum. High humidity during flowering will promote Cercosporidium development, such that heavy leaf loss and damage to the flowers and seed will be sustained. Late infections can be controlled by fungicide application, but usually the operator must resort to expensive aerial spraying to gain access to the crop.

A major disease of fennel in Europe is Phomopsis wilt. Where this disease is prevalent, fennel must be grown as an annual crop. To date this disease is not present in Australia.

Fennel can also be infected by Sclerotinia but infections are not usually severe.

The major yield-reducing pests of fennel are thrips, potato mirids and aphids. Particular care has to be taken with insect pest management during flowering, as bee activity is vital for pollination and subsequent seed set.

Harvest/handling/storage/post harvest treatments/processing requirements

As mentioned previously, fennel can be either forage harvested or direct headed. The stage of maturity at which each harvest type can commence varies, allowing for considerable flexibility in the harvest period and better utilisation of the distillation equipment.

The volumes of crop to be transported to the distillation unit can vary greatly between the two methods: heading allows for crops further away from the distillation unit to be economically processed. Conventional grain handling methods can be used for the handling of headed fennel seed, but as the moisture content is much higher than grain, the product has to be extracted promptly and some handling difficulties may occur. It is important that the seed has the correct moisture content at the time of harvest.

The plant and equipment used for the distillation of other essential oil crops can also be used for the extraction of fennel oil. However, if distillation facilities are used for more than one product, it is imperative that tubs and condensers and separators be cleaned thoroughly between uses as cross contamination of oils may lead to unsaleable products.

Once the oil is extracted and separated, the product is relatively stable for many months provided it is stored out of direct sunlight and away from heat. Poly-lined drums are not suitable for fennel; only galvanised or lacquered drums may be used for its storage and transport.

Financial information

Fennel crops are established by direct seeding and it is important that some form of precision seeder is used to establish the crop at the correct planting density. To date seed costs have been relatively low.

The major advantage of fennel is its robust perennial nature. Proper maintenance has allowed crops in Tasmania to yield more than nine commercial harvests.

As with most essential oils crops the major costs are those for harvest, transport and distillation. On-farm costs are limited to fertilisers, pest and disease control, and irrigation, and slashing of the stubble after harvest. In later years there are some costs associated with deep ripping or inter-row cultivation to maintain vigour.

Contractors can be used for direct heading of fennel, but forage harvesters must be modified if the crop is to be collected in this fashion.
Capital outlay for distillation equipment such as boilers, condensers, separators and tubs is considerable. In general, even with second-hand equipment, setup costs have been in the order of $150,000-250,000 for a regional facility.

Mobile distillation units were tested in Australia but the strict regulations covering boilers have led to both economic and strategic failure.

The following table is a typical gross margin analysis for fennel oil production. As with most niche crops, the price is highly elastic while the costs are not. Growers should be aware that prices will fluctuate and significantly alter the expected gross margin.

Table 1. Gross margin analysis

<table>
<thead>
<tr>
<th></th>
<th>Year 1 ($)</th>
<th>Year 2 onwards ($)</th>
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</thead>
<tbody>
<tr>
<td>Oil yield (kg/ha)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Price</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>Gross income</td>
<td>1,800</td>
<td>1,800</td>
</tr>
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<td>Materials</td>
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<tr>
<td>disease control</td>
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<td>weed control</td>
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<td>pest control</td>
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<td>22</td>
</tr>
<tr>
<td>Tractor and Plant</td>
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<td>planting</td>
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<tr>
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<tr>
<td>harvest and distillation</td>
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<td>600</td>
</tr>
<tr>
<td>Total variable costs</td>
<td>1417</td>
<td>1202</td>
</tr>
<tr>
<td>Annual gross margin/ha</td>
<td>383</td>
<td>598</td>
</tr>
</tbody>
</table>

Key references


About the author

Dr Linda Falzari is a researcher with the Essential Oils Group at the University of Tasmania. She has spent the last ten years studying the cultivation of essential oil crops and the production of essential oils and extracts.

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Key statistics

- World production of anethole is approximately 1000t/annum
- Australian production is approximately 10t/annum

Key messages

- Market has changed from anethole to fennel oil per se
- New techniques have improved efficiency of production
- Small market with risk of oversupply

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Acknowledgement is given to Rosemary Holmes, the author of this chapter in the first edition of this publication.

Introduction

Lavender is an ancient herb with a long history of use in fragrance, medicinal, culinary and aromatherapy applications.

The Lavenders are members of the Laminaceae family and the genus is divided into three main types, namely the Spica, Stoechas and Pterostoechas groups. It is the Spica group which includes the species of most commercial significance.

The three principal commercial species from the Spica group are the English or True Lavender \( L. \text{angustifolia} \) - P Miller (syn. \( L. \text{officinalis} \) - Chaix), Spike Lavender \( L. \text{latifolia} \) and a number of hybrids of \( L. \text{angustifolia} \) and \( L. \text{latifolia} \) known as \( L.x \text{intermedia} \) or Lavandin.

Australia is currently a net importer of lavender oils and opportunities exist for import replacement provided the required quality criteria can be met. It is important to appreciate that a diverse range of lavender products are traded and production systems need to be selected carefully to ensure the desired outcome. To this end, a number of factors need to be considered including the planting stock, the production environment and processing infrastructure.

Production in Australia is set to increase with a large number of new operations throughout the country at the early development stage. However there are good opportunities for more new...
ventures that can target specific market niches.

**Markets and marketing issues**

Lavender products offer a range of market opportunities and most commercial operations would endeavour to capitalise on more than one revenue source. Oil and herb production complement one another well and the crop in full flower is visually spectacular, making an attractive tourist experience, particularly when augmented by suitable interpretation information covering the various aspects of production, extraction, uses and history of lavender.

The price that can be obtained for lavender oil is largely dictated by oil quality and there are various categories defined by international standards.

The highest value oil is produced from True Lavender (L. angustifolia) for use in perfumery. This is frequently referred to as Oil of French Lavender or French Fine Fragrance Lavender.

Most oil production is from the Lavandin hybrid cultivars which have a more vigorous growth habit and higher oil yield, but suffer the disadvantage of high levels of camphor creating limitations for cosmetic and perfume use. Because of this, the use of lavandin oils is generally restricted to general fragrance applications and blending.

Accurate global production figures are difficult to obtain but appear to be of the order of 1,200 t/yr of Lavandin oils compared to about 200 t/yr of True Lavender. Most comes from Europe, with increasing production in the United States. France was once the main supplier but production, particularly of True Lavender, has declined markedly over the last 20 years. There is now a concerted effort to reverse this situation.

Australia currently produces a little over 2 t/yr of lavender and lavandin oils and imports around 32 t/yr.

There is increasing interest in the use of lavender oil for therapeutic purposes and this area could provide significant growth opportunities. There is evidence, often anecdotal at this stage, for a range of effects including calmative, relaxant and sedative responses, as well as antimicrobial and wound healing properties. There is now a considerable amount of research being undertaken to test lavender efficacy claims.

For therapeutic use, products have to be listed on the Australian Register of Therapeutic Goods. At this stage, only oils from L. angustifolia are registered.

**Production requirements**

Lavenders will grow under a wide range of climatic conditions. However, since the native habitat of the Spica lavenders is the sub alpine region of Southern France, this group is generally best suited to temperate conditions. This is particularly so with True Lavender which is only found naturally at higher altitudes where, for high quality oil production, maximum

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**Key messages**

- Identify market opportunities
- Cultivar selection critical
- Good soil drainage required

**Key statistics**

- Australian production of True Lavender and Lavandin is approximately 2t/yr
- Australian imports of True Lavender and Lavandin are approximately 32 t/yr
- Global production of True Lavender is approximately 200 t/yr
- Global production of Lavandin is approximately 1,200 t/yr

---

Hanging bunched lavender to dry
temperatures should not exceed 30°C, and the temperature preferably has a wide diurnal variation. Spike lavender which originates at lower altitudes and the lavandins are the preferred species for warmer locations although *L. angustifolia* can be grown in the highlands of subtropical areas such as south east Queensland. Most lavenders tolerate cold winter conditions and are frost hardy although late frosts in November or December, once flower buds have started to develop, can severely deplete spike numbers and oil yield.

Lavender is generally considered drought tolerant and well-established plants can withstand dry periods. However adequate moisture through spring and early summer when crops are harvested is important for maximum productivity, and a reliable autumn break is required to allow good regeneration after harvest and to maintain plant vigour and longevity.

An ability to irrigate via either sprinkler or trickle systems is an advantage particularly during establishment and later to counter dry periods and to allow good timing of nitrogen side dressings.

Once a suitable soil type has been identified there are a number of other site characteristics which need to be considered. A slightly undulating topography can be an advantage in helping to avoid any risk of waterlogging during extremes of rainfall, in which case it is recommended that rows are planted on the contours to minimise erosion. On the other hand excessive slopes should be avoided on larger scale plantings since access for mechanised harvest and transport systems is required.

Aspect is not critical given the maximum degree of slope likely to be employed but full sun is necessary for good flower development, hence any shading for significant parts of the day should be avoided. For this reason, proximity to trees can be a problem, and certainly any containing essential oils such as the Eucalypts must be avoided due to the added problem of potential oil contamination from fallen leaves.

Exposure to wind should be considered, especially during the flowering period. Lavender is quite robust but like any essential oil crop risks significant volatile loss if exposed to strong wind in the period leading up to harvest.

**Varieties/cultivars**

The choice of cultivar is critical for any lavender enterprise and should be selected to suit the locality and the products required. Vegetative propagation is necessary to maintain cultivar characteristics since seedling stock results in a high degree of variability, which is reflected in both the morphology of plants and the composition of any oil produced.

The requirements for oil production are very specific and the selection of cultivars generally involves a long and detailed process to ensure the resultant oils fit the chemical and organoleptic criteria of the market. Even established commercially available cultivars should be tested for any site-specific variation that might arise from differences in soil types, microclimate, aspect and management techniques.

The difficulties associated with cultivar selection can be exacerbated by poor nomenclature standards within the industry, with no formal varietal certification currently available. There are some reference collections in Australia to assist in identification, for example, the Yuulong Lavender Estate near Ballarat which holds the National Collection of Lavenders for the Ornamental Plant Conservation Association of Australia with some 120 varieties of the genus *Lavandula*.

**Cultural practices/agronomy**

Lavenders originate in France in areas which have predominantly calcareous, stony, free draining soil types. Consequently, areas for plantation lavender must have very well drained soils, preferably within a pH range of 6 to 8. Lavender requires moderate phosphate and potassium levels. Adequate potassium is important for flower development but higher levels can be deleterious. Calcium applications are important in non-calcareous soils. Lavender
responds to nitrogen side dressings in spring resulting in increased spike density and oil yield. However, excessive nitrogen can be counter productive if too much vegetative growth is promoted since it can affect oil quality and the added bulk will increase distillation costs.

Good weed control is vital since lavender is not strongly competitive, particularly during establishment, and weed contamination can be a serious problem for oil production due to the risks of taints and the effect of additional bulk on distillation economics.

Herbicide options are limited with the only chemicals currently registered in Australia being oryzalin and oxadiazon under a general ornamental category.

Perennial weeds must be completely controlled prior to planting with broad range knock down herbicides, with inter-row cultivation and hand weeding generally required for follow up weed control.

The recommended plant density varies depending on the species of Lavender grown.

For L. angustifolia, a plant spacing within the row of 50 cm is preferred in order to give full row cover within 2–3 years. On the other hand, L. latifolia and L. intermedia are generally planted at 80 – 100 cm spacings, depending on the vigour of the particular cultivar. Inter-row spacing should be set to suit the equipment and the practices chosen to manage the crop. Typical row spacing is around 1.8 m to allow tractor access.

### Pest and disease control

Lavender is generally relatively free of pests and diseases. Aphid damage has been reported and can provide a vector for virus infection, particularly the Alpha Mosaic Virus.

If mulch is used, care should be taken with the selection of materials since some can introduce or encourage insect problems. For example, lucerne mulch has been associated with increased aphid difficulties and the Alpha Mosaic Virus.

The spittle bug (*Philaenus spumarius*) is often found in crops in early summer but causes no economic damage unless the crop is grown for the cut flower market.

Fungal problems are rare although root rot conditions will develop if soil structure and drainage are poor or when roots are damaged by inter-row cultivation practices. Nematode damage has also been demonstrated but tends to become significant only when other plant stressors exist.

### Harvest/handling/processing requirements

The scale of lavender enterprises starts with fairly modest operations producing fresh and dried flowers and associated products, with and without oil production, giving annual revenues less than $20,000.

At the other end of the scale are businesses which encompass all aspects of the industry, employing 10 or more staff with 7 figure revenues.

The infrastructure required at the different levels of production naturally varies tremendously.

For the larger oil producing ventures, the harvest has to be mechanised to be able to handle the volumes involved. As an example, Bridestowe Lavender Estate with up to 50 ha under lavender at any one time uses a system which forage harvests the flower heads directly into 250 kg distillation vats trailed behind the harvester.

As each is filled, it is quickly transported to the distillery to be processed in one of three diesel fired water bath stills.

Bridestowe also has mechanised systems for dried flower production. Flowers are dried initially on a large external drying pad, then picked up using a tractor mounted vacuum system before transporting to on-site cleaning facilities where the dried herb is screened and sorted into different product categories.

### About the author

Robert McEldowney is an agricultural scientist with 18 years experience in the essential oil industry. He has experience in all aspects of essential oil production including development of agronomic systems and harvest and extraction technologies relating to a broad range of crops. He is currently General Manager of Essential Oils of Tasmania Pty Ltd.
Financial information

It is impossible to quantify typical returns from lavender enterprises because the range is so diverse. For operations concentrating on oil production, indicative market prices can be obtained, but in most cases there is some degree of value adding, which is enterprise specific.

Like most essential oils, bulk oil prices are quite variable and depend on the quality of the oil and the supply/demand dynamics at any given time. Indicative figures show a range from as high as $A250/kg for top quality True Lavender (although the bulk of sales are probably nearer to $A150/kg), through to around $A30/kg for Lavandin blends.

To some extent, the price disparity is offset by the productivity of the different lavender types. Again, only indicative figures can be offered but generally commercial Lavandins can be expected to yield up to five times as much oil per unit area as L. angustifolia cultivars.

Establishment costs are site specific and can vary significantly depending on the preparation requirements and the type of irrigation installed, if any. Planting stock will always be a major cost since propagation via cuttings is fairly laborious. With up to 12,000 plants per hectare generally involved, plant costs should be negotiated with the relevant nursery – as a guide figures from $A500 to $A1,000 per thousand plants can be expected, depending on the numbers ordered. When time permits, capital outlay can be reduced by establishing field nursery areas. This allows cultivars to be assessed under local growing conditions and those selected for expansion can be used for propagation stock via either semi-hardwood cuttings or splits planted directly into new areas.

Prospective lavender growers should seek detailed advice from industry representatives.

Key references


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Lavender oil
Lee Peterson

Acknowledgement is given Fred Bienvenu, the co-author of this chapter in the first edition of this publication.

Introduction

The two main mint oils that have been produced in Australia are Peppermint and Spearmint oil. Peppermint oil is obtained from the leaves of the perennial herb, *Mentha piperita* L., whilst there are two types of commercial spearmint oil obtained from the leaves of the perennial herbs, *Mentha spicata* L., more commonly known as native spearmint, and *Mentha cardiaca* L., Scotch spearmint. All are members of the Labiatae family. This family includes many well-known essential oil plants such as spearmint, basil, lavender, rosemary, sage, marjoram and thyme. The mint plants are summer-growing perennials with upright square stems reaching a metre in height at maturity.

The oil is found on the undersides of the leaves, is extracted by steam distillation and is generally followed by rectification and fractionation before use. The major end-uses are in toothpaste and mouthwashes, chewing gum and food flavourings.

Commercial production of spearmint oil has declined over the
Mint oil

not as narrow as those for peppermint. Nevertheless, as the general growing requirements, management practices and harvesting techniques are the same for both crops, spearmint is grown in the same production localities as peppermint.

Production has been under way in both these regions for many years but recent expansion in the Victorian region has now ceased and is limited to the Corryong region.

Production techniques are based to a considerable extent on U.S. practices and require a high level of capital input and expertise to produce a saleable product.

Markets and marketing issues

Prices in world markets are dictated by conformity with the characteristics of U.S.-produced oils, which differ from region to region. 'Lower quality' peppermint oils typically command a market price of about $A30/kg, whereas 'higher quality' oils can fetch up to $A60/kg.

The price of spearmint oil fluctuates year to year, with native spearmint at 20-40% lower than peppermint oil and Scotch spearmint 0-10% higher than peppermint oil. Maximum prices are achieved only if the major oil components, carvone and limonene, are in the correct balance with other flavour components.

The buyers’ primary concern is the quality and flavour of the product and the consistency from year to year. This largely stems from the need for a consistent taste in the end-product formulated and delivered to customers.

The world-wide trade in mint oils is generally from growers to traders who may blend or rectify the oils from many growers or even regions to provide a consistent product to the flavour and fragrance houses which then supply pre-formulated product to the manufacturer.

Sales direct to flavour and fragrance houses and manufacturers do occur but require considerable long-term marketing commitment and well established production history.

The level of pesticide residues in the oil is now a key marketing issue. The top end of the market is very discerning and well equipped for residue detection.

Production requirements

Climatic constraint of areas suitable for peppermint oil production has already been mentioned. A major factor in this context is to minimise the production of less desirable compounds, in particular menthofuran.

All mints require a relatively free-draining soil type with a pH of 6-6.5. Areas that lie wet in winter will not perform vigorously and plants may even die. Inundation during the growing season has even greater harmful effects.

The crop has high water demands in the summer. Crops are currently grown under managed flood, high pressure and low pressure irrigation systems. It is the ability to adequately irrigate
which normally limits the growth or expansion of peppermint areas.

Pest and disease management are paramount and efficient broadacre spray equipment is a prerequisite.

Spearmint differs from peppermint in that a healthy crop will regularly produce two harvests each season whereas peppermint usually produces only one harvest. In general, experience has shown that it is better to concentrate on maximising the oil potential for one harvest because of the high costs of harvest and the additional costs of disease management with double harvest.

Harvesting uses conventional forage harvesting technology but distillation of the oil requires specialist equipment and expertise and needs to be regionally based as large volumes of material must be processed.

Varieties

*Mentha spicata* L. and *Mentha cardiaca* L. are sterile perennial herbs, and therefore must be propagated vegetatively. *Mentha spicata* L. is characterised by a high carvone content which accounts for 60-70% of the total oil analysis, accompanied by a limonene content of 8-15%. The odour profile of native spearmint is a fresh and green with very high floral topnotes. The body of the oil is warm and herbaceous.

The carvone content of *Mentha cardiaca* L. is also 60 and 70%, but typically it has a higher limonene content of up to 20%. The oil also has a menthone content of up to 2%. This is the prime indicator of Scotch spearmint oil.

The odour of the oil is light, fresh, and diffusive, with an ethereal topnote and a woody, rapid body expansion. The body of the oil is typically very sweet.

*Mentha piperita* L. is also a sterile, perennial herb and therefore must be propagated vegetatively.

Two main selections are currently in commercial usage throughout the industry. Black Mitcham is the original cross. It is highly valued but susceptible to a soil-borne fungal disease, verticillium wilt.

Todd Mitcham is a more wilt-tolerant selection which now forms the bulk of the world’s production.

Both selections are present in Australia where, to date, verticillium wilt has not been detected.

**Agronomy**

Using stolons from a nursery site of 1 ha, a cropping area of 7-10 ha can usually be achieved the following year.

As the mints are a perennial crop, pre-planting weed control is imperative for the long-term viability of the crop. A well-planned fallow and weed eradication program before planting is therefore strongly recommended.

Specialised lifting equipment is used in Victoria and Tasmania to lift plants and remove soil. In Victoria, a specially designed planter is used to place stolon
fragments evenly in rows. These rows rapidly close over and form a dense canopy in summer. In Tasmania lifted stolons are spread using modified muck spreaders followed by a light discing. Both planting processes work well.

Strong healthy planting material is essential for correct density of established crop.

Fertiliser rates are generally high, as development of the maximum number of leaves and their retention through to harvest is the target. Frequent nitrogen applications are required through the growing season and careful maintenance of soil fertility is needed to ensure the crop remains productive. A commercial crop correctly maintained will yield well for at least 5 years.

Because the mint plant is very succulent, proper timing of all operations is critical for the retention and maximisation of oil glands in the leaves. Oil yield will decrease rapidly if the plant is subjected to either physiological or pathological stress.

**Pest, disease and weed control**

The most significant disease problem encountered with all mint plants is a rust fungus which, if left unchecked, will totally defoliate the plants.

The current method of control is to use the fungicide ‘Tilt’ at strategic times in the life cycle of the rust fungus. The other important factors for control are efficient spray application, removal of any areas that are hard to spray and removal of rogue plants. Scotch spearmint appears to be more sensitive to rust attack than the native spearmint, but both are prone to significant oil loss if the rust is left unchecked.

Pest problems encountered in Australia include cut worms, twospotted mite, brown vegetable weevil and wingless grasshopper.

Weed control programs must be strictly maintained to reduce plant competition but more importantly to eliminate oil contamination. There are a range of herbicides, fungicides and insecticides registered for use in mint crops or under minor use permits, but these should be reviewed annually to ensure that they are current.

**Harvesting, transport and distillation**

The timing of harvest is critical to the quality of the oil. In Tasmania and Victoria an extensive pre-harvest sampling program is employed to schedule harvesting of all mint crops. This sampling examines changes in oil composition from early January onwards.

Mint crops are mown using conventional hay mowers or windrowers. It is very important not to bruise any of the leaves at any time during harvest as this will result in oil losses.

Once the cut herb is wilted it is chopped directly into a distillation vessel, usually referred to as a tub, using a forage harvester. The correct moisture content of the herb is essential for complete and economic oil extraction.

The tubs are then transported to the distillation facility where either wet or superheated steam is passed through the herb and the resulting steam and oil vapour are condensed and separated.

Condensing and separation equipment should be

![Distillation of peppermint oil](image)
manufactured from stainless steel and general processing hygiene followed to ensure no contaminants are present.

In general, the most-economic units distil five or more tonnes of herb at a time. The time for oil extraction varies depending on the type of steam source, the herb weight and the moisture content.

Most distillation units are diesel-fired but wood-fired units are used in Tasmania with success.

Once the oil is separated, the product is relatively stable for many months provided it is stored out of direct sunlight and away from heat. Epoxy-lined and galvanised drums are the commonly used storage and transportation units.

### Financial information

The costs of establishing a mint crop are considerable because propagation is vegetative, as described above. In general, a minimum area of 5 ha is needed within an existing essential oil distillation region of radius 30 km. For a distillation region to be viable a minimum of approximately 80 ha is necessary.

Capital outlay is considerable for dedicated equipment such as boilers, condensers, separators, tubs, and planting equipment. In general, even using second-hand equipment set-up costs have been in the order of $150,000-250,000 for a regional facility. Table 1 shows the gross margin analysis.

### Key references


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Aretander (1960) Perfume and Flavor Materials of Natural Origin - Aretander


### About the author

Dr Lee Peterson is an agricultural professional with extensive expertise in many aspects of agricultural production gained over a period of 20 years in industry, consulting and research. Considerable experience in the development of new crops and production systems with a particular emphasis on essential oils combined with expertise in a wide range of annual and perennial cropping systems provide Lee with a unique range of skills.

### Disclaimer

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### MINT GROSS MARGIN (cont.)

**Year 2 to end of productive life.**

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<td><strong>Price:</strong></td>
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<td><strong>Total Enterprise Output</strong></td>
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<th><strong>VARIABLE COSTS</strong></th>
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<td>Ammonium Nitrate</td>
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<td>Muriate of Potash</td>
<td>125kg/ha @ $408/tonne 51</td>
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<tr>
<td>Cartage</td>
<td>925kg/ha @ $13.50/tonne 12</td>
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<td>Weed Control terbacil****</td>
<td>1spray 1l/ha @ $88.00/litre 88</td>
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<tr>
<td>terbacil spot spraying</td>
<td>0.175l/ha @ $88.00/litre 15</td>
</tr>
<tr>
<td>paraquat****</td>
<td>1spray 1.5l/ha @ $17.40/litre 26</td>
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<tr>
<td>Disease Control mancozeb</td>
<td>2sprays 2l/ha @ $7.60/litre 30</td>
</tr>
<tr>
<td><strong>Tractor and Plant:</strong></td>
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<tr>
<td><strong>Fertiliser Topdressing - 4 operations</strong></td>
<td>2.4hr/ha @ $2.83/hr 7</td>
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<tr>
<td><strong>Weed Control</strong></td>
<td>1spray 0.6hr/ha @ $2.83/hr 2</td>
</tr>
<tr>
<td><strong>Disease Control</strong></td>
<td>2sprays 0.6hr/ha @ $2.83/hr 3</td>
</tr>
<tr>
<td><strong>Mowing for Harvester</strong></td>
<td>1hr/ha @ $2.83/hr 3</td>
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<tr>
<td><strong>Repairs, Maintenance &amp; Lubrication on operations</strong></td>
<td>16</td>
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<tr>
<td><strong>Contract Operations:</strong></td>
<td></td>
</tr>
<tr>
<td>*** Harvesting &amp; Distillation</td>
<td>@ $650/ha 650</td>
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<tr>
<td><strong>Irrigation:</strong></td>
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<tr>
<td>Running costs</td>
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<tr>
<td><strong>GROSS MARGIN - Successive years</strong></td>
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</tr>
</tbody>
</table>

*Fuel cost only.

**Land preparation is assumed to consist of one disc ploughing, two tyne cultivations and one harrowing

**Harvesting costs will vary with district and farm. Raking & baling may require night operations to ensure premium quality, thereby increasing costs.

**Combined in single application.

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**Key messages**

- Environmental/climatic conditions critical for saleable product
- Capital costs high due to specialised machinery and extraction facilities needed
- Field expansion costly and slow

**Key statistics**

- World production 5000 t/year
- World consumption increasing by 5% per year
- Australian production 15 t
Introduction

Parsley, from which parsley essential oil is produced, has the species name *Petroselinum sativum* Hoffm. (formerly *Apium petroselinum* L.) or *Petroselinum crispum* (Mill) Nyam. A third synonym, *Carum petroselinum* Benth. is seldom used.

The species is usually divided into two varieties separated by leaf shape and commonly named Curled Parsley and Italian Plain Leaf parsley.

The essential oil products produced from parsley fall into three categories; leaf oil, herb oil and seed oil. Clearly, leaf oil is produced by distillation of leaves while seed oil is obtained through distillation of mature seeds. Herb oil is produced by distillation of the whole flowering plant while it has immature umbels.

Each type of oil has its own particular characteristics. In addition, different cultivars also produce oils with different characters. It is not possible to define “good quality oil” as the characteristics required vary immensely between end-product users. The chemical components important in imparting each parsley oil with its characteristic organoleptic qualities are menthatriene, elemicin, TMAB (tetramethoxyallylbenzene),
myristicin and apiol. Each oil will have specific concentrations and combinations of these compounds.

**Markets and marketing issues**

The world market for parsley oil is fragmented into a series of niche markets, with each end-user demanding oil of a particular organoleptic character. Penetration of established niche markets is difficult for new suppliers because the markets are small and limited. Current end-users are usually unwilling to take on new suppliers unless forced to do so by external forces such as political instability or irregular supply. Generally each parsley oil niche market is well supplied by current growers and oversupply is a serious risk to future production. New producers may need to seek new niche markets.

Currently Tasmania produces approximately 3.5t of oil from the 70ha of parsley grown in the state. This is exported to Europe, USA and Japan. Tasmanian production supplies about 50% of the world trade in the herb oil of that particular niche market.

Parsley oil is also produced in USA and European countries, including amongst others Germany, France, Holland and Hungary.

**Production requirements**

Parsley prefers a cool, temperate climate and has an optimum, average daily temperature of 20°C. It is well suited to production in south-eastern Australia.

Soil for parsley production needs to be free-draining in order to avoid root disease, particularly through the winter months. Sandy loam is an ideal soil type. The pH may vary from 5 to 8.5 but parsley is more productive on the more alkaline soils.

Irrigation is essential, first during crop establishment and later during flowering. Flood irrigation is not recommended as it can lead to root disease.

A precision seeder should be used to sow the crop, since regular plant spacing will produce a more even crop at harvest time. A forage harvester will be required at harvest time. Post-harvest the crop is steam-distilled to obtain the oil, therefore access to a distillery is necessary.

**Varieties/cultivars**

As detailed in the introduction, parsley oil cultivars are usually divided into two groups based upon leaf shape. They are Curled Parsley and Plain Leaf parsley. The nomenclature for these varieties varies but typically the former, with the curled or crinkly leaf morphology is known as *P. crispum* var. crispum. The latter, with the plain or flat leaf type is called *P. crispum* var *neapolitanum*. Plain leaf parsley is also referred to as Flat leaf parsley or Italian parsley.

Another classification of parsley is based on the chemical composition of the oil rather than the morphology of the leaves. The races are separated on the relative concentrations of three of the main oil components *i.e.* myristicin, apiol and 2,3,4,5-tetramethoxyallylbenzene (TMAB). Each race carries the name of the compound (myristicin, apiol or TMAB) that is highest in concentration. Two mixed races have been also identified.

Parsley of the curled type *e.g.* “Triple Curl” tends to belong to the myristicin race, while Plain Leaf varieties *e.g.* “Dark Green” belong to the apiol race. The plain leaf variety “Napoli” belongs to a mixed race, since it produces oil with similar concentrations of both myristicin and apiol.

The superior cultivar for a particular niche market can only be selected once the requirements of a particular end-user are known. In Tasmania, Triple Curl parsley is currently

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**Key statistics**

- World market is fragmented into a series of niche markets
- Australian herb oil production is 3.5t/annum
- Seed oil market is less than 5t/annum

**Key messages**

- Establishment costs are high
- Risk of oversupply of niche markets
- Careful control of oil separation imperative
grown to produce herb oil with myristicin and menthatriene as the critical components. Plain leaf parsley is used to produce seed oil where apiole and myristicin are the critical components and menthatriene levels are required to be very low.

A by-product of the current commercial Triple Curl herb oil is a heavy fraction that contains predominantly myristicin. This oil contains potentially valuable components but because the balance of these components is inappropriate for the current niche market, it has low saleability.

**Cultural practices/agronomy**

Parsley is grown as a short-term perennial crop however, due to rapidly decreasing vigour, few crops are maintained beyond a second harvest. Botanically, parsley is a biennial, therefore as an herb or seed oil crop it is planted in the autumn. It is generally direct drilled. Since germination is erratic under cold conditions, sowing in Tasmania should be in late January through February. In warmer regions, sowing may be delayed until March.

Parsley seed is small so a well-worked seedbed is desirable. Irrigation is imperative in the establishment phase. Sowing rates vary with the expected germination rate of the seed batch, but are generally in the order of 2kg seed/ha. An even plant density leads to even flower initiation and in turn even flower maturity. This allows greater accuracy in determining optimum harvest time and gives more control over the composition of the distilled oil.

**Pest and disease control**

*Sclerotinia* is perhaps the most economically important disease in parsley. It is a ubiquitous, soil-borne disease requiring management with an effective fungicide program. Growers need to contact the Australian Pesticides and Veterinary Medicines Authority (APVMA) for advice and if necessary, a Minor Use Permit, prior to using any chemicals which are not registered within their area.

*Septoria* leaf spot can be a problem in parsley, more so in Plain Leaf varieties than the curled types. This is a seed borne disease so a clean seed source is desirable. It is also spread through water splash. It can be controlled with copper. Again, a permit is required.

The major pest in parsley is the aphid.

**Harvest/handling/storage/post harvest treatments/processing requirements**

The optimum time for harvesting parsley is determined by the desired oil composition. The balance of components in the oil changes throughout the growing season, as the crop passes through each maturity stage. For example, leaf oil has higher menthatriene concentrations than floral oil and the immature flowers have lower concentrations of apiole than the mature seed. The best method for determining optimum harvest time is to take pre-harvest samples on a regular basis and to analyse the oil yield and composition of these.

Since oil yield is higher in floral rather than vegetative material, oil yield increases as the season progresses. Optimum harvest time is often a compromise between maximum oil yield and premium oil composition. A further consideration in the production of seed oil is that although dry seed has the highest oil content, dry mature seed is very resistant to steam distillation. Steam does not penetrate the seed coat well, making extraction of the oil slow, inefficient and often uneconomical.

Generally harvesting is undertaken using a modified forage harvester. After cutting, the crop is allowed to wilt in the field for one to two days prior to distillation. This reduces the moisture content, giving better steam penetration through the charge during distillation.

Typical fuels burnt to power steam generation are wood, diesel oil or coal. Usually, low-pressure steam is used for the distillation of parsley.

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The duration of distillation affects not only oil yield but also oil quality. Menthatriene has a higher vapour pressure than the other components measured and appears at higher concentrations at the beginning of the distillation. Menthatriene concentration falls with increasing duration of distillation while apiole concentration rises. More of the volatile compounds will appear at higher concentrations in the first fractions of oil collected in the separator. These include compounds such as menthatriene. Elemicin and TMAB will increase in concentration as distillation continues, followed by myristicin and finally apiole. Adjusting the duration of distillation may help produce oil of the desired composition for a particular niche market. Economic aspects, especially the cost of additional fuel, need to be considered when determining the duration of distillation.

Parsley oil forms both a heavy and light fraction in the separator. Separators must be designed so that the oil can be drawn off from both the top and the bottom.

It is possible to make some modification to oil composition by collecting oil fractions from the separator during the distillation instead of collecting the entire yield at the end.

A significant problem to be addressed is the loss of oil in the wastewater discharged from the separator. Parsley oil has a specific gravity very close to that of water, meaning that separation by density is not always complete. Careful control of condenser and separator temperatures is necessary to gain good separation. It is important to minimise turbulence within the separator and maximise the time available for separation of the oil and water distillate. This can be achieved by the use of two separators in series. The first separator should be quite warm to allow separation of the light fraction oil. The draw-off point for this separator should be as low as possible. The second separator should be relatively cool to allow separation of the heavy fraction i.e. to maximise the difference in specific gravity. The use of a high draw-off point on the second separator will maximise recovery of heavy oil.

The first separator should be maintained at a relatively warm temperature (~50°C) in order to maximise separation of the light oil fraction. The temperature of the second separator should be as low as possible, without falling below 30°C in order to maximise separation of the heavy oil. The minimum temperature must be held above the melting point of apiole (29.5°C) or the apiole will solidify.

Starting with the separators empty is of benefit in reducing loss of oil, by allowing more of the distillate to be held for longer and increasing the time available for separation.

The marc (spent plant material) from the distillation can be a valuable mulch material once it is cooled.

Essential oil storage must take into account that the oils are volatile and flammable. The composition of parsley oil is also unstable. Menthatriene is degraded by a photooxidative process. Storage should be in full containers, in a cool dark place.

Financial information

Prices for parsley oil are highly elastic and heavily dependent upon the volumes of oil being traded.

Oversupply is a significant risk to any particular niche market.

Prices are in the order of $100/kg oil for herb oil and $200/kg for seed oil. Of course, these prices are dependent on the producer being able to supply oil of the composition desired by the particular end-user.

Market sizes are small, even in comparison with other essential oil products. The parsley seed oil market is less than 5t per annum. The current Tasmanian herb oil market is around 3.5t per annum.

The gross margin supplied in Table 1 is tentative and should be taken as a rough guide only. Both price and yield will fluctuate dramatically, although the costs of production tend to be quite stable.

Table 1. Tentative gross margin for Parsley (per hectare)

<table>
<thead>
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<th>Description</th>
<th>Cost ($)</th>
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<td>Price ($/kg)</td>
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<td>weed control</td>
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<td>pest control</td>
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<td>Tractor and Plant</td>
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<td>Annual gross margin/ha</td>
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Key references


http://www.hort.purdue.edu/newcrop/med-aro/factsheets/parsley.html (12/3/04, 11am)

http://www.agcom.purdue.edu/AgCom/Pubs/HO/HO-202.html (12/3/04,11am)

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Dr Linda Falzari is a researcher with the Essential Oils Group at the University of Tasmania. She has spent the last ten years studying the cultivation of essential oil crops and the production of essential oils and extracts.
**Sandalwood oil**  
*(West Australian sandalwood)*

**Introduction**

West Australian Sandalwood oil is obtained from the heartwood of *Santalum spicatum* which is an indigenous species of sandalwood with a natural distribution that covers a large proportion of the western half of the Australian continent.

*Santalum spicatum* is a small tree with olive green foliage, that assumes a rounded habit. Sandalwood is often described as “scrubby” and produces numerous branches from a relatively short trunk.

The production of sandalwood oil and its associated use pre-dates written history. However the commercial utilisation of the species endemic to the western half of the Australian continent did not commence until 1845. Prior to this date Indian sandalwood *Santalum album* was the predominant sandalwood species used in Asia, the Middle East and North Africa.

West Australian sandalwood produces a range of products including timber and powders but the oil it produces provides a number of unique opportunities. There is a growth in markets willing to use West Australian sandalwood oil due to the limited and decreasing availability of Indian sandalwood oil. West Australian sandalwood oil has application in the perfume, incense and complementary medicines markets providing the opportunity...
for producers to target a number of market segments.

West Australian sandalwood has been identified (RIRDC Publication No. 00/173) as having potential as a bactericide.

The primary challenge for West Australian sandalwood oil is the education of markets that have traditionally used Indian sandalwood oil. West Australian sandalwood oil cannot be used as a direct substitute for Indian sandalwood oil and has its own unique characteristics.

The strength of Australian production is the credibility of Australia farmers on the global stage accompanied by the stable political and economic climate that allows resource security over the timescales required to achieve a profitable harvest.

Many of the world’s leading perfume houses will only invest in developing a new perfume if they are certain the supply of key ingredient can be maintained for the foreseeable future. Australian growers can offer certainty of supply with guaranteed quality.

Demand for West Australian sandalwood is increasing. Domestic demand for raw material has increased significantly over the past five years from less than ten tonnes per annum in 1998 to approximately 700 t in 2003.

Total production of West Australian sandalwood oil is approximately 12 t/annum.

Commercial oil production is almost entirely located in WA and relies on the natural harvest of 2000 t/annum, which is strictly controlled by the Forest Products Commission of WA (FPC). However a number of small research trials and feasibility studies are under way in the Eastern States.

At least 1000 ha of private plantations have been established in Western Australia and less than 200 hectares in SA and NSW combined. The rate of private plantation establishment is increasing and is estimated to be in the order of 500 ha/annum. Currently there are no known overseas growers of S. spicatum.

Potential growers must have a long-term outlook and a thorough understanding of tree growing fundamentals.

**Markets and marketing issues**

Quality assurance is critical to potential buyers of wood or oil. Growers should determine whether they choose to be a supplier of wood to an oil processor or whether they wish to become an oil producer.

In either case, production techniques must be environmentally sustainable and minimise the use of chemicals in the plantation.

Producing sandalwood oil for sale to an oil buyer is only an option if quality control can be maintained. As sandalwood oil is used as a raw material in a range of products it is critical that sources of contamination of oil at all stages of processing are eliminated. This may prove difficult for small-scale operations.

Foreign oil producers normally obtain their sandalwood in a powder form from importers or powder men. Large foreign oil producers, most notably in India, powder sandalwood purchased direct from government auctions or importers to their own standards.

Domestic oil producers purchase sandalwood powder from the FPC.

Oil processors will not tend to buy direct from a sandalwood grower.

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**Key messages**

- Industry is in its infancy
- Long term crop
- Capital costs for oil production high due to specialised equipment and techniques required for extraction
- Markets require product to be free of all chemical contamination

**Key statistics**

- Current estimated Australian sandalwood oil production 12t/annum
- Current estimated Indian sandalwood oil production 150t/annum
- Indian Government sandalwood production has declined 20% in 12 years
- Indian Government price for sandalwood has increased over 80% in 12 years
Australian sandalwood oil sells for between $350 and $600/kg depending on the grade of the oil. The global trend for sandalwood is that demand is unable to be satisfied from traditional sources due to overexploitation in many countries and strict environmental controls in Australia. This has opened a window for plantation grown sandalwood.

**Production requirements**

Sandalwood requires drained sites in areas with a mean annual rainfall of 400 – 600 mm. The preferred soil type is sandy-loams over clay. The soil depth should be at least 1.5 m. Soils comprising white or grey sands, heavy clay soils and sites prone to waterlogging or salinity are to be avoided.

There are no existing cultivars or varieties that have been developed. However a tree breeding program has been established and work is being undertaken by the FPC to examine the heritability of sandalwood oil yield and quality. Trials are also underway in Queensland, the Northern Territory and WA to investigate the potential of other *Santalum* species.

It is important to note that the quality of sandalwood produced from plantations will not match naturally grown sandalwood. This is due to the faster growth rates achieved in plantations which in turn leads to a lower proportion of heartwood in plantation grown sandalwood when compared to an equivalent diameter sandalwood log from a naturally grown stand.

Sandalwood oil

Sandalwood with Jam (*Acacia acuminata*) Host (Photo: Forest Products Commission WA)

Sandalwood oil sells for between $350 and $600/kg depending on the grade of the oil.

The global trend for sandalwood is that demand is unable to be satisfied from traditional sources due to overexploitation in many countries and strict environmental controls in Australia. This has opened a window for plantation grown sandalwood.

**Establishment**

As sandalwood is a parasite it is necessary to establish host plants that will survive for the expected rotation period of the plantation. Research indicates that nitrogen-fixing legumes are suitable hosts. The preferred host for most plantations has been Jam (*Acacia acuminata*). Recent research is indicating that *Acacia saligna* may also be a good host but only in the initial stages of the plantation rotation as it is not particularly long lived.

In the establishment year the planting area should be ripped on lines 4m apart with a single tyne ripper to a depth of 0.5 m between March and May. Weed control should be undertaken using a control method appropriate to the site using either chemical, mechanical or organic means as preferred. In July or following a minimum of 50mm rainfall, plant Jam seedlings along rip lines at 2m spacings. This will provide 1,250 Jams/ha.

Follow up seeding of sandalwood can occur in the following year or two years after initial host establishment. Timing is dependant on the survival rate and vigour of the host plants.

To seed the area, plant one sandalwood seed 0.5 to 1 m from each Jam seedling. Plant the seeds 2–3 cm below the surface in the rip line. A critical factor in successful establishment relies on each sowing spot being free of weeds before the sandalwood seedlings emerge. Due to the extreme variation in the target weeds species that may be encountered

*Santalum spicatum* seed can be purchased from the FPC and native seed merchants.
and the significant variation in climate and land systems on which sandalwood can be established, it is not possible to provide specific information on weed control methods.

During the following year sandalwood seedlings that have successfully established should be thinned to 400 stems/ha to obtain a ratio of 1:2 sandalwood to hosts or a ratio of 1:3 on harder sites with lower rainfall.

Sandalwood may need to be pruned to ensure growth is concentrated in one main stem. During the mid term of the rotation an application of fertiliser may be required to maintain the health and vigour of the hosts. A good local nursery will be able to provide advice on the most suitable fertiliser for native species in the area.

Sandalwood plantation establishment utilises standard equipment used in tree establishment. Growers considering on-site oil extraction would need to invest considerable funds in setting up an extraction facility. The minimum cost of setting up a suitable scale plant is estimated to be in excess of $100,000. However extraction technology is improving rapidly and processing equipment is likely to fall in price by the time plantations are ready for harvest.

The time taken for sandalwood to reach harvest is dependant on the site and rainfall. As a general rule sandalwood will take a minimum of twenty years to produce a suitable size log that has enough heartwood of suitable quality for oil production.

Ongoing maintenance of the plantation is minimal apart from initial weed control in years one to three. Sandalwood does not have any major pests or diseases and the main threats are fire and unintended grazing by stock.

It is important to maintain a sandalwood to host ratio of at least 1:2 throughout the rotation period of the plantation. If host trees appear under stress or have died then infilling with new host seedlings should be undertaken to maintain the correct ratio.

**Harvesting and processing requirements**

Sandalwood trees are harvested by complete removal from the ground. This is due to the large amount of heart wood contained in the butt and roots of the tree. This is normally achieved by “pulling” the tree from the ground using a small loader or large tractor.

The stem is then cut into short lengths of 0.5 to 1 m. The pieces are debarked using mechanical tumbler or high pressure water cleaners. At this point the sandalwood can be packed and transported to a buyer or broken down further for oil production.

Prior to oil processing the sandalwood is broken down into a powder or pre-grind. This is similar to coarse sawdust. The powder is then placed in an extraction vessel and oil extraction is undertaken by either steam or solvent extraction methods. Steam distillation requires steam to be passed through a “charge” in an extraction vessel over an extended period of time, up to 100 hours. The condensate containing water and oil is collected and the oil separated and bottled. Solvent extraction is a more technical process and requires specialised equipment to operate at a commercial scale. In
simplified terms a solvent is mixed with the sandalwood “charge” and heated. The solvent containing the oils is then re heated and recaptured leaving behind only the sandalwood oil.

Financial information

The initial establishment cost of a sandalwood plantation is slightly higher than normal tree crop establishment on a comparable site. Additional costs are incurred due to the need to direct seed the sandalwood seed after the establishment of the host species.

Trials to date indicate that four to five tonnes of sandalwood can be produced per hectare over a twenty year period. At a current domestic market value of $5,000/t the gross return per hectare is approximately $22,500. The yield of oil from one tonne of Western Australian sandalwood averages 2%, by weight (20 kg). At a price of $500/kg the gross return from oil production is estimated to be $10,000/t or $45,000/ha.

Oil processing costs are highly variable and dependant on the method of processing and the scale of the plant. It is vital that prospective growers recognise that the plantation sandalwood industry is in its infancy in Australia and the above prices represent the current supply/demand scenario. It is expected that as supply increases there will be a corresponding fall in prices paid. Future prices, in today’s terms are estimated to be in the vicinity of $4,000/t for wood and $350/kg for oil. This would provide gross returns of $18,000 for wood or $31,500 for oil per hectare, in today's dollar terms.

Key references

Brand and Jones. (1997) Growing Sandalwood (Santalum spicatum) on Farmland in Western Australia. Forest Products Commission WA.


Table 1. Establishment and harvesting costs per hectare

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Introduction

Tea tree can hardly be classed as a new rural industry as it has been distilled for the production of medicinal tea tree oil for 80 years. It is only in the last 20 years that *Melaleuca alternifolia* has been cultivated intensively as a commercial agricultural crop. Producers were able to use existing eucalyptus oil technology as a model, adapting where necessary to cater for the peculiarities of this steam-distilled oil producing crop.

While sourcing oil from natural stands of this Australian native plant, tea tree remained a cottage industry. When sourced from plantations, production increased rapidly, peaking in the late nineties before falling back to more sustainable levels. Most of these plantations are located on Australia’s sub-tropical and tropical eastern coastal hinterland.

Once established, tea tree is a hardy perennial crop which survives well. Plantings established 20 years ago are still giving good yields. Apart from the normal horticultural crop skills required for such farming practices, mechanical expertise in the harvesting and distillation areas will also reduce costs. Poor management leads to highly variable returns. New opportunities exist for the establishment of superior plantations based on the improved genetic material now available.

Local practical knowledge in tea tree oil production gives Australia a technological and marketing advantage over the rest of the world which must not be lost as has happened with the eucalyptus.
oil industry. Australia currently accounts for approximately 80% of world supply with the remainder chiefly sourced from China (approx. 15%) and Zimbabwe (approx. 3%).

Australian tea tree oil is marketed in health-care products. Research in recent years has confirmed this *in vitro* activity which is now being supported by *in vivo* clinical trials. The opportunities provided by these positive results now present a challenge to the industry to aggressively market the product and reverse the current trend of declining production and lower prices.

### Markets and marketing issues

Producers usually supply oil to the essential oil industry for purchase by formulators who supply the marketplace with value-added products. More than 80% of Australian oil is exported mainly as bulk oil with a small proportion in value-added products. Because of substantial anti-fungal, anti-bacterial, anti-viral and anti-inflammatory activity the oil is sold over-the-counter as neat oil in small bottles, 10-15% tea tree oil solutions or in formulated products for healthcare, cosmetic, pharmaceutical, veterinary or aromatherapy use.

Potential use in agricultural, hospital (the oil is effective against Golden Staphylococcus (*Staphylococcus aureus*), veterinary and industrial applications present opportunities to further expand the market.

The increased production resulting from plantation establishment has not been maintained in recent years due to overproduction. The increase from below 10t/annum to more than 600t/annum by the turn of the century has now steadied to around 300t/annum. Prices have varied accordingly from base values of $10/kg to about $60 during the early nineties to less than $20 ten years later (Fig. 1).

The industry stabilisation predicted in the previous edition of this chapter has been reached with respect to volume of production (approximately 300t/annum compared with an estimate of 360t/annum) and halved with respect to price (approximately $17/kg compared with an estimate of $34/kg).

In addition to Australian production, increasing volumes are coming from off-shore. In 2003, estimated production from Zimbabwe and China are 12 and 70-80 tonne respectively although some of the latter oil has been of substandard quality.

### Production requirements

The main production area is the north coast of NSW chosen because *Melaleuca alternifolia* is native to the region and consequently was the home of the bush industry. Significant plantings have also been made further up the east coast especially in far north Queensland where tea tree has been grown as a substitute crop for tobacco in the Mareeba-Dimbula district. More recently plantations have been established in western NSW, south-western WA and the Ord River area of northern Australia.

With plant variety and processing procedures optimised, the variable which farm management must maximise is leaf yield. Trees grow best with ample supplies of heat and moisture as provided by the tropical and sub-tropical climates of eastern Australia. Plants approach dormancy when soil temperature is below 17 °C and are susceptible to frost damage.

**Fig. 1.** Estimated price and production of tea tree oil in Australia over 20 years

**Key messages**

- Industry uses an Australian native plant
- Supply/demand seeking better balance
- Improved genetic material now available
Severe frost can cause extensive defoliation and kill some trees.

Plantations, except those in low rainfall areas, are only irrigated during the establishment phase. Plants have a poor regulation of water use and growth declines markedly as the soil begins to dry out. As trees are tolerant of wet conditions and need good water supplies, plantations are commonly situated in high rainfall districts (>1000mm/year) or where there are plentiful supplies of irrigation water. Growth is best on medium textured soils and plantations are often sited on alluvial flats.

**Varieties**

Tea tree oil is sourced from *Melaleuca* species rich in terpinen-4-ol, the bio-active ingredient. Although *M. linariifolia* and *M. dissitiflora* can give acceptable oils, most of the industry is based on the terpinen-4-ol rich chemical variety of *M. alternifolia*.

Whereas seed collected from bush plants has been used in the past for plantation establishment, improved seed, seed orchards and hence clonal material are now available. This has come about because of a long-term tea tree breeding project conducted by NSW Agriculture and the CSIRO and funded by the Rural Industries Research and Development Corporation (RIRDC) and the Australian Tea Tree Industries Association (ATTIA).

Some workers have selected superior trees and have used clonal methods to propagate large numbers of plants. This approach provides a quicker route to capture genetic gain at a higher cost per plant. The narrow genetic base for such an approach is of higher risk without the meticulous selection and testing of parent trees.

For seed collection, mother trees are usually selected on the basis of oil yield and composition. Progeny vary however because of very strong outcrossing during pollination. Also growth vigour is unknown unless a separate and time-consuming step of conducting yield trials is included before seed is sold. Consequently government and industry saw the need to fund a major plant breeding project which was based at the Wollongbar Agricultural Institute.

Beginning in 1993, improved types were selected for oil concentration and composition, growth and coppicing ability. The project released best provenance natural stand seed in 1997. Following the establishment of the first generation seedling and clonal seed orchards following yield, progeny and coppicing trials, improved seed became available in 1999. Yield trials on orchard seed have shown improvement of up to 91% over unimproved seed. The best material from these orchards, along with controlled crosses and clones has been incorporated into a second generation seedling seed orchard which is expected to yield seed giving even greater gains.
Cultural practices

Tea tree is grown as a perennial row crop and many of the husbandry practices are similar to those used for other row crops. One of the advantages of tea tree is that harvest time is not critical. At establishment, however, planning and procedures are of the utmost importance. Being a perennial crop, good establishment provides benefits over many years. For example, laser levelling is often used to optimise paddock drainage and facilitate flood irrigation. The design and depth of drains in areas with acid sulphate soils, as are common on the east coast, are also important. Good drainage also means access during all but the wettest periods. Timing is critical for weed and insect control and poor drainage can restrict these operations at critical times.

Direct sowing is not an option due to the minute size of the seed and poor survival rates. Seedlings are raised in nurseries and planted out at 10-16 weeks. Planting densities and configurations need careful planning. Densities of up to 35,000 trees/ha achieve full ground cover quickly after harvest and compete better with weeds by shading. Row spacing and configuration need to be planned with respect to the size of the tractors, mowers, cultivators, sprayers and harvesters likely to be used.

The first two weeks after transplanting are critical as seedlings have a poor competitive ability and the survival and vigour of adult plants is dependant on good husbandry during this phase. Weed control and adequate water are the most important factors during this time. Although irrigation becomes less critical from then on, weed control remains an important issue even in established plantations.

Nutritional requirements of tea tree are not well understood. Each harvest removes a large quantity of biomass and some return of nutrients is essential for long term productivity. Nevertheless, a number of trials have given small or no response to conventional fertilisers possibly because tea trees tap into soil nutrients below the rooting depth of previous crops. If so, the lack of fertiliser response should be viewed as a short-term condition. There are some indications that tea tree requires a slow steady supply of nutrients as can be obtained from organically bound nutrients. In a trial conducted in north Queensland, the addition of N, P, K fertilisers at four different rates enhanced the productivity of 6 year old trees that had been harvested 7 times. Although oil concentration was not affected (an anticipated result as oil concentration is known to be largely genetically controlled), biomass yields were increased by up to 50%. The estimated cost of fertiliser application however would not give any significant cash returns at present oil prices.

In NSW, the crop is ready for harvest after 18-24 months and then every 12 months thereafter. Although oil concentrations are highest in late summer, this is negated because regrowth is best after a spring harvest and hence month of harvest does not seem to affect oil yield. In north Queensland, harvest time can be reduced to 8-9 months because of the absence of the winter dormancy period. In practice however, yearly harvests are preferred because of tree deaths that occur during a post-harvest wet period.

A plantation then requires farm machinery suitable for row cropping along with specialised harvesting and steam-distillation equipment. Some producers pool their resources in a co-operative and use a single distillation unit. In some districts, harvesting and distillation is done under contract.

The oil yield from a plantation is dependant on both oil yield from the leaf and leaf yield from the plant. Target oil yields from unimproved seed should be in the 170-220 kg/ha range with occasional reported yields exceeding 300 or even 400 kg/ha. Yields from the new selections should make these higher yields...
commonplace with even higher yields expected.

**Pest and disease control**

Insect problems with tea tree result in reduced growth rather than the death of the plants. Most damage is done to young growth and the plant generally responds by re-shooting from dormant buds. The most important insect pests are pyrgo beetle (*Paropsisterna tigrina*), psyllids (*Trioza* spp.) which forms pits on the leaf and mites (*Eriophyoid* spp.).

The impact of these pests can be reduced by the presence of beneficial insects. Hence integrated pest management strategies need to be adopted to prevent broad-acre spraying that also removes the beneficial insects. A list of pesticides currently registered for use with tea tree is available from the Australian Pesticides and Veterinary Medicines Authority.

There are no known serious diseases of tea tree.

The growth of plantation weeds can be prolific, especially in the high rainfall coastal regions.

Research has shown that tea tree is sensitive to weed competition both at the seedling and post-harvest regrowth stages due to competition for light, moisture and nutrients. Weeds can reduce leaf yields by 30-50% during regrowth periods if left unchecked and some interfere with harvesting. Control strategies include managing them for 12 months prior to establishing a plantation. Pre-emergent herbicides applied to the bare ground at planting time are strongly recommended for control for up to 12 weeks. Managing the crop to optimise tree growth will also minimise weed problems. Recommended methods for controlling weeds include inter-row cultivation, mowing, mulching, perennial ground covers, grazing, flame cultivation and herbicides.

**Harvest and post harvest**

A heavy duty forage harvester is used to cut the stems close to ground level, chop the stem material and feed it into a transportation bin. The bin can also be designed as the distillation vessel by incorporating perforated steam inlet pipes into the base and a sealable lid with an outlet for a condenser that can be attached when the bin is transported back to the distillation facility. Steam injected from a separate steam boiler then vaporises the oil which is then condensed and separated from the condensed water by flotation.

The farm-gate product must meet the buyer’s quality control criteria which are normally based on at least one of an increasing number of national or international standards. The International Standards Organisation (ISO), the European Pharmacopoeia (EP) and World Health Organisation (WHO) have produced
international monographs and Australia, France and Germany have published national standards.

As long as producers plant the right cultivars and distil the leaf material using conventional stills, the quality of the resultant oil is guaranteed as oil quality is highly heritable. Terpinen-4-ol, the active ingredient, must be present at between 30 and 48% and cineole at 0-15% so as to avoid confusion with the cineole variety oil which does not have equivalent bioactivity. Market forces favour oils with tighter limits and suggest that oils with more than 38% terpinen-4-ol and less than 5% cineole are desirable for the trade.

The oil has a long shelf-life if stored appropriately to suit market considerations. Clean, inert containers, sealed to exclude water vapour, flushed with nitrogen to retard oxidation, are desired. Stainless steel is commonly used, not only for storage containers but for all distillation vessels and tubes that contact the oil.

Oil quality is determined by Gas Chromatography for each batch to determine the chemical composition of the oil for any potential buyer. There are numerous registered laboratories able to provide the appropriate analysis and issue a quality control certificate. More sophisticated tests are available (eg full ISO standard, peroxide value, chiral column analysis) but not generally required at the first point of sale.

Financial Information

Tea tree oil has been classed as a high return crop. Establishment costs are so variable that it is not possible to give an estimate.

Whilst, plantations are expensive to establish, the plant’s perennial habit and the value of the oil when the price was high, gave high profits.

Now with prices about one third of what they were ten years ago, “returns for capital invested” tables need to be extrapolated to allow for the lower price.

One such revision is shown in Table 1. At times when prices are low, such a table confirms the value of a breeding project which has the ability to double oil yields.

### Key references


### Table 1. The effect of oil yield and price on return (%) on capital

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(extrapolated from Murtagh, 1991)
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Introduction

Durian (*Durio zibethinus* Murr.), is considered the “King of Tropical Fruits” by most Asian and smitten Western consumers. The fruit is highly esteemed and widely grown throughout the wet tropics of SE Asia. The fruit is considered a delicacy and aphrodisiac by many dedicated consumers but is also renowned by some Europeans for its complex flavour and odour interactions which have been described as akin to eating custard in the lavatory. The durian tree is a member of the Bombacaceae family which includes economically important members such as; balsa wood, kapok and pachira. Forest trees in the same family include Australia’s northern Baobab (*Adansonia gregorii)*.

The centres of production in decreasing order are Thailand, Malaysia, Indonesia, Vietnam and Philippines. Durian was introduced into Australia in the early sixties and clonal material was first introduced in 1975 (Watson 1988). Over thirty clones of *D. zibethinus* and six Durio species have been introduced into Australia (Lim, 1997, Zappala et al. 2002). In Australia an industry has established along the wet tropical coast of north Queensland from Cape Tribulation (16°S) to Tully (18°S). There are 30 growers with 8,000 trees. A smaller, but geographically concentrated industry, has developed in the rural environments around Darwin (12°S). There are 6 growers with approximately 5,000...
trees. Current Australian fruit production varies from 20 to 50 t/annum with a maximum value of $0.5M.

The Australian industry strengths include:
- a world class gene pool introduced by government agencies and dedicated growers
- out of season production with neighbouring Asian production areas
- a dedicated domestic consumption base for Australian grown fresh fruit
- growing areas are currently free of the durian fruit borer, a major pest in Asian orchards.

Constraints to industry development include:
- a stall in investment by current and potential growers due to the recent (2001) approval by Biosecurity Australia to allow imports of fresh fruit from Thailand. NB. The approval has not been acted on by Thailand at the time of writing.

World production is estimated at 2.0 million t annually and Thailand the major producer is a major exporter of both fresh and frozen fruit to Asian metropolises such as Singapore and Hongkong and whole frozen fruit to USA, Australia and Europe (Subhadrabandu and Kesta, 2001). Malaysia and the Philippines, although major producers of durian, are reported to import fresh fruit from Thailand (Table 1).

The main Australian consumer demand is from ethnic Asians who are located in Sydney, Melbourne and Brisbane. In the growing regions fruit is commonly available, during the season (Table 2), for sale in local fresh fruit and vegetable markets in Cairns and Darwin. Many fruit are pre-ordered by friends and acquaintances of the growers. Growers report an increasing demand for fresh fruit from European converts. Current fruit prices vary from $8 to $12/kg depending on cultivar and availability. Semi processed fruit,

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**Markets and marketing issues**

Current Australian production, from 20 to 50 t/annum with a maximum value of $0.5M, is miniscule. Australian tree number statistics (13,000 trees) and conservative production (50 fruit/tree at 2.5 kg/fruit) and price estimates ($6.50/kg) suggest that by 2010 the industry could produce 2,000 t valued at $12M from 130 ha.

The main Australian consumer demand is from ethnic Asians who are located in Sydney, Melbourne and Brisbane. In the growing regions fruit is commonly available, during the season (Table 2), for sale in local fresh fruit and vegetable markets in Cairns and Darwin. Many fruit are pre-ordered by friends and acquaintances of the growers. Growers report an increasing demand for fresh fruit from European converts. Current fruit prices vary from $8 to $12/kg depending on cultivar and availability. Semi processed fruit,
Durian aril packed in punnets, has sold for $20/kg. Watson (1988) suggested that the domestic market could absorb production from 100 ha of durian.

Approximately 1,000 t of whole frozen fruit is imported from Thailand each year. The frozen fruit is distributed through retail shops specialising in Asian foods. Retail prices vary from $3.00-6.00/kg. The recent (2001) approval by Biosecurity Australia to allow imports of fresh fruit from Thailand (not acted on by Thailand at the time of writing) may dramatically change the market in Australia. Thailand is able to produce fresh fruit from March until September, due to climatic variation from southern to northern growing areas (Subhadrabandu and Kesta, 2001).

The season can be further extended by the use of growth regulators such as Paclobutrazol. Fresh fruit could be landed in Australia from February to October, hence eliminating any seasonal advantage Australian producers may have had. On the other hand a regular supply of fresh durian on Australian markets may help increase demand for fresh product and grow the market. Australian producers may still have a relatively competition free market window from November to March which takes into account the bulk of production.

**Production requirements**

The durian is a tree native to the wet tropics of Peninsular Malaysia, Sumatra and Borneo (Brown, 1997) and is now grown extensively throughout SE Asia (Macmillian, 1991, Subhadrabandhu and Ketsa, 2001). Nanthachai (1994) reports that durian in their native environment experience an average temperature range from 24-30°C and high rainfall from 1,600 – 4,000 mm/year. Subhadrabandhu and Ketsa (2001) suggest that the most favourable regions for commercial durian cultivation as being within 12° north and south of the equator, at altitudes of up to 700 m which experience a temperature range from 22°C to 32°C and an annual rainfall of 2,000 to 5,000 mm preferably distributed over six to eight months of the year. High humidity for most of the year is also essential. The production areas in Australia, Darwin and the wet tropical coast of far north Queensland do not have a climate that matches the ideal (Table 3). Darwin has a long dry season where irrigation is essential for at least 8 months of the year while the wet coast of far north Queensland experiences a cool winter well below that experienced in durians native growing area.

Durians can be grown on a range of soils with the correct nutrient and water management. Optimum growth and fruiting occurs on rich, deep, well drained sand to clay loams which are rich in organic matter. Excellent drainage is a most essential criteria as durian roots are susceptible to root rot. Clay soils with poor drainage should be avoided, unless extensive drainage and mounding works are incorporated in the orchard plan.

Vietnamese farmers are successfully growing durian on water inundated delta soils through the use of extensive mounding. In Australia durian is successfully grown over a range of soil types Ferrosols (Krasnozems and Euchrozems) and Brown Kandosols (Yellow earths). Soil

| Table 3. Climate comparisons between SE Asian and Australian growing areas |
|---|---|---|---|---|---|
| **Rainfall (mm/annum)** | **Average Evaporation (mm/day)** | **Months experiencing water deficit (evaporation exceeds rainfall)** | **Mean annual maximum temperature (°C). and monthly extremes.** | **Mean annual minimum temperature (°C) and monthly extremes.** |
| Chanthaburi, Thailand (12.36°N) | 3015 | 4.3 | 6 | 31.5 Apr – 33.4 Aug – 30.4 | 22.6 Aug – 24.0 Jan – 19.6 |
| Jakarta, Indonesia (6.11°S) | 1823 | 2.8 | 4 | 31.9 Oct - 32.9 Jan - 30.1 | 23.5 May – 24.0 Jul – 22.9 |
| Darwin, Australia (12.25°S) | 1664 | 7.4 | 8 | 31.9 Oct – 33.1 Jul – 30.4 | 23.2 Nov – 25.3 Jul – 19.3 |
| South Johnstone, Australia (17.36°S) | 3308 | 4.3 | 4 | 28.1 Jan – 31.2 Jul – 23.8 | 19.0 Feb – 22.5 Jul – 14.4 |

Durian
pH (water) is generally acidic and can be as low as pH 4 in sugarcane growing regions.

**Varieties**

Durian seeds were first imported from Malaysia, Indonesia and Thailand in the early 70's (Watson 1988). As growers gained a taste for and commercial interest in Durian, budwood and grafted trees were imported. Approximately 40 clones of *Durio zibethinus* and seven other *Durio* species have been introduced into Australia (Lim 1997).

Varieties that are showing promise and being grown in commercial orchards include Monthong (Thailand), Luang (Thailand), D24 (Malaysia), D2 (Malaysia), Hew 2 and 7 (Malaysia), Hepe and Permasuri (Indonesia). A number of local seedling selections have been made and include Limberlost, Jacki and Chong. A recently completed evaluation of Durian germplasm, carried out in north Queensland, suggests that several other *D. zibethinus* clones (Hepe, D 175, DPI Monthong, Hawaiain Monthong, D190 and Kradum Thong) and *D. macrantha* should also be considered for commercial production in north Queensland (Zappala et al. 2002).

In Australia durian clones are chiefly produced by budding or cleft graft techniques. Clonal production remains a relatively specialised task and further information is available from the following publications (Zappala et al. 2002; Lim et al., 1992, Subhadrabandhu and Ketsa 2001).

**Cultural practices/agronomy**

Site preparation will vary depending on growing location. Windbreak trees are considered essential particularly in areas prone to prevailing winds. Species used include Jak fruit, which can be used to contribute to orchard income in the early years (Hassall and Associates, 2000). Orchard spacing can range from 6 to 10 m within the row and 8 to 12 m between rows, depending on variety selected, growing environment and land availability. Durian trees can grow to 20 m tall with a diameter of 8–10 m within 15 to 20 years. Deep ripping along and across the intended tree lines is essential in some soils. Mounding should be carried out where water logging may be an issue and should be considered an essential input in the high rainfall growing areas of north Queensland.

The use of clean nursery stock from a recognised nursery which produces advanced planting material (trees six to twelve months old) is recommended. Lim (1997) recommends that orchards consist of mixed clonal stands to reduce the incidence of self-incompatibility. Where possible varieties should be planted within the same row to allow control of irrigation and hence flowering. Newly planted trees should be protected with shade cloth surrounds or alternatives such as dried palm fronds. Young trees in the NT and Queensland may benefit from the use of plastic covers during the cooler winter months. Trees should be mulched with non-compacting straw (eg. sugar-cane or spear grass), which remains well aerated under wet conditions. Application of regular small amounts of a well-composted chicken or alternative manure may be advantageous.

Fertiliser management research and information is limited and durian is managed similarly to many other tropical fruits with growers adopting strategies to suit their orchards. Based on the
fertiliser regime used at the Centre for Wet Tropics Agriculture, South Johnstone, a 10 year old tree would receive a total of 5.0 kg of 13:2.2:13.3:18.7 (N:P:K:S) and 4.0 kg of Dolomite, which is equivalent to 650 g Nitrogen, 110 g Phosphorous, 665 g Potassium, 935 g Sulphur, 800 g Calcium and 320 g Magnesium.

A foliar fertiliser spray to run-off, consisting of iron sulphate and zinc sulphate, each at a concentration of 1 g/litre four times per year (January, April, August and November) is also added. Appropriately less fertiliser should be applied evenly throughout the year for young vegetative trees. Once trees reach reproductive maturity (5 – 7 years) the bulk of NPK should be applied from fruit set to just after harvest (Lim, 1997). Tentative leaf nutrient guidelines were developed for NT growers by Lim (1997) and work is currently underway in north Queensland.

Irrigation is essential particularly during plant establishment and during the long dry season as experienced in the NT. Irrigation rates of up to 2,000 L/tree/week for trees 8 m in diameter from September to November have been recommended in the NT. Subhadrabandhu and Ketsa (2001) suggest that frequent watering in small amounts is more beneficial than applying large amounts of water infrequently.

The use of soil moisture monitoring devices eg tensiometers and moisture probes, is recommended. These devices assist in determining irrigation rates and scheduling.

First fruit can be expected five to seven years following planting of clonal material, with regular production occurring from 10 years and onwards. Withdrawal of irrigation for 10 to 14 days is reported to assist flowering. Heavy rain post-flowering is associated with flower drop and poor pollination and subsequent fruit set.

A range of insect and mite pests are found in Durian orchards in northern Australia (Zappala et al., 2002). The banana spotting bug (Amblypelta lutescens) or fruit spotting bug is considered to be the most serious, causing fruit drop and damage due to its feeding habit (sucking) from early fruit set through to fully developed fruit. Flesh eating beetles, in particular Rhyparida sp. can cause serious damage to young trees during periods of active leaf flushing. Green ants (Oecophylla smaragdina) are known to nurture colonies of mealy bugs (Planococcus citri), which can cause damage to developing flowers, young and developing fruit.

In the NT the larvae of longicorn beetles (Acalolepta mixus and

### Table 4: Comparison of durian leaf nutrient levels for the Northern Territory, Queensland and Malaysia

<table>
<thead>
<tr>
<th>Durian leaf analysis</th>
<th>N %</th>
<th>P %</th>
<th>K %</th>
<th>S %</th>
<th>Ca %</th>
<th>Mg %</th>
<th>Na %</th>
<th>Cl %</th>
<th>Mn mg/kg</th>
<th>Fe mg/kg</th>
<th>Cu mg/kg</th>
<th>Zn mg/kg</th>
<th>B mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durian (Innisfail region) Av.</td>
<td>1.95</td>
<td>0.24</td>
<td>1.53</td>
<td>0.24</td>
<td>1.59</td>
<td>0.70</td>
<td>0.04</td>
<td>0.02</td>
<td>69.52</td>
<td>57.35</td>
<td>8.06</td>
<td>11.95</td>
<td>58.96</td>
</tr>
<tr>
<td>Durian (Innisfail region) stdev</td>
<td>0.23</td>
<td>0.05</td>
<td>0.40</td>
<td>0.05</td>
<td>0.37</td>
<td>0.09</td>
<td>0.01</td>
<td>0.01</td>
<td>30.18</td>
<td>18.45</td>
<td>1.71</td>
<td>2.57</td>
<td>18.65</td>
</tr>
<tr>
<td>Malaysian recommended range (leaf age 4-6 months) min</td>
<td>1.80</td>
<td>0.12</td>
<td>1.60</td>
<td>0.16</td>
<td>0.90</td>
<td>0.25</td>
<td>na</td>
<td>na</td>
<td>25.00</td>
<td>50.00</td>
<td>6.00</td>
<td>15.00</td>
<td>15.00</td>
</tr>
<tr>
<td>Malaysian recommended range (leaf age 4-6 months) max</td>
<td>2.30</td>
<td>0.25</td>
<td>2.20</td>
<td>0.25</td>
<td>1.80</td>
<td>0.50</td>
<td>na</td>
<td>na</td>
<td>50.00</td>
<td>150.00</td>
<td>10.00</td>
<td>40.00</td>
<td>80.00</td>
</tr>
<tr>
<td>NT Standards (TK Lim, 1997) min</td>
<td>1.58</td>
<td>0.18</td>
<td>1.48</td>
<td>0.17</td>
<td>1.11</td>
<td>0.25</td>
<td>0.01</td>
<td>0.05</td>
<td>6.25</td>
<td>15.02</td>
<td>5.82</td>
<td>11.92</td>
<td>33.29</td>
</tr>
<tr>
<td>NT Standards (TK Lim, 1997) max</td>
<td>1.98</td>
<td>0.22</td>
<td>1.96</td>
<td>0.22</td>
<td>1.88</td>
<td>0.50</td>
<td>0.09</td>
<td>0.07</td>
<td>27.65</td>
<td>30.86</td>
<td>12.47</td>
<td>14.64</td>
<td>38.52</td>
</tr>
</tbody>
</table>
Platyomopsis pedicornis) has been noted to cause severe damage to young trees and mature trees following pruning. Durian, like many other minor fruit crops, has a distinct lack of registered pest control chemicals. Minor use permits, which expire regularly, are a feature of the industry.

Durian die-back, is the major threat to the viability of the industry. This generally occurs on mature fruit-producing trees. Symptoms include, initial leaf yellowing and leaf loss from the top of the canopy, with further loss of leaf occurring through the canopy at varying rates. New shoots may appear following initial severe defoliation, but further development and growth is unusual. Tree death generally occurs in four to twelve months from the initial onset of symptoms.

The soil borne pathogen Phytophthora palmivora was the major pathogen implicated as it was regularly isolated from rotten feeder roots, collar rots and rotting fruit. It is the known cause of root death, stem canker and fruit rots and is reported to be a major cause of tree loss in commercial orchards in SE Asia (Lim 1990).

Work in north Queensland as part of an ACIAR funded project has shown that the fungal pathogen Pythium vexans is also implicated in tree decline in north Queensland. Regular use of the chemical potassium phosphonate (Fosject®), only effective against P. palmivora, is part of the integrated program to control durian decline.

It is recommended that young trees be sprayed regularly with the phosphonate fungicide while older trees may benefit from trunk injection with potassium phosphonate.

Tree decline and death has continued to occur in north Queensland despite the input of phosphonate either via foliar spray or injection. Other diseases of less economic importance include leaf blight (Colletotrichum gloeosporioides), tip die back (Pusarium sp.) and fruit rot (Lasiodiplodia theobromae, Erwinia spp.).

Fertiliser and irrigation management and its possible interactions with, tree productivity and cultivar/rootstock susceptibility to dieback deserves further investigation. As an interim measure growers are recommended to begin a leaf and soil nutrient monitoring program and to fertilise in small amounts regularly rather then a few infrequent large doses which may affect the delicate balance in soil micro flora.

Irrigation management can also have a major impact on root rot development. Moisture stress can increase the susceptibility of roots to infection, and over-watering can increase the severity of the disease. Mulching of trees, during the drier months, is highly recommended.

Exposed locule of durian showing the creamy aril (flesh) that surrounds the seed

Harvesting and postharvest handling

In Australia growers generally pick ripe fruit after they have dropped or when the peduncle (fruit stalk) begins to swell and split indicating that fruit drop is imminent. Picking fruit at this stage results in a full flavoured and odoriferous fruit, preferred by consumers who developed their taste for durian in Malaysia and Indonesia. Mature, dropped fruit tend to have a short shelf life and the pericarp (skin) will split open commencing at the fruit tip within 2 to 3 days. The shelf life of intact fruit can be lengthened by cold storage at 5 – 10°C. Dropped fruit often suffer damage on falling that further reduces the shelf life.

Durian is a climacteric fruit like mango and papaya, that is, it will continue to ripen if picked at a hard mature stage. Harvesting of fruit prior to the ripening process commencing results in fruit with an extended shelf life, however, fruit maturity plays an important role in the development of favour when ripe. Durian postharvest research is the most advanced in Thailand where new and
Durian developing export markets require ever more innovative practices to ensure sound good quality fruits reach distant markets. Subhadrabandhu and Ketsa (2001) report that in Thailand a range of techniques are utilised to determine harvest maturity. These include:

- calendar days from full bloom; Variety and climate dependent
- fruit colour; as the fruit approach maturity the colour of the base of the spines from dark to light green or brown
- sound; mature fruit give off a hollow sound when the spines are tapped
- spines; become more flexible and can be more easily pushed inwards
- odour; the fruit emits a characteristic odour as it begins to ripen.

Thai postharvest techniques for export fruit include cold and modified atmosphere storage and waxing to prevent water loss.

In Australia mature, sound, odour free fruit are packed in cardboard cartons and dispatched to southern markets, via airfreight, where ripening continues. Where developing fruit odour may be a problem a sealed polystyrene carton is used. In addition CSIRO has recently developed an odour proof packaging for this product. This requires a double packing technique, utilising a plastic wrap around the inner carton, which is then repacked into an outer carton.

The aril (flesh) of durian fruit can be susceptible to wet or hardcore at certain times of the year. Industry observations indicate wet or hard core condition of the aril is caused by excessive rainfall or other climatic variations. Both of these serious flesh conditions can result in the aril becoming inedible. To minimise the rejection of fruit in southern markets, some growers have minimally processed fruit by extracting the aril and packaging it in cling wrapped Styrofoam trays. This technique requires a sound cold chain to ensure that the aril reach southern markets in a sound condition.

Financial information

Financial analysis of a durian orchard, based on information provided by a north Queensland grower, performed by Hassall & Associates, indicates that durian production in north Queensland has a 25% internal rate of return (Hassall and Associates, 2000). Establishment costs for a 10 ha orchard are approximately $330,000 with recurrent input costs of $232,000/annum.

The investment break even period is 11 years. These figures were based on the assumption that Thai fresh durians would not be allowed into Australia. Biosecurity Australia has sanctioned the imports of fresh fruit, but to date none have occurred.

Tree dieback, should it occur, would impact heavily on the economic performance of a durian orchard. In a number of cases major tree losses have occurred in producing orchards once they reach 12 to 15 years of age.

Acknowledgement

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References


About the author

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Key message

- Durian prefers a true tropical climate
- Tree dieback, particularly in mature trees, can occur rapidly, especially in wet years
- Durian is for experienced horticulturists only
- Thai fresh fruit can be imported into Australia

Key statistics

- Estimated total durian production in Australia in the 2002/03 season was 35 t with a value of $350,000
- During this season, 10 t was produced in the Northern Territory and 25 t in Queensland

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Introduction

The lychee (*Litchi chinensis* Sonn.) and longan (*Dimocarpus longan* Lour.) are two of the most important commercial species of the Sapindaceae family, which also includes rambutan (*Nephelium lappaceum* L.). Lychee and longan are grown for their value as fresh fruit and are both believed to be native to North Vietnam and southern China where these species can still be found in remnant forests.

It is assumed that Chinese immigrants introduced lychee and longan seed into Australia during the gold rush in north Queensland in the late 1800’s. Lychee marcotts (*cv*. Tai So and Wai Chee) were introduced from China in 1930 by the Wah Day family who had settled in Cairns, north Queensland. Commercialisation of lychee and longan began in the 1970s and production has continued to expand despite many challenges.

China, Vietnam, India, Taiwan and Thailand are the major lychee producers with production areas in 2002 reported to be 600,000, 62,000, 56,000, 11,900 and 20,000 ha respectively. Longans are predominantly grown in China, Thailand, Vietnam and Taiwan with production areas in 2002 reported to be 440,000, 82,000, 64,000 and 12,000 ha respectively. Other minor production areas for both crops include, Malaysia, Indonesia, Australia, USA, South Africa, Madagascar, Israel,
Central America, Mauritius and Reunion Island produce lychee. Australia is a relatively small producer of lychee with 4,000-6,000 t produced by 250 commercial growers. Current longan plantings are reported to be in the vicinity of 45,000 trees and the annual production of 300-500 t is valued at $2.0M.

Lychee is difficult to grow and yield consistently with irregular flowering and premature fruit drop being major problems. Longan is not as difficult to crop, however small fruit size and limited domestic and export markets are major hurdles to industry expansion. Both crops require considerable horticultural management skills.

Markets and marketing issues

Lychee and longan are principally traded as fresh fruit on the domestic market. Australia produces 4,000-6,000 t of lychee. Growing regions are spread 2,100 km along the east coast and with variation in cultivars allows the season to be spread from November/December until February/March. The bulk of production is consumed on the domestic market (Sydney and Melbourne). Approximately 20-35% of the lychee crop is exported with major markets being China (Hong Kong), Singapore and Europe. Current longan production varies from 300-500 t annually and is valued at $2.0M.

Production is centred on the Atherton Tablelands in north Queensland but occurs in small areas along the east coast of Queensland into northern NSW. Since the introduction of a flowering stimulant (potassium chlorate) in longan, Australian longan producers have lost export markets based on counter-seasonal production advantages.

The availability of longan on the domestic market has spread from six to nine months of the year.

The Australian market chain for both crops is made up of growers, marketing groups, agents, Asian wholesalers, boutique fruit retailers and supermarkets. Buyers are clearly demarcated, the bulk of sales are to ethnic Vietnamese and Chinese who are reported to be the main consumers while consumption by the Caucasian mass market via supermarket chains is still relatively small due to low consumer awareness, poor retail shelf life and high retail prices.

The recent proposal by Biosecurity Australia to allow imports of lychee and longan from China and Thailand will significantly alter the current market volumes and prices. The Australian longan industry will face direct competition from year round production in Thailand and to a lesser extent in China. The Australian lychee industry will still maintain its counter seasonal advantage and off-season imports may assist the development of the domestic market.

Access for Australian lychees into China during the lucrative Chinese New Year festive season may improve.

### Table 1. Lychee average wholesale prices $/5 kg carton for large seeded and small seeded varieties at the Sydney market and main supply region

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan Qld</th>
<th>Feb Qld/NSW</th>
<th>Mar Qld</th>
<th>Apr NSW</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep Qld</th>
<th>Oct Qld</th>
<th>Nov Qld</th>
<th>Dec Qld</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>24(45)</td>
<td>23(37)</td>
<td>23(35)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>40(75)</td>
<td>25(39)</td>
</tr>
<tr>
<td>2000</td>
<td>19(29)</td>
<td>22(31)</td>
<td>16(27)</td>
<td>14(23)</td>
<td>14</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>nd</td>
<td>nd</td>
</tr>
<tr>
<td>2001</td>
<td>22(40)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>37(69)</td>
<td>23(35)</td>
</tr>
<tr>
<td>2002</td>
<td>29</td>
<td>26</td>
<td>35</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>74</td>
<td>53</td>
<td>36</td>
</tr>
</tbody>
</table>

### Table 2. Longan average wholesale prices and (highest/lowest price) ($/kg) at Sydney markets

<table>
<thead>
<tr>
<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>12</td>
<td>7</td>
<td>6</td>
<td>12/3</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>7.5</td>
<td>5.6</td>
<td>5.1</td>
<td>-</td>
</tr>
<tr>
<td>2002</td>
<td>7.9</td>
<td>4.8</td>
<td>6.7</td>
<td>10/4</td>
<td>9.8</td>
<td>16.9</td>
<td>12.8</td>
<td>7.5</td>
<td>5.6</td>
<td>7.5</td>
<td>8/7</td>
<td>-</td>
</tr>
</tbody>
</table>

Lychee and longan
Production requirements

The native environment of lychee and longan is sub-tropical with a period of relatively cool weather (12-20°C) required for flower initiation. The climatic requirements for flowering and subsequent fruit set vary with cultivars.

There are a number of cultivars that have the ability to flower more regularly in warmer environments. However, areas that have a cool winter followed by relatively humid and warm spring/summer periods are preferred.

Hot dry weather during fruit development can be associated with fruit drop, browning, splitting and poor fruit colour development.

Approximately 50% of Australia’s lychee production occurs north of the Tropic of Capricorn (Mackay, Ingham, Cardwell, Mossman and the Atherton Tablelands). The remaining production occurs in central Queensland (Rockhampton, Bundaberg, Childers), southern Queensland (Gympie, Nambour and Beerwah) and northern NSW as far south as Coffs Harbour. Longan production occurs primarily on the Atherton Tablelands with small areas of production along the east coast of Queensland to northern NSW.

Flat to undulating areas are preferred due to the high level of mechanisation required for orchard management and the requirement for netting during the fruiting season to control winged vertebrate pests.

Observations indicate that lychee and longan thrive on a wide variety of soil types as long as drainage is good enough to prevent waterlogging and supplementary irrigation is available during prolonged periods of dry weather. Lychee and longans trees thrive best on deep clay loam soils and prefer a slightly acid (pH 5.0 to 6.5) soil. Soil types that support lush growth may be counterproductive to regular fruit production, particularly in environments where a check in growth caused by either dry or cool conditions does not occur.

Irrigation is required for commercial fruit production. Water requirements for mature orchards vary from 0.6 ML/ha to 5.0 ML/ha depending on growing location and average annual rainfall. Water quality, although not an issue in most growing areas, should be low in dissolved salts (< 600 microsiemens/centimetre).

Varieties/cultivars

There are over 40 cultivars of lychee and 20 of longan in Australia. Both industries have a collection of preferred commercial cultivars. For lychee the cultivars Bosworth 3 (syn. Kwai Mai Pink) and Tai So are the predominant cultivars throughout the production area with Tai So becoming less important in southern growing regions.

In northern Australia the early cultivar Sony Tung and early small seeded cultivar Fay Zee Siu are preferred for new plantings while in southern growing areas the small seeded Salathiel and late cultivar Wai Chee are being planted to extend the growing season. Recent imports of new cultivars from China and the potential release of material from a CSIRO breeding project may impact on the commercial cultivar mix.

The major longan cultivars are Kohala, Chompoo and Biew Kiew. The Florida selection Kohala is planted due to its earliness, however as the latter two cultivars become available the markets prefer them. The use of chemicals for out of season flower induction may lead to a change in cultivar mix.

Both lychee and longan are propagated vegetatively by marcotting (air layering). Plants are readily available from commercial nurseries and are also commonly produced on-farm.
Cultural practices

Protected areas, free of prevailing winds with no topographic limitations and well-drained soils are preferred for lychee and longan orchards. As the crop is long lived (25 years + commercial life) and netting will be required, it is important that careful planning of orchard layout is undertaken. Lychee growers should consult the Queensland Departments of Primary Industries Lychee Agrilink (Menzel et al., 2002). The manual comprehensively covers land preparation, planting and tree management issues.

Lychee and longan were traditionally planted at low densities (70 to 100 trees/ha) with inter-row and intra-row spacing varying from 10 m to 12 m. To accommodate netting and pruning practices both crops are increasingly being planted at higher densities.

In north and central Queensland new longan and lychee plantings at 6 m between rows and 2.5 m within rows are being explored (666 trees/ha). Standard densities are in the range of 150 to 200 trees/ha. Tree row direction is best running north to south, particularly from central Queensland south, however, terrain and other issues needed to be taken into account. Following planting of young potted trees; mulch, irrigation and individual tree wind/shade covers should be applied. A few growers have successfully planted marcotts directly from the tree to the paddock, however, if climatic conditions are harsh, high losses can be expected.

Young trees in the first two to three years following planting benefit from regular small applications of compound fertilisers high in nitrogen. Fertiliser applications immediately post planting should be avoided, particularly for lychee, until roots begin to explore beyond the pot. Application of fertilizer needs to correspond with differing needs at various stages of the growth cycle.

Diczbalis (2002) reported that for a longan crop yielding 25 t/ha the macronutrient inputs per hectare required to replace total nutrient loss are 118 kg N, 109 K, 45 kg Ca, 26 kg P, 11 kg Mg, 7.2 kg S. Similarly a 10 t/ha lychee crop would require the following macronutrient nutrient replacement, 22 kg N, 6 kg P, 23 kg K, 3 kg Ca and 4 kg Mg. Micro nutrients such as zinc, iron and boron may need to be applied regularly. Fertiliser management can be enhanced by the use of soil and leaf analysis (early panicle emergence) and nutrient replacement based on nutrient removal plus losses due to leaching, runoff or volatilisation.

Irrigation is required for all commercial orchards and understory systems are generally used. Drip irrigation is increasingly being used particularly in association with high-density orchards. In dry growing areas young trees will have to be watered regularly to ensure growth is not restricted and particular care is required from flowering to harvest to ensure that irrigation inputs are sufficient to allow maximum fruit numbers and size to develop.

Tree pruning is a vital management practice and starts within the first twelve months after planting to establish the preferred tree shape. Young lychee and longan trees need to be pruned to develop a strong tree structure that will minimise damage caused by wind and maximise the fruit bearing area. The pruning strategy used will depend on the growth habit of the variety. Removal of weak branches, tip pruning (particularly in long-limbed cultivars) and skirting are all required to establish the canopy.

Bearing trees require both structural and strategic pruning. Structural pruning is required to further develop the canopy structure and to set the desired tree height, internal branch...
thinning and skirting form part of this activity. In lychee strategic pruning is based on the use of mechanical pruning machines to prune the outer surface of the tree, at a specific time, based on growing location (latitude) and cultivar so that the synchronous development of new vegetative flush will promote new terminal bud movement in mid winter when the likely hood of average temperatures below 20°C is at its highest, thus maximising flowering.

Lychees and longans are terminal flowering trees, that is; the floral panicle develops on relatively young wood. A number of growers in Australia are currently using mechanical pruners, following harvest, to reduce tree size and shape trees to allow machinery access. The effect of mechanical pruning on tree productivity depends on the time of pruning and the amount of wood removed. In situations where relatively heavy pruning has taken place, flowering may be delayed to the following season. Internal pruning is required to remove water shoots; pest and disease infected shoots and dead branches, along with crossing branches.

**Pest and disease control**

Winged vertebrate pests (birds and fruit bats) are the main threat to fruiting lychee and longan trees in all growing regions. Growers must have the ability (financially and physically) to net trees as fruit approach maturity. Netting systems vary from simple throw-over arrangements to permanent enclosures, depending on growing region and management preferences. Excellent developments in throw-over systems have occurred in the last few years.

The Australian lychee industry has been well serviced by entomology and pathology expertise. Invertebrate pests of the greatest economic importance include Erinose mite (*Aceria litchi*), Macadamia nut-borer (*Crytophlebia ombrodelta*), fruit spotting bug (*Amblypelta lutescens* and *A. nitida*), flower caterpillars (*Platypeplus aprobola* and *Isotenes miseran*) and fruit piercing moths (*Eudocima salamina* and *Othreis fullonia*). Leaf swarming beetles (*Rhyparida* spp. and *Monolepta* sp.), scale (*Coccidae*) and assorted ants and mealybugs can also be problematic. Current control strategies are based on routine spraying or when growers become aware of an insect outbreak. Regular use of monitoring as part of an IPM strategy is still relatively rare, however, an increasing number of growers are utilising the services of commercial “bug checking” services to improve strategic spraying.

In Australia lychee diseases are generally not considered to be a major issue. Sudden tree dieback continues to occur and the causes are not well understood. However, the relatively minor nature of the problem suggests that little effort will be applied to understanding the problem in the near future. A disease that is rapidly becoming a major problem is “Pepper Spot” caused by *Colletotrichum gleosporioides*. The name describes the symptoms, which occur as small, slightly raised dark spots on lychee leaves and petioles and most importantly on fruit. The disease was first noticed and recorded in 1993 on lychee orchards in south east Queensland but is now commonly observed in coastal lychee orchards from far north Queensland to Byron Bay in north coastal New South Wales (Drew and Drew, 2001). Pepper Spot symptoms on fruit render the fruit unsaleable and severe losses have been reported in some growing districts and seasons.

Longan trees and fruit experience a similar pest and disease range as lychee but are not susceptible to Erinose mites and to “Pepper Spot”. For both crops the pest and disease complex changes with growing region.
**Harvesting and post harvest handling**

Lychee and longan must be harvested when ripe, as they do not continue to ripen after harvesting. Lychees are best harvested when fruit colour is appropriate to the cultivar and the protuberances on the skin are flattened. Most importantly, the fruit must taste ready to eat with the correct balance of sugar to acid. Fruit colour changes with cultivar and fruit of the cv. *Fay Zee Siu* are often still partially green when at the best eating stage. Longan are judged mature when they have reached sufficient size to be classed as first grade fruit (28 mm diameter +) and flavour. Care must be taken as the fruit can quickly become bland if picked over-mature.

Lychees are picked individually or by the panicle depending on flower synchrony and market prices. Picking should be restricted to the early hours of the morning to ensure fruit are fully turgid (hydrated). Picking during the heat of the day results in soft fruit that rapidly lose their attractive colour. Harvested fruit, rapidly lose water and start to dry out and brown.

Management systems should be in place to ensure that picked fruit are kept moist and rapidly transferred back to the shed. Handling systems differ depending on management preference. In north Queensland most growers “hydro-cool”, that is soak fruit in cold water (5 to 12°C) prior to destalking, grading and packing. In South East Queensland there is a mixture of practices with a preference for the use of “forced air” systems post packing to cool fruit. Either way, fruit should be free of surface moisture prior to packing to avoid post-harvest rots. The standard lychee carton is 9 L in volume and holds 5.0 kg of fruit, which are packed, into two 2.5 kg bags. Bags used are either a crispy bag (finely perforated) or a low-density polyethylene bag depending on marketing group and market preference. Following packing fruit should be stored at 5°C at high relative humidity.

Many small scale growers are members of one of the marketing groups which have specific grade standards and many of them are under the umbrella of the United Lychee Marketing Association (ULMA).

Longans similarly need to be picked in the early morning prior to the heat of the day. Longans are panicle picked and after being transported to the shed the panicles are sorted and trimmed by hand to remove undersized or defective fruit. Longans are sold on the panicle. After grading small bunches of fruit on the panicle branchlets remain, but generally all wood above 5 mm diameter is removed. Longans are either packed into 9 L cartons holding 5.0 kg wrapped in paper or into open webbed plastic crates holding 8.0 kg. Longan growers can choose to treat fruit with sulfur dioxide prior to dispatch to market although many smaller growers do not undertake this operation preferring to send high quality fruit which is quickly consumed once it reaches the markets. Longans are best stored at 8-10°C (Drinnan, 2003). Sulfur dioxide treated fruit may be stored at 4-5°C without chill damage.

**Financial information**

Financial information is detailed in the Lychee Agrilink kit (Menzel 2002), however the financial returns are very sensitive to yield and price expectations hence all prospective growers should consider the information carefully, preferably with the assistance of a financial/business professional. The economic analysis indicates that lychees and longan enterprises are marginally economic and should not be considered as a lifestyle choice.

Aside from the cost of land which varies greatly depending on location new investors will need at least $500,000 to set up a viable 7 ha lychee farm. This takes
Lychee and longan yields vary considerably from 10 to 100 kg/tree. Season, cultivar and location can all influence yield. Average yields are expected to vary from 5 kg/tree at five years increasing to 50 kg/tree for a 10 year old tree. For lychee a yield greater than 10 t/ha is considered excellent but not unachievable. Longan yields also vary but their average yield (15 – 20 t/ha) is generally higher than that of lychee with extremes of 35 t/ha being measured on the Atherton Tablelands, Sarina and Yeppoon.

Prices vary considerably, Tables 1 and 2 show the large difference in price which can occur during the season. Early and late crops tend to achieve higher prices while the price of mid season crops of less preferred cultivars can be marginal at best. Gross margins have been calculated for lychee on the Atherton Tablelands. A yield of 55 kg/tree for a planting density of 140 trees/ha (7.7 t/ha) the estimated gross margin (income minus variable costs) is approximately $21,600/ha. These figures take into account the normal distribution of fruit sold as first, second and farm gate sales.

The gross margin is very sensitive to price. These issues can be further explored using a computer based model designed to look at the economics of netting orchards (Johnson et al. 2002).

**Key messages**

- Lychee and longan are suited to moist and humid areas from the Atherton Tablelands to northern NSW.
- Recent laws allowing the import of lychee and longan from China and Thailand may impact on profitability. Longans may be disadvantaged and lychees may profit.
- Both crops have a concentrated harvest season over the summer months.
- A strong commitment to quality and group marketing is required by growers.

**Key statistics**

- Commercial Australian growers produce 4,000–6,000 t of lychee.
- Current longan plantings are reported to be in the vicinity of 45,000 trees.
- The annual longan production of 300–500 t is valued at $2.0M.

**About the authors**

Yan Diczbalis has worked in the tropics his entire professional career, the last 14 years of which he has worked with the tropical exotic fruit industry. He is currently based at the Centre for Wet Tropics Agriculture, South Johnstone, Queensland. His interests include the commercial development of exotic tropical crops based on an understanding of crop production patterns in relation to their growing environment. He currently works on a range of crops including; lychee, longan, rambutan, durian, mangosteen, pitaya and cocoa.

Terry Campbell is a Principal Horticulturist based at Bundaberg Research Station. He has worked in tropical tree fruits for 15 years in both production and post harvest systems. He is currently involved in the DPI&F, industry and HAL funded project Unlocking Lychee Research Project, benchmarking post harvest system handling systems and investigating the suitability of fruit coatings to extend retail red/shelf life.
References


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Minor tropical fruits

Yan Diczbalis and Gerry McMahon

Introduction

There is a large range of exotic tropical fruits available in Australia, many of them only of interest to the rare fruit collector, but many more which have a potential commercial niche market. A number of the main exotics, including lychee, rambutan, mangosteen and durian, are on their way to being well recognised due to their exotic and palatable reputations.

A number of the lesser-known exotics with market potential (Table 1) often struggle for market recognition in the mainstream domestic markets of Australia and are only well known by ethnic buyers resident in the major capitals or the locals in the growing areas with a sense of adventure. These fruits generally have a strong market presence in their countries of origin or localities where they are considered as endemic.

The aim of this review is to list the many exotics which are currently grown and marketed in tropical Australia and to concentrate on a number of the better performers; e.g. Pitaya (dragon fruit), Pomelo, Jack fruit, Hog Plum and Carambola.

Pitaya, pithaya or dragon fruit are all common names used for a number of Hylocerus spp. now regularly seen on the market floor and increasingly in our supermarkets. These cactus fruits have beautifully coloured exteriors and either red or white flesh peppered with small black...
seeds. The fruit make beautiful centrepieces to fruit bowls. Pitaya is native to Central America, and is grown commercially in Israel, Thailand, Vietnam and Australia. In Vietnam it is known as Dragon Fruit or Thanh Long, where it has become a large commercial crop. Pitaya was introduced into Queensland in 1970’s and is now grown in Western Australia, Northern Territory, Queensland and New South Wales.

Pomelo, Pummelo, Shaddock (Citrus grandis), a citrus best suited to the hot humid tropics, is the largest of the citrus fruits with specimens recorded up to 6 kg in weight. Pomelos are round or pear shaped, depending on cultivar and tend to have relatively thick rind. Skin colour is generally light green, yellow or light pink. The flesh varies in colour from pale yellow to pink. The juice sacks are large and lightly crunchy containing a mildly sweet acidic juice. The fruit is a favourite among Chinese people, particularly during festivals such as Chinese New Year and the Moon Festival. The pomelo is popular throughout SE Asia and is often sold from specialist road-side stalls in pomelo growing areas.

Jackfruit or Jakfruit (Artocarpus heterophyllus), a relative of breadfruit and mulberry, is chiefly grown for its ripe fruit that is eaten fresh or used in desserts and sweet drinks. Green fruit is also commonly used in vegetable curries and the seed of ripe fruit can be eaten after being boiled or roasted. Fully mature Jackfruit range in size from 5 to 30 kg. The flesh covering the seeds is the edible fruit portion and the bulk of the fruit is made up of stringy segments that are the remains of the inflorescence. Jackfruit is indigenous to South Western India, and has been introduced

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Botanical name</th>
<th>Family</th>
</tr>
</thead>
<tbody>
<tr>
<td>abiu</td>
<td>Pouteria caimito</td>
<td>Sapotaceae</td>
</tr>
<tr>
<td>black sapote</td>
<td>Diospyros digyna</td>
<td>Ebenaceae</td>
</tr>
<tr>
<td>breadfruit</td>
<td>Artocarpus altulis</td>
<td>Moraceae</td>
</tr>
<tr>
<td>caimito</td>
<td>Chrysophyllum caimito</td>
<td>Sapotaceae</td>
</tr>
<tr>
<td>canistel</td>
<td>Pouteria campechiana</td>
<td>Sapotaceae</td>
</tr>
<tr>
<td>carambola</td>
<td>Averrhoa carambola</td>
<td>Oxalidaceae</td>
</tr>
<tr>
<td>chempedak</td>
<td>Artocarpus polyphema</td>
<td>Moraceae</td>
</tr>
<tr>
<td>duku/langsat</td>
<td>Lansium domesticum</td>
<td>Meliaceae</td>
</tr>
<tr>
<td>durian</td>
<td>Durio zibethinus</td>
<td>Bombacaceae</td>
</tr>
<tr>
<td>granadilla</td>
<td>Passiflora quadrangularis</td>
<td>Passifloraceae</td>
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<td>grumichama</td>
<td>Eugenia brasiliensis</td>
<td>Myrtaceae</td>
</tr>
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<td>guava</td>
<td>Psidium guajava</td>
<td>Myrtaceae</td>
</tr>
<tr>
<td>jaboticaba</td>
<td>Myrciaria cauliflora</td>
<td>Myrtaceae</td>
</tr>
<tr>
<td>jakfruit</td>
<td>Artocarpus heterophyllus</td>
<td>Moraceae</td>
</tr>
<tr>
<td>jujube</td>
<td>Ziziphus spp.</td>
<td>Rhamnaceae</td>
</tr>
<tr>
<td>longan</td>
<td>Euphoria longana</td>
<td>Sapindaceae</td>
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<tr>
<td>malay apple</td>
<td>Syzygium malaccense</td>
<td>Myrtaceae</td>
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<tr>
<td>mamey sapote</td>
<td>Pouteria (Calacarpum) sapota</td>
<td>Sapotaceae</td>
</tr>
<tr>
<td>mangosteen (purple)</td>
<td>Garcinia mangostana</td>
<td>Guttiferae</td>
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<tr>
<td>pitaya</td>
<td>Hylocereus undatus</td>
<td>Cactaceae</td>
</tr>
<tr>
<td>pomelo</td>
<td>Citrus maxima</td>
<td>Rutaceae</td>
</tr>
<tr>
<td>rambutan</td>
<td>Nephelium lappaceum</td>
<td>Sapindaceae</td>
</tr>
<tr>
<td>rollinia</td>
<td>Rollinia delicosa</td>
<td>Annonaceae</td>
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<td>salak</td>
<td>Zalacca edulis</td>
<td>Palmaeae</td>
</tr>
<tr>
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<td>Manilkara sapotilla</td>
<td>Sapotaceae</td>
</tr>
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<td>soursop</td>
<td>Annona muricata</td>
<td>Annonaceae</td>
</tr>
<tr>
<td>sugar apple</td>
<td>Annona squamosa</td>
<td>Annonaceae</td>
</tr>
<tr>
<td>wax jambu</td>
<td>Syzygium samarangense</td>
<td>Myrtaceae</td>
</tr>
<tr>
<td>betel nut</td>
<td>Areca catechu</td>
<td>Palmaeae</td>
</tr>
<tr>
<td>coconut (green)</td>
<td>Cocos nucifera</td>
<td>Palmaeae</td>
</tr>
<tr>
<td>galip</td>
<td>Canarium indicum</td>
<td>Burseraceae</td>
</tr>
<tr>
<td>pili nut</td>
<td>Canarium ovatum</td>
<td>Burseraceae</td>
</tr>
<tr>
<td>cassava</td>
<td>Manihot esculenta</td>
<td>Euphorbiaceae</td>
</tr>
<tr>
<td>ceylon spinach</td>
<td>Basella alba</td>
<td>Basellaceae</td>
</tr>
<tr>
<td>kava root</td>
<td>Piper methysticum</td>
<td>Piperaceae</td>
</tr>
<tr>
<td>plantain</td>
<td>Musa sp.</td>
<td>Musaceae</td>
</tr>
<tr>
<td>tannia</td>
<td>Xanthosoma spp.</td>
<td>Araceae</td>
</tr>
<tr>
<td>taro(Samoan)</td>
<td>Colocasia esculenta</td>
<td>Araceae</td>
</tr>
<tr>
<td>winged bean</td>
<td>Psophocarpus tetragonolobus</td>
<td>Leguminosae</td>
</tr>
<tr>
<td>yam</td>
<td>Dioscorea alata</td>
<td>Diosceraceae</td>
</tr>
</tbody>
</table>
Minor tropical fruits

into Malaysia, South East Asia, and East Africa. Now it can be found in most tropical lowland regions of the world. In Australia it is found in tropical Queensland and in the Top End of the Northern Territory.

Hog Plum, Fiji Apple, Ambarella, Vi Apple or Otaheite Apple (Spondias cythera) is a member of the mango and cashew family. The fruit, dark green in colour, is plum shaped sweet-sour to taste and is eaten at all stages of ripeness. The fruits have a distinct spiny seed that hardens as the fruits mature thus requiring care when the flesh is sucked from the seed. Although the fruit is native to the Pacific it is now commonly grown and eaten throughout SE Asia and Central America. In Australia it is grown commercially in Queensland and the Northern Territory.

Carambola, Star fruit or five corner fruit (Averrhoa carambola) is ubiquitous to SE Asia and is commonly used to make a refreshing juice. Transverse sections of the fruit are star shaped and make an excellent addition to an antipasto. The fruit are rich in both vitamins C and A and are reputed to be an excellent cure for a hangover. Believed to have originated from Malaysia or Indonesia, and began moving around the world more than 150 years ago. Now it is found in most lowland tropical and subtropical areas. It came to Australia at the end of the nineteenth century.

Many of the tropical exotics can be difficult to produce and require specialist knowledge that comes from years of experience, others are easier to produce but sustained market growth to meet expected increases in production is the main challenge.

**Markets and marketing issues**

Vinning and Moody (1997) in their report on the market prospects of tropical fruits, vegetables and nuts give an overview of the domestic and export potential for a range of crops. This information by its nature becomes quickly redundant and today with the proliferation of tropical fruit marketing sites on the internet there is the potential to rapidly gather a picture of world markets and export potential for any particular product.

The domestic markets for many of the exotic tropical fruits are currently dependent on buyers of ethnic origin. Prices rapidly fall during peak seasonal production periods because production exceeds demand. Not all fruits will break through the ‘recognition’ barrier due to organoleptic reasons (e.g. Marang and Santol) and the fact that a number of them have difficulty in making it to market due to rapid ripening and postharvest breakdown (e.g. Abiu and Rollinia).

Pitaya, Pomelo, Jackfruit, Hog Plum and Carambola have all been good market performers but this does not imply that their status will continue. Other new or currently known fruits may overtake them. Important characteristics of the five selected fruits are that they are all relatively trouble free to propagate, grow and have a relatively sound postharvest life.

**Table 2. Production figures for 2002 – 03 season**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Quantity NT* (tonnes)</th>
<th>Total Value* NT ($)</th>
<th>Quantity Qld* (tonnes)</th>
<th>Total Value* Qld ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitaya</td>
<td>41</td>
<td>492,500</td>
<td>40</td>
<td>320,000</td>
</tr>
<tr>
<td>Pomelo</td>
<td>1.42</td>
<td>3,500</td>
<td>300</td>
<td>900,000</td>
</tr>
<tr>
<td>Jackfruit</td>
<td>338</td>
<td>1,290,840</td>
<td>150</td>
<td>450,000</td>
</tr>
<tr>
<td>Hog Plum</td>
<td>52</td>
<td>191,088</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Carambola</td>
<td>16</td>
<td>80,550</td>
<td>60</td>
<td>240,000</td>
</tr>
</tbody>
</table>

*Source: Economics Research Branch, Department of Business Industry and Resource Development.

**Table 3. Average wholesale prices ($/kg) in 2002/2003 at the Sydney markets**

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitaya</td>
<td>6.00</td>
<td>3.84</td>
<td>3.90</td>
<td>7.00</td>
<td></td>
<td></td>
<td>10.00</td>
<td></td>
<td>7.14</td>
<td>7.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pomelo</td>
<td>4.49</td>
<td></td>
<td>2.69</td>
<td>2.60</td>
<td>2.46</td>
<td>2.13</td>
<td>2.92</td>
<td>3.26</td>
<td>3.44</td>
<td></td>
<td>7.14</td>
<td></td>
</tr>
<tr>
<td>Jackfruit</td>
<td>3.14</td>
<td>2.85</td>
<td>2.60</td>
<td>2.73</td>
<td>2.74</td>
<td>2.79</td>
<td>3.63</td>
<td>3.66</td>
<td>3.54</td>
<td>3.49</td>
<td>3.37</td>
<td>3.12</td>
</tr>
<tr>
<td>Hog Plum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carambola</td>
<td>4.24</td>
<td>3.75</td>
<td>3.75</td>
<td>3.83</td>
<td>3.51</td>
<td>3.55</td>
<td>4.05</td>
<td>5.58</td>
<td>6.00</td>
<td></td>
<td>7.58</td>
<td></td>
</tr>
</tbody>
</table>

*Source: Rural Industry Business Service, DPI and grower associations.*

na: not available
Production requirements

Most of the fruits, vegetables and nuts listed in Table 1 have a distinct preference for a tropical climate. That is they prefer warm temperatures, frost-free year-round and have a relatively high water requirement. Despite their common preference for a warm climate they come from a diverse range of environments.

Experience suggests that all the above fruit will perform well in the wet/dry tropics of northern Australia with variable performance in the wet tropical belt from Cairns to Tully. Some of their more specific requirements are:

Pitaya prefer a dry tropical climate with an average temperature of 21-29ºC, but can cope with a range from 0 to 40ºC. They perform well in full sun but can be damaged by high levels of radiation resulting in sunburn. Rainfall of 600 – 1300 mm is required.

Pomelo prefers a hot, humid tropical environment and can thrive in wetter tropical areas. The fruit develops better flavours in tropical environments. They are commonly grown in peninsular Malaysia, Thailand and Taiwan on raised mounds in lowland areas that are flooded for most of the year. In Australia pomelos are grown in northern Australia around Darwin and in northern Queensland. They grow well on a range of soils but prefer sandy loam to loam soils with a minimum of 1.0 m of soil depth and a pH of 5.5 – 6.5.

Jackfruit like a warm humid climate with an average rainfall of 1500 mm/year. They have a poor tolerance to cold, drought and flooding and prefer deep, well-drained soil in lowland areas.

Hog Plum grow well in a humid tropical or subtropical regions, and can grow at altitudes up to 700 m. They do well across a range of soil types.

Carambola prefer a tropical or warm subtropical lowland areas with an average temperature range of 21 – 32ºC. They cannot withstand frost and are adaptable to poorer sandy soils, if organic manures and water are provided. Sunny conditions, year-round, are preferred for large-scale production.

Varieties/cultivars

Pitaya is a generic name for a number of edible cactus fruits. The white flesh (Hylocereus undatus) and red fleshed (Hylocerus polyrhizus) are the most popular on the market floor. A smaller fruiting yellow pitaya (Selenicereus megalanthus) has yellow skin and white flesh is also seen on the markets. In Darwin, commercial selections of H. undatus have been introduced from Vietnam. There are a number of local selections from the ornamental “moonlight cactus” that have proven to be very poor producers.

Table 4. Native environment and areas in which selected fruit are commonly grown

<table>
<thead>
<tr>
<th>Crop</th>
<th>Native environment</th>
<th>Commonly grown in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carambola</td>
<td>Malukas</td>
<td>SE Asia, Hawaii, Florida</td>
</tr>
<tr>
<td>Hog Plum</td>
<td>Eastern Pacific</td>
<td>SE Asia, West Indies</td>
</tr>
<tr>
<td>Jackfruit</td>
<td>South India</td>
<td>India, SE Asia</td>
</tr>
<tr>
<td>Pomelo</td>
<td>SE Asia</td>
<td>SE Asia, China, Tahiti, Florida (USA)</td>
</tr>
<tr>
<td>Pitaya</td>
<td>Mexico and Central America</td>
<td>SE Asia, Israel</td>
</tr>
</tbody>
</table>
There is a range of pomelo cultivars in Australia, mostly based on the introduction of seeds from overseas. Pomelo seeds are rarely true to type hence the selections from these seedling introductions are not considered to be representative of the parent material. Popular cultivars in Queensland include Bosworth Pink, Termat, and K17. A range of new cultivars is being evaluated. New cultivars are not readily available due to the five-year quarantine time required for introductions. However, a number of registered cultivars are available through accredited tropical fruit nurseries.

Jackfruit is a major crop in Malaysia and Thailand and both countries support active breeding and selection programs. Australia has a limited range of cultivars with the majority of material based on seedling selections introduced during the 1960’s and 1970’s. Fruit are either soft or firm fleshed (crispy) and the aerial colour is yellow to pinky-orange. The crispy pink/orange fleshed cultivars generally obtain the highest market prices.

The Hog Plum has had little selection, although a dwarf cultivar is available.

**Cultural practices**

Protected areas, free of prevailing winds with no topographic limitations and well-drained soils are preferred for most orchard crops.

Pitaya is best grown from healthy green cuttings, as seedlings are very slow growing and are unreliable producers. Cuttings of 30-50 cm are cured in a dry place for a couple of weeks, and then potted into a free-draining mix. They require minimal shade and a weak foliar fertiliser spray can be applied. When they have developed a shoot they can be planted out into a well-drained mound of sand and organic material.

A wooden or concrete post is used for support, with a wooden frame at the top to train the branches over. Poles should be at least 2 m high and 3 m apart in the row and 4 m apart between rows depending on machinery available.

A single stem is grown up the post then allowed to branch and hang down over the frame. When the branches hang they will flower, which is about 12-15 months after planting the cutting.

A balanced NPK fertiliser every three months is suggested, with an annual application of lime and organic material. Urea sprays, at 3-5%, can be used to encourage vegetative growth, with micro elements added if required. *H. undatus* is a long-day plant, requiring longer days to induce flowering. In northern Australia the fruiting season extends from October to April. Buds emerge from the hanging stems and then form into branches or flowers. The scented, white, night-blooming flowers attract bats and moths. Bees and other insects visit the flowers before dusk as the petals open, and after dawn as the flowers begin to close.

Pomelo in northern Australia is commonly propagated by budding or cleft grafting. A range of standard citrus stocks are used but the interactions between scion and stock are not well understood.

Troyer-citrange stock has proved to be useful at the Center for Wet Tropics Agriculture, South Johnstone. Planting density varies with each orchard and range from 200 to 300 trees/ha. North-south planting patterns are preferred with anecdotal evidence that east-west patterns are less productive.

Pruning, fertilising and water management are based on management techniques used for grapefruit and are all integral to obtaining maximum yields. In north Queensland cropping can extend from April to early September depending on season.

Jackfruit are often utilised as windbreak trees due to their fast growth and tree shape characteristics hence they are
not often grown specifically as an orchard crop. Tree spacing of 6-12 m are suitable depending on growing location. Seedling trees take 5-6 years to produce fruit. Seedling or grafted trees should be propagated in tall pots to allow the development of the tap root. Air layering, inarching, epicotyl grafting and bud grafting are methods of propagation that have varying degrees of success, depending on time of year and tree selection. A regular application of a mixed fertiliser is beneficial during all growth stages.

Hog Plum, is easily propagated by seed, large hardwood cuttings, air layering or grafting. Seedlings may fruit when 4 years old, and young trees should be given some light shade. Mature trees are somewhat brittle and can be damaged by strong winds. No other information has been gathered on plant spacings or fertiliser requirements but general orchard practices apply.

Prior to planting Carambola, consideration should be given to providing netting to eliminate attack by birds and fruit piercing moth. Under netting, trees have to be planted at higher densities and periodic pruning, hedging and topping have to be carried out to keep trees to a manageable height. Planting distances are 4-6 m within the row by 6 m inter-row, giving densities of 280-420 trees/hectare. Higher densities can be used such as a T-trellis system with plants at a close spacing of 1-2 m within rows. Current recommendations are to shape trees when young to 4-6 sturdy, wide angled branches with a vertical leader. Low hanging, criss-cross branches are removed periodically to open up the canopy and facilitate sunlight penetration and pollination activities. Trees planted at higher densities, for instance under netting or in a trellis system, need to be hedged and topped at least once a year.

Pomelo are susceptible to a range of pests and diseases similar to that experienced by other widely grown citrus. Leaf eating beetles (Monolepta sp. and Rhyparida spp.) can severely defoliate young trees. Ants, mealy bugs and associated sooty mould that cover fruit can also be a problem. Although the mould can often be washed off with the use of high pressure washers its best to avoid the problem by judicious ant control. Fruit spotting bugs (Amblypelta lutescens) can sting fruit at all stages of development.

Pest and disease control

Winged vertebrate pests (birds and fruit bats) are the main threat to a number of tropical fruits. Netting is required for Carambola and may be required for Pitaya as birds have caused serious damage to both these crops.

Meat ants, ginger ants, caterpillars and mites have been recorded as causing damage to Pitaya. A watery rot on the stems has also been recorded if conditions are too wet or the plant has suffered injury e.g. sunburn. This can be a major problem in some growing areas.

Pomelo are susceptible to a range of pests and diseases similar to that experienced by other widely grown citrus. Leaf eating beetles (Monolepta sp. and Rhyparida spp.) can severely defoliate young trees. Ants, mealy bugs and associated sooty mould that cover fruit can also be a problem. Although the mould can often be washed off with the use of high pressure washers its best to avoid the problem by judicious ant control. Fruit spotting bugs (Amblypelta lutescens) can sting fruit at all stages of development.

Insect pests of Carambola include fruit fly, fruit piercing moth (Othreis spp. and Eudocima salaminia), fruit eating caterpillars, green vegetable bugs, flatids and red-banded thrips. Leaf eating beetles (Monolepta sp. and Rhyparida spp.) can severely defoliate young trees.

Some of the major pests and diseases of Jackfruit include shoot borers, bark borers, mealy bugs and scale insects. Blossom and fruit rots, pinks disease and bacterial dieback can also be a problem. Most of these do not cause economic damage to any great extent, and regular monitoring and
appropriate control measures will reduce most problems although fruit rots caused by *Rhizopus stolonifer* can be a significant postharvest problem.

No particular pests or diseases have been recorded on Hog Plum in Darwin although leaf eating beetles (*Monolepta* sp. and *Rhyparida* spp.) can severely defoliate young trees.

**Harvesting and post harvest handling**

All the fruit covered in this review are relatively trouble free when it comes to harvesting and post harvest handling. Specialist systems are required to cater to the peculiarities of each crop.

Pitaya season extends from September to March. Fruit maturity occurs approximately 28 to 30 days after flowering when 85% of the fruit has attained a pink colour. The fruit are cut off at the short stem, placed carefully in crates so as not to damage the soft scales surrounding the fruit. Fruit are washed, dried and packed into single layer trays (cardboard or polystyrene). Fruit are generally sold on count and the pack weight may vary from 3.5 to 5.0 kg. Pitaya should be stored at 5°C and 90% relative humidity, and can be stored for up to 40 days.

Carambolas have to be harvested when mature. Fruit should be harvested when there is some tinge of yellow, i.e., covering less than 25% of the fruit surface or in the case of some varieties, when the fruit is pale whitish green.

Carambola require careful handling so that the edges of the wings are not bruised and damaged. To avoid fruit bruising and to extend postharvest shelf life, fruit should be carefully harvested with hand or picking pole with an attached bag and carefully cleaned, washed, graded and packed. Pack size depends on market requirements but are usually 4.0 to 6.0 kg in weight. Fruit wrapped in paraffin paper or netted socks are placed in a carton lined with foam.

Carambola can be stored up to 5 weeks with or without packaging and retain acceptable flavour. Mature green fruits can be stored at 10°C up to 5 weeks and still ripen in storage to the ripe yellow colour with acceptable flavour; and fruit destined for processing can be stored at 5°C up to 10 weeks without appreciable loss in flavour.

Jackfruit are picked as immature green fruit for curries or as mature fruit which will ripen during transit. The fruit is mature when there is a change in colour, from pale green to brownish-yellow. The spines also flatten out and there is a characteristic odour. The stalk must be cut with a sharp knife and the fruit carefully lowered to the ground. The fruit are usually washed prior to packing. The large size and weight of the fruit make it expensive to transport fruit the long distance from northern growing areas to the main domestic markets on the east coast. Fruit are normally packed in large cardboard cartons to a weight of 20 kg. Fruit rots can be a problem in some months with the problem worsening as the fruit ripen.

Jackfruit can be kept wrapped in polyethylene bags and stored at 12°C for 20 days. Temperatures lower than this will cause chilling injury.

Pomelos are ready to harvest approximately six months after flowering. Fruit do not drop when mature and skin colour change is a good indicator of maturity, however, coloured fruit can safely hang on the tree for a further three months. Picked fruit are pressure washed to remove dust and sooty mould and then dried prior to packing in cartons containing 20 kg. Some growers market their fruit in bulk crates holding several hundred kg. The thick rind reduces the requirement for packing material between fruit. Pomelo fruit store relatively well at room temperature. The Chinese custom of eating the fruit after it has spent 15 days on the temple altar is reported to enhance fruit flavour. The fruit will store for a longer period under refrigeration (7-9°C, 85-95% RH), but fruit appearance may deteriorate as the rind begins to shrivel.

Current research into pitaya fruit maturity indicates that the optimal harvest time for local markets is 28-30 days after flowering. The fruit are cut off at the fruit stalk, placed carefully in crates so as not to damage the soft scales surrounding the fruit. Fruit are washed, dried and packed into single layer trays (cardboard or polystyrene). Fruit are generally sold on count and the pack weight may vary from 3.5 to 5.0 kg. Pitaya should be stored at 5°C and 90% relative humidity, and can be stored for up to 40 days.

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Hog plum are picked washed and packed in 36 L cartons. Hog Plum is available most of the year in Darwin, and should be stored at 10-15° C with a relative humidity of 90-95%.

**Financial information**

Financial analysis of these five crops is lacking due to the small size of the industries. Most of these crops are grown as part of a suite of crops by growers and hence are not the sole source of farm income. The main investment costs (shed, tractors, mowers, irrigation system) are similar to other mainstream tree crops. The need for netting and support infrastructure, as required by carambola and pitaya, should also be taken into account.

The largest risk associated with investment in these crops is the limited domestic market. Prices are currently favourable, however, this could rapidly change if large volumes of fruit were to reach the market. Intending growers should carefully assess the market volumes and prices prior to investing.

**Acknowledgement**

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**References**


**Key message**

- There is a large range of tropical exotics with a potential market
- The market for exotic fruit is often limited and linked to buyers of ethnic origin
- Check the markets and determine who wants your product before you invest
- Demand will increase with time
- Imaginative approaches to market growth are required e.g.
  - e.g. increased promotion via life-style television programs
  - Internet and direct home marketing
- Advocate required in market place to promote and foster sales.


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Introduction

The rambutan (*Nephelium lappacium* L.) is grown for its value as a fresh fruit. The rambutan is a close relative of lychee and longan and the three fruits are known in SE Asia as the “three venerable gentlemen”. The attractive red or yellow fruits are an essential addition to any fruit basket. The fruits range from 25 to 60 g in weight and are oval to round in shape. Generally 5 to 20 fruits occur on a panicle. The outer skin (pericarp) is 2-4 mm thick and covered in long soft spines (spinterns).

Whitehead (1959) indicates that the species is indigenous to the Malay Peninsula and widely cultivated in the area whereas Van Welzen and Verheij (1991) report that the exact origin of rambutan is untraceable because of a long history of domestication. Rambutan is now well-distributed and produced throughout Southeast Asia. The crop is grown in a number of locations outside of its natural distribution, including Central America, Sri Lanka, India, New Guinea, tropical Africa, Hawaii and northern Australia.

Thailand, Indonesia and Malaysia are the major producers with production areas in 2002.
reported to be 88,000, 80,000 and 20,000 ha respectively. China, which until recently was not considered to be a producer or consumer of rambutan has become a major producer of rambutan in the last 10 years. There are 2,000 ha planted in Baoting county on Hainan Island. The major production area is on the south side of the island protected from the cold northern winds by a mountain range. Researchers estimate that the planted area will expand to 6,600 ha by 2005. Smaller but active growing areas are in Hawaii (100 ha) and Tropical America (Guatamala, Honduras, Costa Rica and El Salvador). The total area of rambutan in Central America is 300ha with approximately 200 ha grown in Guatamala.

Rambutans from Hawaii currently undergo electronic irradiation for disinfection prior to export to mainland USA. Tropical American countries have submitted protocols for export fruit to the USA for consideration. Tropical American production is aimed primarily at local consumption. However, these growing areas may meet the challenge of supplying the US and Japanese markets.

Australia produces between 500 to 1,000 t of rambutan per annum from approximately 32,000 trees on 150 ha (Table 1). The variation in production is a result of seasonal variation and management. The bulk of plantings (24,000 trees) are located from Cooktown to Tully. A smaller industry (8,000 trees) is based in Darwin, NT. The industry supplies fruit mainly to buyers of Asian descent in the State capital cities with an increasing demand from Australians of European decent, particularly those who have travelled extensively or lived in SE Asia where the fruit is an everyday favourite commonly available from street fruit vendors. The Australian industry has started to focus on overseas markets and a small but growing market is being developed in Japan.

A rambutan orchard requires considerable horticultural management skills and should not be taken on lightly unless a secure income from alternative sources is available.

### Markets and marketing issues

The rambutan is principally traded as fresh fruit on domestic and export markets. The major Asian producers of rambutan also process fruit and a common product available in the Asian food section of Australian supermarkets is canned rambutan stuffed with pineapple. The Australian market chain is made up of growers, marketing groups, agents, Asian wholesalers, boutique fruit retailers and supermarkets.

| Table 1: Australian rambutan production for the 2002/03 season |
|-----------------------------|-----------------------------|-----------------------------|
| State | Production (t/annum) | Value ($) |
| Northern Territory | 80 | 719,000 |
| domestic | 68 | 599,000 |
| export | 12 | 120,000 |
| Queensland | 600 | 3,600,000 |
| domestic | 550 | 3,000,000 |
| export | 50 | 600,000 |
| TOTAL | 680 | 4,319,000 |

| Table 2. Rambutan production intensity and regions of availability and associated average wholesale prices ($/kg) at the Sydney market |
|-----------------------------|-----------------------------|-----------------------------|
| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Rambutan | NT/Qld | Qld | Qld | Qld | Qld | Qld | Qld | Qld | NT | NT | NT |
| 1999 | 5.65 | 5.53 | 6.18 | 7.15 | - | - | - | - | - | - | - |
| 2000 | 5.23 | 4.38 | 2.60 | 2.08 | 2.25 | 2.78 | - | - | - | - | - |
| 2001 | 6.66 | 5.09 | 4.15 | 4.13 | 5.00 | - | 13.75 | 13.13 | 6.01 | 5.76 |
| 2002 | 6.33 | 5.11 | 3.10 | 3.69 | 4.38 | 4.38 | 5.15 | 12.50 | 7.61 | 6.30 | 192 |
(Noller, 2001). Buyers are clearly demarcated, the bulk of sales are to ethnic Vietnamese and Chinese who are reported to be the main consumers while consumption by the Caucasian mass market via supermarket chains is still relatively small due to low consumer awareness and high prices at the retail end.

Production varies from year to year, due to the biennial nature of the crop with a gradual upward trend due to new plantings coming into production (Table 2). At the same time smaller older orchards are being abandoned due to the high management requirements of the crop. Most orchards are less than 500 trees in size. In north Queensland there are several orchards with tree numbers in the 2,000 to 4,000 range. Average tree yields range from 30 to 60 kg, with yields up to 200 kg/tree being recorded on older trees at wide spacings. Australian production varies from 500 to 1,000 t/annum with approximately 50 to 150 t being exported. Exports to domestic markets and Japan are channelled via several marketing groups and their coordinators

**Production requirements**

The native environment of the rambutan is characterised by high, evenly distributed rainfall (2,000 mm or greater), high humidity, low evaporation rates and average minimum temperature above 20°C. In South East Asia rambutan flowering is correlated with the end of the dry season. A dry period of at least a month is thought to be essential to initiate rambutan flowering. Rambutan is considered not to have a cold requirement for flowering and is suited to tropical areas with a temperature range of 22°C to 30°C.

In Australia, flowering in the dry tropics (Darwin, 12.5°S) usually follows the onset of cool nights (18-12°C) in July to August (Diczbalis et al. 1996). However in the wet tropics of north Queensland flowering is reported to occur throughout the year, regardless of climate (Watson 1988) but usually occurs from September to October following a short dry season. There are limited areas in Australia that have the climatic attributes required for rambutan production.

Observations indicate that rambutan thrive on a wide variety of soil types as long as drainage is good enough to prevent waterlogging and supplementary irrigation is available during prolonged periods of dry weather. Rambutan trees thrive best on deep clay loam soils and prefer a slightly acid (pH 5.0 to 6.5) soil. Soil types that support lush growth may be counterproductive to regular fruit production, particularly in environments where a check in growth caused by either dry or cool conditions does not occur.

**Varieties/cultivars**

Salma (1993) identified and developed a key to 31 cultivars of rambutan grown in Malaysia out of a collection list, which exceeds 65. Each country has selected material suited to their growing climate and local palette.

Breeding and crop improvement are limited. Sarip et al. (1996) report on the outcomes of a large-scale evaluation of F1 hybrids based on two maternal parents (R99 and R134) and fourteen popular Malaysian cultivars. Six years after the establishment of 7,000 open pollinated seedlings, 50% of the population had flowered and about 40% of them were males. Seven percent of the population flowered two weeks earlier than both maternal parents (R99 and R134) and 1% produced high quality fruits with the combined attributes of good appearance, high recovery and cling free.

The Australian industry has had the opportunity to select material from over 50 imported clones. Most of the selected clones are marketed as “Classic Red” which includes six varieties (Binjai, Jitlee, R134, R156 (red), R162, R167). These varieties are similar in colour and shape and the flesh...
is easily removed from the seed. A further two varieties R9 and Rongrien are marketed separately due to shape and colour differences.

Varieties are propagated vegetatively, primarily by budding that can only be successfully carried out by a few specialist propagators. The Asian industry is primarily based on budded trees due to the low long-term survival rate of marcotted trees. In the last five years the Australian industry has increasingly turned to the use of marcotted trees due to the shortage and expense of budded trees.

**Cultural practices**

Protected areas, free of prevailing winds with no topographic limitations and well-drained soils are preferred for rambutan orchards. Deep ripping and mounding may be pre-plant options that require consideration. Rambutans were traditionally planted at low densities (70 to 100 t/ha) with inter-row and intra-row spacing varying from 10m to 12 m. Rambutans are increasingly being planted at higher densities. In the Northern Territory 10 m between rows by 5 m within rows is a popular spacing (200 trees/ha). While in north Queensland new plantings at 6 m between rows and 3 m within rows are being explored (555 trees/ha). Following planting of young budded trees six to twelve months of age, mulch, irrigation and individual tree wind/shade covers should be applied. A few growers have successfully planted marcotts directly from the tree to the paddock, however, if climatic conditions are harsh, high losses can be expected.

Young trees in the first two to three years following planting benefit from regular small applications of compound fertilisers high in nitrogen. Rambutans are relatively shallow rooted trees and small regular irrigations are most beneficial. Rambutans are sensitive to water stress, particularly in the hot dry environment experienced in growing areas around Darwin or Cooktown. Detailed irrigation recommendations are available Diczbalis (1997).

The crop requires adequate moisture, from rainfall or irrigation, during fruit set and growth. Irrigation is required for rambutan grown for high value domestic and export markets as water stress during flower and fruit development leads to reduction in yield and fruit size. Irrigation is also essential during the vegetative flushing stage after harvest but should be limited during floral initiation. Pre-flowering water stress that does not induce leaf wilting, can induce earlier flowering and improved harvest synchrony. High rainfall during blooming can lead to poor fruit set. Rambutan have a shallow root system with 80% of the roots in the top 15 cm which does not extend beyond the tree canopy sometimes necessitating irrigating up to three times a week. In trees grown on sandy soils in hot dry growing environments severe leaf loss can occur within 4 to 10 days of withholding irrigation. The amount of irrigation should at a minimum, replace that lost by evaporation particularly from flowering to harvest.

Early pruning is required to establish the tree shape. A single trunk with three to four branches commencing at 0.5 to 1.0 m above ground level is recommended. Further branching at approximately 0.6 m intervals is ideal.

Trees should commence flowering and fruit set in their third year. Growers are encouraged to nurture this first crop, which can assist in tree size control.

Application of fertiliser needs to correspond with differing needs at various stages of the growth cycle. Diczbalis (2002) reported that a crop yielding 6,750 kg/ha in north Queensland would remove 13.6 kg N, 2.1 kg P, 12.1 kg K, 3.7 kg Ca, 1.9 kg Mg and 1.3 kg S. The study reported tentative leaf nutrient standards (north Queensland) at early panicle emergence should be; 2.01% N, 0.21% P, 0.66% K, 1.2% Ca, 0.32 % Mg, 0.21% S, 485 mg/kg Mn, 102 mg/kg Fe, 54 mg/kg Cu, 26 mg/kg Zn, 51 mg/kg B. The report suggests

**Key messages**

- Rambutans are an attractive and tasty fruit with potential to grow domestic and export markets
- Rambutans require intensive care (fertiliser, irrigation and pruning) if yields are to be maximised
- Control of moisture loss and temperature control are vital for successful postharvest management

**Key statistics**

- Australia has an estimated 32,000 rambutan trees on 150 ha
- Estimated total Australian production 2002-2003 season is 680 t/annum with a value of $4,319,000
- The Northern Territory produces 80 t/annum of which 68 t is for the domestic market and 12 t is exported
- Queensland produces 600 t/annum of which 550t is for the domestic market and 50 t is exported
that fertiliser management in rambutan can be enhanced by the use of soil and leaf analysis (early panicle emergence) and nutrient replacement based on nutrient removal plus losses due to leaching, runoff or volatilisation. Compound fertilisers must be free of chlorine based sources of potassium otherwise leaf burn and fruit drop can occur.

When pruning mature trees growers must be mindful that rambutans are terminal flowering trees, that is; the floral panicle develops on relatively young wood. A number of growers in Australia are currently using mechanical pruners, following harvest, to reduce tree size and shape trees to allow machinery access. The effect of mechanical pruning on tree productivity depends on the time of pruning and the amount of wood removed. In situations where relatively heavy pruning has taken place, flowering may be delayed to the following season. Internal pruning is required to remove water shoots; pest and disease infected shoots and dead branches, along with crossing branches.

**Pest and disease control**

Winged vertebrate pests (birds and fruit bats) are the main threat to fruiting rambutan trees in both the Northern Territory and north Queensland growing regions. The rainbow lorikeet (Trichoglossus haematodus) is the major bird threat in both growing regions, while fruit bat species varies with region except for the Black Flying Fox (Pteropus alecto), which is common to both. The bulk of growers have the ability to net trees as fruit approach maturity. Netting systems vary from simple throw-over arrangements to permanent enclosures, depending on growing region and management preferences. Excellent developments in throw-over systems have occurred in the last few years.

Astridge (2004) has identified over 35 pests of rambutan. The major categories include:

- leaf swarming beetles - Rhyparida spp. and red shouldered leaf beetles Monolepta sp which damage new flush
- moths and caterpillars – yellow peach moth (Conogethes punctiger) saed, rambutan fruit borer (Triathaba rufivena), fruit piercing moth (Eudocina sp.), flower eating caterpillars (number of species), primarily attack fruit and flowers whereas loopers (Oxyodes tricolor, Achaea janata) and leaf rollers (Adoxophyes sp., Lobesia sp. and Toricidae family) damage leaves.

**About the author**

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• red banded thrip (*Selenothrips rubrocinctus*) and mites (*Tatranychus* sp and *Brevipalpus* sp.) damage fruit and foliage

• plant hoppers (*Colgaroides acuminata*), mealy bugs and scale all cause damage to flowers and fruit. The latter two are often managed by ants, which feed on the secreted honeydew they secrete. Fruit and banana spotting bugs (*Amblypelta* spp.) sting fruit from early to late maturity.

A restricted list of control measures is available to control the above and growers should check with their state government chemical coordinator or InfoPest as to the legality of application of pesticides. There are also a number of beneficial insects that growers should learn to recognise and foster. The most important of these are lacewings, parasitic wasps, predatory bug, spiders and *Cryptolemus* larva which although are often confused with mealy bugs are important predators of the former.

Diseases are generally less of an issue than winged vertebrate and insect pests. Fruit rots, such as *Colletotrichum gloeosporioides*, *Pestalotopsis* sp, *Phomopsis* sp can occur particularly following damaged caused by insects or fruit rub. Under sustained wet conditions algal leaf spot caused by *Cephaleuros virescens*, can develop on older leaves. Stem canker, categorised by the development of a dark brown flaky crust on the main trunk and branches of older trees is reportedly caused by *Dolabra nephelae*. Pruning which allows increased air and light penetration along with the judicial use of copper fungicide (free of chlorine) can assist with the management of all of the above.

**Harvesting and post harvest handling**

Rambutans are a non-climacteric fruit, and must be harvested when ripe, as they do not continue to ripen after harvesting. The fruit are best harvested when the body of the fruit is fully coloured and the spinterns still retain some green colour. This is usually associated with a total soluble solids (brix) level of 19 to 22°. A number of the marketing associations have their own maturity standards which members are obliged to follow. A picking poster which documents fruit maturity, fruit quality and packing standards is available from the Northern Territory Department of Business, Industry and Resource Development.

Individual fruit or whole panicles of fruit are picked depending on flower synchrony and market prices. Picking should be restricted to the early hours of the morning to ensure fruit are fully turgid (hydrated).

Picking during the heat of the day results in soft fruit that rapidly lose their attractive colour. Harvested fruit, rapidly loose water from the many stomata that surround the spinterns. Fruit post-harvest shelf life is markedly improved under high humidity cool conditions. Management systems should be in place to ensure that picked fruit are kept moist and rapidly transferred back to the shed where they can be wet down with cool water prior to grading and sorting. A common system is seen in Figure 1.

Grading and handling systems vary with size of the enterprise and management preferences. Size grading is important to assist with packaging, particularly when punnet systems are used. The minimum acceptable fruit size is 34 g, but most growers are packing fruit in the 40 to 50 g range. Size grading systems vary from simple diverging belt to mechanical and electronic weight systems. All packaging is designed to minimise moisture loss from the fruit. The domestic market accepts single layer trays, six punnet packs and fruit on the panicle at Chinese New Year. The 250 g punnets are primarily designed for the export markets.
**Financial information**

Most rambutan growers have an alternative income source either on or off farm. Ngo (1996) shows that the profitability of a 5 ha rambutan orchard in the NT can be high at yields of 10 t/ha and a domestic prices of $5/kg. Profitability is further affected by yield fluctuations or cost of production. Netted orchards perform well due to the higher yields and the expected payback period for a fully netted orchard is 7 to 9 years. The cost of netting is a major capital cost and netting enclosures range in price from $7,600 to 17,500/ha for row and permanent systems respectively. Land and other capital costs such as buildings and machinery vary depending on location and quality, however, establishment costs for a 8 to 10 ha farm are unlikely to be less than $250,000. Similar studies have not been carried out for north Queensland growing areas, but less profitable returns are expected given the higher volume of production and the lower returns experienced as a result.

**References**

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Azuki and kintoki beans

Anthony Hamilton

Acknowledgement is given to Peter Desborough and Robert Redden, the authors of this chapter in the first edition of this publication.

Introduction

Azuki (*Vigna angularis* (Willd.) Ohwi and Ohashi) is a summer pulse crop grown in southern/central Queensland, the North Coast of New South Wales (NSW) and irrigated regions in southern/central NSW. The grain resembles mung beans but has a maroon seedcoat and is slightly larger (100-160 mg). Although it is the sixth most commercially important crop in southeast Asia and is the most important pulse after soybeans, it is a minor crop in Australia. The key market for Australian azuki beans is Japan, where the beans are used to make a sweetened paste (ahn) that is made into a range of products such as traditional confectionery (wagashi), cakes and buns. Although usually referred to as adzuki bean in Australia, it is more correctly referred to as azuki, which means small red bean in Japanese.

Taisho kintoki is a large (500-600 mg), red-seeded kidney bean (*Phaseolus vulgaris* L.) grown in Japan. It has been included in various culinary bean trials in Australia since 1995 by Dr Robert Redden (formally Qld DPI) but not yet grown on a commercial scale. Small quantities of seed were imported into Australia to assess its potential, and NSW Dry Bean Growers Association (NSWDBGA), in conjunction with NSW Agriculture, is increasing basic seed stocks as some Japanese companies have expressed interest in purchasing kintokis from Australia.

As with azuki, kintoki is also used in confectionery, but differs from azuki in that it is usually consumed as whole seeds after infusion with sugar. Experience in Australia and North America have shown that harvesting can be a major problem with Kintoki.

Seed moisture at harvest needs to be 20-25% to prevent seed splitting. Tebo beans (*Phaseolus vulgaris* L.) are another culinary bean, similar to kintokis but possessing a white seed coat. Much of the agronomy and marketing for Tebo beans is similar to Kintoki beans.
Markets and marketing issues

Most azuki grain is traded through dealers, who may issue contracts. Harvested grain has to be carefully graded to produce a uniform and attractive sample. Most grain is exported to Japan, where Erimo is the preferred variety. A premium price is paid for large (120-160 mg), bright, light red azuki, seed free of hard seeds. It is difficult to compete with cheap imports from China for lesser quality seed. Small, niche markets exist for larger seeded ‘Dainagon’ type azuki, and there is some interest in purchasing white seeded azuki and Japanese ‘heritage’ cultivars such as Takara from Australian producers.

In irrigation areas, where the majority of azuki crops are grown, it is important to select well-drained soils and be prepared for frequent light irrigation to alleviate moisture stress, as they are both shallow rooted crops, easily reverting to indeterminacy when stressed.

Key Messages

- High value pulse crop but Japanese markets can be volatile
- Limited but lucrative local and primarily export markets
- Scope for value adding in Australia
- Requires good farmer skill levels

Key statistics

- Annual azuki production 1500 –2000 t
- Price range $750-1,500/t
- Yield range 1.5-3.0t/ha

As production from these companies increases, it is anticipated that at least 3,000 t of azuki may be produced in Australia.

Grain traders who buy azuki also source kintoki in Japan, and may purchase kintoki in future from Australian growers. It is anticipated that this market would be small (about 500 t), grown opportunistically in response to shortages in Japan. Figure 1 indicates the price variation in Azuki, Tebo and Kintoki beans since 1982.

Production requirements

Azuki and kintoki are summer crops and are considered more demanding than some other pulse crops, such as mung bean or soybean. Successful azuki crops have been produced in many areas in NSW and Queensland with yields of 2.5-3.0 t/ha possible under ideal conditions, with most growers being able to harvest 1.5-2.0 t/ha. Kintokis have achieved similar, to slightly higher, yields than azukis for comparable sowing times in trials.

In irrigation areas, where the majority of azuki crops are grown, it is important to select well-drained soils and be prepared for frequent light irrigation to alleviate moisture stress, as they are both shallow rooted crops, easily reverting to indeterminacy when stressed.

Seed quality is higher where pods can ripen under milder temperatures. This can be achieved by matching the sowing time to the location (altitude and latitude) in order for the crop to be ripening under cooler conditions with daily mean temperatures typically less than 20°C. Excessive summer heat can result in poor
quality small and dark coloured seed.

The main azuki bean growing areas in Japan are located on the northern island of Hokkaido (lat > 42°). The key azuki growing areas in north America are in Michigan and Ontario (lat ~ 42°). Both of these areas have mild summers which result in excellent quality beans. Azuki beans are grown in Australia at latitudes of 36- 20° which experience hot summer conditions. They therefore need to be sown much later than in the Northern Hemisphere so as that the beans mature during cooler autumn temperatures.

### Varieties

Azuki cultivation commenced in Australia in the 1970s with ‘Dalgety’. It was then superseded in 1980 by ‘Bloodwood’, a variety bred by the pioneer of the Australian azuki industry, Peter Desborough of NSW Agriculture. ‘Erimo’ is currently the most widely grown variety in Japan and was released in Australia in 1997 where it is now almost exclusively grown. Dainagon was also released in 1997.

There are promising new lines in Japan. However, they cannot be grown in Australia until plant variety patents expire. The Japanese Ministry of Agriculture randomly tests imported azuki for these varieties. Chinese varieties were also evaluated in Australia, but as yet have not been commercially released. NSW Agriculture has also evaluated Japanese varieties including so-called ‘heritage’ azuki cultivars Takara and Kotobuki.

Taisho is the major kintoki variety grown in Japan and is the only commercially available kintoki variety in Australia. Tancho kintoki has larger seeds but is protected by plant variety rights and is not yet available to Australian growers.

### Agronomy

Publications containing detailed information on growing azuki are listed in ‘Key References’. NSW Agriculture publishes seasonal updates. There is limited published information about growing kintoki in Australia. However, information about both azuki and navy bean agronomy would be applicable.

Azukis are usually grown on narrow row spacings (15-30 cm) and high plant densities (500,000 to 700,000 plants/ha) and can be sown with a conventional combine or airseeder. This seems to promote taller plants, with pods above cutterbar height. Although wider row spacings and lower plant densities, with inter-row cultivation can produce good results (and are the most common systems used in Japan and North America), most trials have shown increased yield responses to higher densities. Kintokis, having much larger seeds, should be preferably sown with a precision seeder to achieve the desired plant population (300,000 to 500,000 plants/ha).

The optimum sowing time is usually a compromise between sowing early enough to have the crop mature before winter and late enough to achieve high quality seed. Both azukis and kintokis flower in response to thermal time (heat unit accumulation) and the growing period, from sowing to harvesting, ranges from 80 days in northern warmer climates to 140 days in cooler southern areas. Kintokis mature about 7-10 days earlier than azukis at comparable sowing times. Suggested sowing dates are as follows:

- Bathurst – early December
- Wagga – early January
- Forbes – mid January
- Southern Qld / NSW North coast – late January/early February

Azuki need to be correctly inoculated with Rhizobium, whereas nitrogen fertiliser is needed for kintokis, which cannot fix sufficient nitrogen for their requirements.

Crop of azuki beans close to maturity
Azuki and kintoki crops are best grown on light freely drained soils. They are unsuited for cultivation on heavy self-mulching clays.

Irrigation management is critical to the success in inland irrigation districts as azuki and kintoki have poor tolerance to waterlogging.

**Pest and disease control**

Azuki and kintoki are slow growing in the first few weeks and need excellent weed control. Registration of suitable herbicides and insecticides has been difficult due to the limited scale of these crops. However, there is now a range of registered herbicides that control most grasses and broadleaf weeds in azuki crops. Growers should consult their agronomist for advice about suitable herbicides and insecticides.

Azuki and kintoki are most vulnerable to insect attack, especially from leaf and pod-eating caterpillars such as Heliothis (Helicoverpa spp.), Lucerne Seed Web Moth and Bean Pod-borer, and pod-sucking species such as Green Vegetable Bug as well as thrips, aphids, bean fly and mites. Crops must be scouted regularly and growers should budget on at least two insecticide applications. Insecticide resistance is an ongoing issue. Integrated pest management (IPM) including rotating chemical groups is useful for delaying resistance.

Sclerotinia can be a major problem, especially with azukis grown on centre pivot irrigation. Isolated instances of Powdery Mildew and a condition known as ‘Gummy Pod’ which results in sticky exudates from ripening pods, have been periodically reported in some azuki crops. Gummy pod is thought to be a symptom of hot conditions during flowering and can be over come by sowing at the correct sowing date. Powdery mildew is a more significant problem with kintokis than azukis, as is root rot due to Fusarium solani.

**Harvesting and grading**

Under the right conditions, azuki crops will mature over a relatively short period. However, indeterminacy can be a problem and most azuki crops are desiccated with glyphosate prior to harvest. Seed crops should be desiccated with diquat to ensure there is no reduction in seed viability. Crops can then either be windrowed or, more usually, direct headed. A conventional harvester can be used but rotary headers do a better job with less cracked seed. Harvesting kintokis can be a major problem in environments with low humidity, as the seed splits easily making it unsuitable for whole seed uses. One option is to grow kintokis under spray irrigation and apply a light (~5mm) irrigation just prior to harvest to soften the seed. This seed could be harvested above 30% moisture content and subsequently dried.

Japanese buyers look for a uniform sample with large (120-160 mg) azuki seed displaying a pale, bright colour and large (500-600 mg) kintoki seed displaying a dark but bright maroon seed coat. Some buyers measure colour with a colorimeter quantifying brightness (L*), redness (a*) and yellowness (b*) values. Seed must be graded to ensure uniformity and freedom from contaminants. Kintoki seeds may need to be sorted with a colour sorter to remove any mottled coloured seeds.

A recognised quality assurance system will assist in marketing the crop. Cool storage should be contemplated for any long-term storage (>6months) as azuki will darken and deteriorate with age.

**Financial information**

The attractiveness of azuki and kintoki crops depends, in part, on the range of alternative crops and, in part, on the Japanese crop prospects and quota allocations. Azuki prices have been quite volatile in the past ranging from $600 to $2000/t. Kintoki prices are similar to azukis but, in some years, can be counter-cyclical to azuki prices (Figure 1).

Benchmarking azuki crops by NSW Agriculture in conjunction...
with Co-ordinated Marketing Systems (CMS), Lachlan Rural Consultancy and the NSWDBGA shows a large range of gross margins (Figure 2). These are primarily determined by the yield of the crop, and to a lesser extent by the price received for the grain. Input costs, while high, are not the major determinant of gross margin. They are costly crops to grow so need to be well managed to produce high yields (Table 1).

Azuki and kintoki crops are short season crops suitable to double-cropping with wheat. The combined gross margin of a well-grown azuki crop followed by an irrigated wheat crop can be about $2,000/ha.

Table 1. Typical gross margin analyses for azuki and kintoki crops

<table>
<thead>
<tr>
<th>Activity</th>
<th>Azuki ($/ha)</th>
<th>Kintoki ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tractor costs</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Seed &amp; fertiliser</td>
<td>220</td>
<td>920</td>
</tr>
<tr>
<td>Sprays</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Irrigation</td>
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<td>160</td>
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<tr>
<td>Harvest &amp; freight</td>
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<td>80</td>
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<tr>
<td>Grade &amp; bag</td>
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<td>180</td>
</tr>
<tr>
<td>Other costs</td>
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<td>100</td>
</tr>
<tr>
<td>Total cost</td>
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<td>1740</td>
</tr>
<tr>
<td>Yield (t/ha)</td>
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<td>2.5</td>
</tr>
<tr>
<td>Price ($/t)</td>
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<td>1200</td>
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<tr>
<td>Total Income</td>
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<td>3000</td>
</tr>
<tr>
<td>Gross Margin</td>
<td>1430</td>
<td>1260</td>
</tr>
</tbody>
</table>

Figure 2. The effect of yield and price paid for azuki on gross margin. (Data are from 1999/2000 crops “benchmarked” by NSW Agriculture.)

About the author

Anthony Hamilton is a farmer based at Forbes NSW. He completed his PhD in 2002 studying aspects of the agronomy and seed quality of azuki and kintoki beans and was awarded an Australian Nuffield Farming Scholarship in 2003 to further study these crops. He operates a mixed farming and grazing property with his parents-in-law, producing beef cattle, lucerne, jojobas, cereal and oilseed crops, and azuki crops.
**Key references**


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Introduction

Guar, *Cyamopsis tetragonoloba* (L.) Taub. or ‘clusterbean’ is a tropical summer grain legume that has potential for the farming systems of Queensland, northern New South Wales and the Northern Territory. Its seed contains 20-30% galactomannan gum; this vegetable gum is widely used in food processing and in the building, petroleum, mining, paper, textile and pharmaceutical industries.

India and Pakistan have been traditional producers of guar grain but the increasing world demand for the gum product and its derivatives has seen processors seek alternative sources of supply. As a deep-rooted crop, guar exhibits good tolerance of the high temperatures and dry conditions found in grain growing regions of northern Australia.

The galactomannan gum fraction of the seed is removed with the endosperm or ‘splits’. Guar seed is rich in protein (around 35%) and should be heat-treated before feeding to non-ruminants. As a summer legume, guar may be useful in crop rotations to increase soil nitrogen for subsequent crops. Actively growing plants and guar stubble are both considered good fodder.

Markets and marketing issues

In 2001 the world market for guar gum was estimated at 160 000 tonnes (equivalent to 650,000 tonnes of seed). Australia itself imported 3000 tonnes of processed gum (12,000 tonnes of seed) to meet domestic demand.

A Guar Industry Development Association has been set up by a number of growers and industry stakeholders in southern Queensland over the past two years. This group is focused on marketing and agronomy to foster the development of a viable Australian guar industry.
It is essential that a buyer be arranged prior to growing guar in a commercial situation. In the past five years a European based multinational company has purchased guar grain from Australia in an attempt to diversify their source of supply. This company is now looking to source guar ‘splits’ (gum plus the seed coat) rather than whole grain from Australia.

In the 2002/03 season, the price for good quality grain was $330/t. Evaluation of a new milling process is underway in Queensland that will allow the export of guar ‘splits’ rather than whole grain. For information on marketing and grain processing see the Key Contacts section.

**Production requirements**

Guar is best adapted to dry tropical or sub-tropical regions with summer dominant rainfall. In India and Texas the main production areas for guar receive less than 800mm rainfall. Guar can also be grown as a supplementary irrigated crop, however over-watering can result in excessive production of vegetative growth and reduction in harvest index. The crop grows best under hot conditions, with maximum summer temperatures of 35-40°C. The crop is highly susceptible to frost.

Deep, well-drained sandy loam or sand soils with moderate alkalinity (pH 7.5–8.0) are considered optimal for guar. Well-drained alluvial clay and clay loams are also suitable. Care should be taken when growing guar on heavy, clay soils where the crop may be exposed to wet conditions; soil crusting can reduce seedling emergence and waterlogging increases the likelihood of root diseases.

**Cultivars**

At present only one variety of guar is available commercially, ‘CP177’. This is an erect, minimal branching, long season variety. Current seed stocks appear to be contaminated with off-types so some variation in plant type will be observed.

Over 400 lines of guar held at the Australian Tropical Crops and Forages Genetic Resource Centre in Biloela have been evaluated for their suitability to commercial production. The collection reflects the diverse nature of the crop and contains forage, grain and vegetable varieties of guar. Multi-location field trials are underway to identify a suitable grain cultivar for commercial production.

Additional varietal improvement is being undertaken by Australian Gum Products and by some independent growers.

**Agronomy**

Paddock selection is vital for successful production of guar. As well as considering soil type it is important to select an area that is free from summer growing weeds. In the early stages the crop is susceptible to weed competition and there are no herbicides registered for use in guar in Australia in 2004.

October to late December is the preferred planting time for guar in Queensland and New South Wales. For the Northern Territory optimum planting time is between mid-December and early January. Soil temperatures should be 20°C to produce reliable germination.

The current commercial variety of guar is photoperiod sensitive and planting after mid-January will result in smaller plants, premature flowering and reduced yield potential.

Guar has a high requirement for phosphorous. Deficient soils or those with low levels of vesicular-arbuscular mycorrhiza (VAM) will require moderate to high levels of P fertiliser at sowing. As a legume guar requires inoculation with Rhizobium bacteria in order to fix atmospheric nitrogen. The correct strain of inoculant for guar is CB3035, which should be applied to the seed at planting.

Established plant populations of 100,000 to 200,000 plants/ha are satisfactory for dryland crops. The seed size of guar is approximately

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### Key messages

- Ensure you have a buyer before planting
- Paddock selection is vital
- Pay good attention to nutrition and seed inoculation
- Yields of up to 1t/ha dryland and 3t/ha irrigated

### Key statistics

- World market for guar gum was estimated at 160,000 tonnes (equivalent to 650,000 tonnes of seed) in 2001
- Australia imported 3,000 tonnes of processed gum (12,000 tonnes of seed) to meet domestic demand (2001 figures).
30,000 seeds/kg, which equates to a planting rate of 7-10 kg/ha. Good results have been achieved with row spacings from 30-100cm. In the absence of registered herbicides wider row spacings allow inter-row cultivation for weed control.

**Pest and disease control**

Leaf sucking insects such as thrips (*Thrips* spp.) and leafhoppers (*Austroasca* spp.) can attack young plants. Telltale signs are white spots or stippling on the leaf surface. Green vegetable bug (*Nezara viridula*) and brown bean bug (*Riptortus serripes*) feed on developing pods and can cause seed damage or pod abortion. In particular Central Queensland crops or those grown under irrigation are at greater risk from these pests.

In Australia, the main diseases of guar are ashy stem blight, (*Macrophominia phaseoli*) and root rot (*Fusarium* sp.) both of which are associated with crops grown on poorly drained soils. In addition leaf spot (*Alternaria cucumerina*) thrives under humid conditions and is characterised by brown target-like lesions on the leaves. In acute cases, lesions may cover the whole leaf surface and lead to leaf drop. *Alternaria* has caused economic damage in some Queensland guar crops.

No insecticides or fungicides are registered for use in guar in Australia in 2004.

**Harvesting**

The current commercial variety of guar is indeterminate and will continue growing until soil moisture or low temperatures become limiting. Particular care should be taken when harvesting crops that contain a mixture of mature and immature seed pods. Wet or humid conditions during grain development as well as harvesting at high grain moisture contents can both result in weathering of the grain. This grey or black discolouration reduces the commercial value of the crop.

Guar holds its seed relatively well and shattering losses are generally low.

The crop can be harvested with conventional headers using a low drum speed to minimise seed damage. Some guar pods may be held at or near ground level. These are difficult to harvest, especially on uneven ground and can result in loss of yield. Volunteer guar in subsequent crops can be controlled by the use of rotations. Yields of around 1t/ha dryland and 3t/ha irrigated are achievable from well-managed crops.

**Further work required**

Marketing studies and varietal assessments funded by RIRDC are under way. In addition to marketing studies, further development work is required by growers and the industry to make guar a viable and competitive crop.
that will fit into current rotations. Some of the studies that are needed are:

- Testing herbicides and insecticides for registration
- Agronomic studies on nutrition, sowing date, row spacing and plant population

**Key references**


Various authors (2001) Proceedings of Guar Workshop Roma. Queensland Department of Primary Industries and Fisheries


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Col Douglas holds a Masters degree in Plant Genetics. He is Research Scientist with QDPI&F Agency for Food and Fibre Science (AFFS) at Biloela in Central Queensland and since 1999 has worked on agronomic evaluation of new field crops such as guar and grain pearl millet in Australian farming systems. Previously Col was the key researcher in a UK project that resulted in the commercialisation of new niche oilseed crops for pharmaceutical and nutraceutical products.

Richard Routley has over 20 years experience in various advisory, teaching, extension and research positions in the broadacre cropping industries in southern Qld. He is currently Senior Development Agronomist based at the QDPI&F AFFS Research Station at Roma in South West Qld.
**Introduction**

Lima beans (*Phaseolus lunatus*) are in the same plant genus as common, or navy beans (*Phaseolus vulgaris*), to which they are distantly related. Currently up to 700 t/year of raw beans are imported, while some are imported in processed products from offshore canneries (although navy bean production has exceeded 9,000 t/yr, it is currently about 3,000 t/yr). No lima beans are commercially produced in Australia despite several years of research demonstrating the feasibility of such production.

For dry grain production under rainfed conditions in Queensland, lima beans are 20–40% superior in yield to navy beans, and are more drought-tolerant. Because of the extensive low branching of the bean bushes and indeterminate pod maturity on flower bearing stalks (racemes), cutting and windrowing harvest techniques are recommended. Equipment for this is available in traditional navy and peanut areas such as the Burnett (Qld).

The major competitors for exports of ‘green baby’ and other lima market classes are USA and Myanmar. Australian production, besides meeting local demands, could target Japan for high quality exports. Potential producers require skills in intensive crop management superior to those needed for navy beans.

Skilful harvesting is needed to preserve seed coat integrity, to be free from chipped grain and maintain the right seed colour to meet market specifications, or risk being disposed of in the low value market for stock feed.
Markets

Australian lima grain imports are 400 t/year of the large green-white and about 300 t/year of the small white and small ‘green baby’ lima beans. The large lima beans are retailed direct to food consumers in small 200g-1kg dry bean packages through supermarkets, and may be self served from large sacks in specialty food stores. However the canning industry mainly uses the ‘green baby’ lima beans canned in brine either alone or in 3-4 bean mixes for use in salads. Lima beans are imported from Delaware and California, USA, where they are the by-product of harvesting immature ‘wet’ green beans, the latter need to be immediately canned. Given the small scale of demand in Australia, such a specialised industry for ‘wet’ lima bean canning would not be feasible here, however Australian production of dry grain could replace the current imports for both the canning and packaged grain markets.

Principal market outlets in Australia are the major supermarket chains for dry bean packages, while canneries include Simplot at Bathurst, Western Port at Tyabb Victoria, and Windsor Farms at Cowra. Health and specialty food shops are also retail outlets for raw beans. Potential export markets included Japan and East Asia.

The market chain to canneries is from producers via intermediate grading plants capable of meeting delivery specifications, such as Bean Growers Australia, Kingaroy. Most raw grain is distributed to retailers from importers who specialise in repacking bulk shipments, as do, for example, Ward McKenzie, and Trans Global Food Traders.

Prices for beans landed in Australia are based on world parity with associated fluctuations in a 10-20% range. Current prices of raw bean seed landed in Australia are $1,600 - 1,700/t for large, and $1,400 - 1,500/t for small, lima beans.

Production requirements

Lima beans are a summer crop of 90-110 days duration, best suited to a 20-35°C range. The cropping zones of southern Queensland and northern NSW are suitable for rainfed crops in the 600-1000 mm rainfall zone with a predominantly summer peak. Although more tolerant of water stress than navy beans, lima beans are more sensitive to daily minimum temperatures below 15°C and have a narrower climatic crop window than navy beans. In southern Queensland best yields are obtained with early summer sowing, whereas a late (February) summer sowing lowers yield, delays maturity and reduces seed size to a much greater extent than for navy beans.

With irrigation, the crop could be summer grown from central NSW to central Queensland and winter grown in both north Queensland and the Ord River irrigation region. The crop needs 300-400 mm of irrigation.

Lima beans are best suited to light, well-drained soils with deep profiles. Yields can be very constrained on some heavy black mulching clays.

Agronomy

Lima beans can be drilled either into conventionally tilled seed beds or directly into minimum tillage stubble, using either row crop or conventional seed drills. ‘Trifluralin®’ herbicide can be applied pre-emergence, while post-emergence weed control can be achieved with ‘Basogram®’ and ‘Stomp®’, in the lower range of recommended navy bean rates for all herbicides – none of which are yet registered for lima beans. Alternatively inter-row cultivation

Key messages

- No lima beans are commercially produced in Australia despite several years of research demonstrating the feasibility of such production
- Under rainfed conditions in Queensland, lima beans are 20-40% superior in yield to navy beans, and are more drought-tolerant
- Australian production, besides meeting local demands, could target Japan for high quality exports
- Potential producers require skills in intensive crop management superior to those needed for navy beans
- Skilful harvesting is needed

Key statistics

- Currently up to 700 t/year of raw beans are imported
- Current prices of raw bean seed landed in Australia are $1,600 - 1,700/t for large, and $1,400 - 1,500/t for small, lima beans
can be used with a row width of 70 cm, which allows full canopy ground cover to be obtained in early pod fill.

Under irrigation, yield of crops grown with 17.5 cm row spacing exceeded yields from crops grown at 35 cm or 70 cm row spacing. A sowing rate of 250,000 seed/ha was superior in yield to 125,000 seed/ha, in one trial in southern Queensland. The yield response was greater for row spacing than for seeding rate. Under rainfed conditions, wide rows of 70-90 cm are preferred for inter-row weed control cultivation, with lower sowing rates around 150,000 seed/ha.

For optimal yields, the potential crop nutrient requirement must be supplied as fertiliser; under rainfed conditions, 40 kg/ha of nitrogen for a 1 t/ha harvest; and up to 80 kg/ha for 2 t/ha irrigated crop.

Under Australian conditions the nitrogen fixation capacity is unreliable.

The growth rate of lima beans is very temperature sensitive with maturity delayed as minimum temperatures fall below 15°C.

Due to indeterminacy in growth habit, the plant’s leaves often remain green and functional while pods mature, especially if moisture and temperature are favourable.

The interval from planting to first ripe pod is in the range 75-80 days, with 1-2 weeks more for 50% ripe pods. In southern Queensland, optimal sowing time is November-December, with some reduction in yield potential with either earlier or later planting.

In other regions sowing could be timed to place the crop in the warmer summer months in more temperate latitudes, or early winter in tropical latitudes.

Abortion of flowers and pods is a risk with regular maximum temperatures above 40°C, and USA experience indicates that a high relative humidity is an advantage to crop growth and pod maturity.

**Varieties**

The emerging varieties suited to production in south Queensland and with acceptable canning quality include the ‘Green Baby’ series, ‘Improved Kingston’ and ‘Mendoza Bush’.

**Pests and diseases**

Diseases of lima beans are minor, with insignificant damage due to a bacterial ‘chocolate spot’ and to root rot fungi.

Field comparisons of lima beans with navy beans indicate that lima are more susceptible to the pests: myrids, thrips, *Helicoverpa* (*Heliotis*) spp and *Nezara viridula* vegetable bugs. Myrids are very difficult to detect, since most of their life cycle is spent inside developing pods and seed. Control will require targeting of adults with preventative insecticides before they lay their eggs, i.e. from early flowering.

Thrips, heliothis and vegetable bugs can be controlled, as for navy beans, with a range of insecticides including lannate®, largin®, decamethrin® and endosulphan® (though not yet officially registered for lima beans in Australia).

However, closer monitoring is required with lima beans, possibly with shorter intervals between applications. Integrated pest management approaches have not yet been developed with lima beans, but would be worthwhile if specific pest population threshold levels for action are determined for lima bean crops.

**About the author**

Dr Robert (Bob) Redden is curator of the Australian Temperate Field Crops Collection, with responsibility for worldwide collections of the genetic resources of pea, lentil, chickpea, faba bean, vetch and the Brassica oilseeds (eg. canola). Previously he bred navy beans, culinary phaseolus beans, adzuki and lima beans based at DPI Hermitage Research Station Queensland, with activities of introduction of genetic resources, germplasm evaluation for both agronomic and food processing traits, and adaptive research to fit Australian farming systems.
Harvest

Although lima beans have seed pods with thick hard shells, they tend to split open along the inner suture, exposing seed to the weather and, at full maturity, tend to dehisce. Due to uneven ripening of pods over a 2-3 week period and non-ripening of up to 20% because of indeterminate flowering and partially developed pods, timing of harvest is problematic. The desired green coloration of seed is best expressed at point of maturity - seeds tend to be bleached white at full maturation.

The best compromise appears to be harvest when pods are 30-50% mature, although immediate grading to remove green leafy trash is required to avoid growth of moulds on damp seed. Harvest trials using desiccants and different harvest timing points have indicated that growers can achieve optimal retention of marketable grain colour with either windrowing or desiccation at 50% pod maturity, but maximisation of grain yield at 90% pod maturity. Yields may be reduced by up to 20% if the crop is harvested before 50% maturity, however, prices drop to feed grain levels if the grain does not meet market specifications.

For marketing for human consumption, deliveries to grading facilities should have less than 5% trash/foreign matter. This should fall to zero after grading, which will also remove split and undersized seed. It may be important to arrange for grading immediately after harvest. Direct harvest rather than windrowing may reduce the level of dust on the seed, which for the red soils of the Burnett region in Queensland is difficult to remove for market acceptance.

Financial information

Although lima beans are suited to a wider geographic area, commercial trials have only been conducted in the Burnett region of Southern Queensland, where gross margins under rainfed conditions are likely to be at least 20% better for lima than for navy beans. Input costs for the two crops will be similar but yields and prices will be higher for lima beans.

At 0.74 t/ha, gross margins for navy beans are $207/ha. Lima beans are likely to yield at least 20% better on average and to be up to 100% better in price with a gross margin of up to $900/ha, although losses during grading to meet commercial specifications are likely to exceed those for navy beans. Harvest risks are also high with lima beans, with stringent market specifications and a ‘cliff face’ drop to feed grain prices if unacceptable.

Establishment costs may be minimal for current peanut and navy bean growers who can use existing equipment for cutting and windrowing at harvest. However, for other growers, either specialised harvesting equipment will need to be purchased, or locally suitable harvest methods will need to be developed.

Key references


University of Queensland Gatton College, p 8


Sesame

Introduction

Sesame, *Sesamum indicum* L., is an ancient oil crop supplying seeds for confectionery purposes, edible oil, paste (tahini), cake and flour. It is typically a crop of small farmers in the developing countries. In 2001, all but 1,000 ha of the about 8 million ha of sesame grown were in developing countries (Table 1).

Sesame has important agricultural attributes:

- it is adapted to tropical and temperate conditions;
- it grows well on stored soil moisture with minimal irrigation or rainfall, and
- it can produce good yields under high temperatures while its seed is of high value, $A1,000/mt (export quality).

Sesame world production areas have remained generally stable over the years, however in some countries the crop is being marginalised. Competition from more remunerative crops and a shortage of labour has pushed sesame to the less fertile land and to areas of higher risk. Left unchecked, world sesame production may decrease in the foreseeable future. This provides an opportunity for Australia to produce larger quantities of high quality sesame seed to replace 'lost' world production.

The areas and production of sesame in Australia from 1999/01 – 2002/03 is shown in Table 2.

About the author

Malcolm Bennett (B. Agric Sc), Sesame Agronomist for 16 years with NT Department of Business, Industry and Resource Development.
Before sesame can realise its potential, extensive research is needed to adapt sesame to mechanical agricultural systems. Furthermore, as Australia is becoming more involved with Asian regional activities, where much of the world’s sesame is grown, Australia’s own agricultural self-interest could be combined with its international extension and aid programs by taking the lead in a regional sesame research and development project.

### Markets

In 2000, world exports of sesame seed were 657,000 t, with Japan being the largest importer taking 23% of the world imports.

European Community, Korea and USA are the other major importers of sesame seed.

It is forecasted that the imports of sesame seed will grow at between 4% and 6% per annum until the year 2012.

### Oil industry

Australia imported 1,116 t of sesame oil and sesame products in 2002 (worth $A4.2 million). Currently, there is one sesame oil processor in Australia producing small quantities of sesame oil from locally produced seed.

### Confectionery and biscuit industry

The raw seeds currently used in Australia for confectionery and biscuit production are sourced from both local and overseas suppliers.

### Table 1. Sesame areas, production and yields in 2001 by region

<table>
<thead>
<tr>
<th>Region or Country</th>
<th>Harvested area (1,000 ha)</th>
<th>Production (1,000 mt)</th>
<th>Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>7,784</td>
<td>3,150</td>
<td>405</td>
</tr>
<tr>
<td>Total Developed countries</td>
<td>1</td>
<td>&lt;1</td>
<td>600</td>
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</table>

<table>
<thead>
<tr>
<th>Regions</th>
<th>Harvested area (1,000 ha)</th>
<th>Production (1,000 mt)</th>
<th>Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>America</td>
<td>238</td>
<td>148</td>
<td>647</td>
</tr>
<tr>
<td>Asia</td>
<td>4,753</td>
<td>2,263</td>
<td>476</td>
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<tr>
<td>Africa</td>
<td>2,793</td>
<td>739</td>
<td>264</td>
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</table>

<table>
<thead>
<tr>
<th>Major producers</th>
<th>Harvested area (1,000 ha)</th>
<th>Production (1,000 mt)</th>
<th>Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mexico</td>
<td>72</td>
<td>41</td>
<td>567</td>
</tr>
<tr>
<td>India</td>
<td>2,180</td>
<td>730</td>
<td>335</td>
</tr>
<tr>
<td>Myanmar</td>
<td>1,311</td>
<td>426</td>
<td>325</td>
</tr>
<tr>
<td>China</td>
<td>702</td>
<td>1,127</td>
<td>791</td>
</tr>
<tr>
<td>Nigeria</td>
<td>151</td>
<td>69</td>
<td>457</td>
</tr>
<tr>
<td>Sudan</td>
<td>1,900</td>
<td>300</td>
<td>158</td>
</tr>
<tr>
<td>Uganda</td>
<td>203</td>
<td>102</td>
<td>502</td>
</tr>
</tbody>
</table>

* Source: FAO Production Yearbook, Vol. 55, 2001
* Countries using mechanised harvesting practices
* Author’s estimate

Table 2. Areas and production of sesame in Australia

<table>
<thead>
<tr>
<th>Year</th>
<th>Northern Territory</th>
<th>Southern Queensland</th>
<th>New South Wales</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Area (ha)</td>
<td>Production (t)</td>
<td>Area (ha)</td>
</tr>
<tr>
<td>1999-00</td>
<td>350</td>
<td>189</td>
<td>*</td>
</tr>
<tr>
<td>2000-01</td>
<td>620</td>
<td>200</td>
<td>*</td>
</tr>
<tr>
<td>2001-02</td>
<td>30</td>
<td>10</td>
<td>*</td>
</tr>
<tr>
<td>2002-03</td>
<td>30</td>
<td>11</td>
<td>*</td>
</tr>
</tbody>
</table>

1 Farming region affected by drought
* Figures not available
Tahini industry
Tahini, a traditional Middle Eastern sesame paste is made from hulled sesame seed. Market demand is currently met by local manufacturers and imports from Mexico, the Middle East and some Mediterranean countries.

Dip and spread manufacturers
Dip manufacturers add ingredients, such as chickpeas and eggplant, to tahini and call the products Hommus and Baba Gannouj. These manufacturers purchase their tahini from local suppliers and some also use imports.

Bakery industry
The bakery industry prefers dehulled seeds that are purchased from local and overseas suppliers.

Halva industry
Halva is a popular sweet made by mixing approximately 50% tahini with boiled/whipped sugar and several other ingredients to a manufacturer’s recipe. At present all halva sold in Australia is fully imported from Greece, Turkey and Israel.

Flour industry
A project to design and install a commercial scale extraction facility to produce protein flour from sesame seed is under development.

Marketing issues
Two aspects, antioxidants and organic sesame, would improve marketing of Australian sesame seed. Sesame seed contains antioxidants, which inhibit the development of rancidity in the oil. In the food industry where synthetic antioxidants are used extensively, there is an increasing demand for more natural products. With the growing demand for organically grown food there is also a market for sesame products produced under organic conditions.

Australian unhulled sesame seed is sold according to (Australian) Grade Standards. Specifications include Australian Premium grade for export, Australian Number 1 grade for the top end of the domestic market and Australian Standard grade which is designed for sesame import replacement.

Crop potential
During the 1970-80s Australian agronomists targeted chick-pea and canola in their search for new commercial crops. Now, almost two decades later, chickpeas and canola are grown extensively with domestic and international sales. Sesame has the potential to follow their development pattern with adequate research and persistence by scientists and farmers.

Production requirements
Soils
Sesame grows best on well-drained soils of moderate fertility. The optimum pH for growth ranges from 5.4 to 6.7. Good drainage is crucial as sesame is very susceptible to short periods of waterlogging. Sesame is intolerant of very acidic or saline soils.

Climate
The response of sesame to both temperature and day length indicates that it is well adapted to wet season production in the tropics or summer production in the warmer temperate areas.

While there is some variation between cultivars, the base temperature for germination is about 16°C. In temperate areas soil temperatures determine the earliest date of sowing. The optimum temperature for growth varies with cultivar from 27 to 35°C.

Periods of high temperature above 40°C during flowering reduce capsule and seed development.

Because sesame is a short day plant with flowering being initiated as day length declines to a critical day length, cultivars are developed for particular latitudes.

The total amount of water required to grow a sesame crop ranges from 600 to 1,000 mm depending on the cultivar and the climatic conditions.

The water requirement can be met from available soil moisture at sowing, rainfall during the growing season and irrigation.

Hail and frost cause severe damage to sesame crops. Strong winds as the crop matures will greatly increase the likelihood of lodging and pre-harvest seed losses.

Cultivars
Five sesame cultivars are recommended for use in Australia. They are Yori 77 and Edith for the NT and northern WA and Magwe Brown, Aussie Gold and Beech’s Choice for QLD and northern NSW. The characteristics of these cultivars are given in Table 3. There are no cultivars recommended for growing in central and southern NSW and it is advised that prospective growers seek advice from Namreh Grain Trader Pty Ltd., NSW. Namreh Grain Trader anticipates the release of two new cultivars in the 2005 season.
Agronomy

Crop rotations
There are a number of advantages in including sesame in a crop rotation system. If sown after a leguminous crop, sesame can utilise the residual nitrogen from the legume. If the leguminous crop made good growth then the residual nitrogen should meet about one-third to one-half of the sesame crop needs.

Where sesame is rotated with a cereal, there can be mutual benefits in weed control. Broad leaf weeds can be readily controlled in the cereal crop using selective herbicides, such as atrazine or 2-4 D, greatly reducing the risk of broadleaf weeds in the subsequent sesame crop. Similarly, grass weeds which are difficult to control in the cereal crop can be fairly easily controlled in a conventionally tilled sesame crop using pre-emergent herbicides such as Treflan®, Dual® and Stomp®. Eptam® can be used as a pre-emergent herbicide for the control of some broadleaf weeds.

Paddock selection
Paddocks to be sown should have an even grade and be well drained. As control of broadleaf weeds is a problem in sesame, paddocks should be chosen which have a low content of broadleaf weed seeds.

Date of sowing, seed rate, and sowing depth
The optimum sowing date for sesame in northern NSW is the first half of December, in QLD the second and third weeks of December while in the NT the second and third weeks of January are recommended.

Seed should be sown in rows 30 to 50 cm apart to give 30 to 35 plants/m². Generally a sowing rate of 3.3 kg/ha of seed is required. If sesame is sown on one metre row spacing to fit with equipment configuration or irrigation bed arrangement then the seeding rate should be reduced by half. Sowing in cool conditions in NSW will require higher sowing rates.

As sesame seed is small, sowing depth should be no greater than 2.5 cm and the seed should be sown into moist soil using press wheels on the planting equipment.

Fertilisers
The fertiliser requirements for sesame will depend on the fertility of the soil which will vary with soil type and previous land use. The following is a guide on the type and rate of fertiliser to be applied.

An application rate of 60 kg/ha of nitrogen is likely to be adequate based upon the nitrogen content of the seed being 4%. The nitrogen should all be applied at sowing as there appears to be no advantage in a split application.

Most sandy loam soils can be expected to be deficient in P, K, S, Cu, Zn and B. Unless the area has received prior applications of fertiliser an application of at least 100 kg/ha of both single superphosphate plus trace elements and Muriate of Potash is warranted.

The clay soils tend to be more fertile and don't require K but do require P, S, Cu, Zn and B.

Irrigation
The number and timing of irrigations will depend on soil type, location and seasonal conditions. Generally the crop requirements for water can be expected to be about half of that for cotton or maize. The preferred method for establishment is an initial watering prior to sowing. The soil needs to be kept moist until the beginning of flowering to help early growth and to maintain herbicide activity. The most critical time for moisture is between first flower and completion of flowering. The final irrigation should be applied when the lower capsules turn yellow.

Weed control
Sesame grows slowly during the early stages of growth and is not strongly competitive with weeds. Poor weed control early in the life of the crop can result in greatly reduced crop yields.

In the NT, zero-tillage techniques are recommended to assist establishment. Zero-tillage involves sowing the crop into mulch which reduces weed growth and has other beneficial

<table>
<thead>
<tr>
<th>Characters</th>
<th>Queensland</th>
<th>Northern Territory</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Magwe Brown</td>
<td>Aussie Gold</td>
</tr>
<tr>
<td>Seed yield (t/ha)</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>Seed size (g/1 000)</td>
<td>2.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Oil content (%)</td>
<td>54</td>
<td>50</td>
</tr>
<tr>
<td>Plant height (cm)</td>
<td>80</td>
<td>94</td>
</tr>
<tr>
<td>Branches per plant</td>
<td>4.2</td>
<td>3.8</td>
</tr>
<tr>
<td>Capsules per leaf axil</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Days to flower</td>
<td>36</td>
<td>36</td>
</tr>
</tbody>
</table>
Sesame effects. These include reducing soil temperatures, reducing soil surface evaporation and protecting the soil from erosion. No post-emergence herbicides for grass control can be used.

In NSW where wide row spacing is used, interrow cultivation and spot spraying with glyphosate is possible. The pre-emergent herbicides trifluralin, metolachlor, and pendimethalin can be used for control of grassy weeds. Sesame is extremely sensitive to low concentrations of the residual herbicides in the sulfonylurea family which are widely used in wheat and barley. These include Glean®, Logran® and various products containing metsulfuron such as Ally®. Growers should observe the plant back periods listed on the label. The control of broadleaf weeds poses a major problem at the present time as no effective post-emergent herbicides have been identified.

**Pest and disease control**

While a wide range of insect pests attack sesame around the world only the sesame leaf webber (Antigastra catalaunalis), Heliothis caterpillars, Helicoverpa punctigera and H. armigera and Green Vegetable Bug (Nezara viridula) have caused serious problems in Australia. To date, sesame leaf webber has not been observed in NSW. Mirids can also infest sesame crops. The yellow mirid is beneficial and should not be sprayed, while the green mirid may require control.

Heliothis caterpillars are highly mobile and can rapidly damage sesame capsules. Control is made difficult by the high levels of pesticide resistance found in Heliothis. Regular monitoring and the application of integrated pest management strategies are essential to minimise their impact. Similar pest management strategies to those used for cotton are recommended. The threshold level for spraying is one small to medium sized caterpillar per ten plants. To date two applications of insecticide have provided satisfactory control.

Sesame is prone to root and stem diseases associated with waterlogging while damping-off diseases can also occur if humidity is high. While seven diseases affecting sesame have been identified only two Corynespora cassiicola (target spot) and Pseudocercospora sesami (large cercospora leaf spot), can severely affect grain yields.

Large cercospora leaf spot causes large spots on the foliage which are dull brown in colour, and irregularly shaped. The spots often coalesce, killing portions or entire leaves on susceptible cultivars during humid conditions.

Target spot first appears as dark (often purplish) spots on leaves, stems and pods. As spots enlarge they develop lighter coloured centres.

**Harvesting, handling and storage**

The indeterminate growth habit of sesame with its subsequent uneven ripening of the capsules creates difficulties for mechanical harvesting. However, techniques have now been developed that reduce seed losses during harvesting to less than 10%.

It is important that the crop be completely dry prior to harvesting as sap from green material passing through the header can discolour and taint the seed creating off-flavours in subsequent processed products.

The recommended procedure for harvesting sesame is to spray the crop with a desiccant when at least 70% of the capsules have changed colour from dark green to light green or yellow. In northern Australia an aerial application of Reglone® at 1 l/ha has proved effective.

In New South Wales and southern Queensland the rate of Reglone® should be increased to 2 to 3 l/ha. In southern NSW where Commercial sesame cultivars grown in Australia include ‘Edith’, ‘Yori 77’, ‘Aussie Gold’ and ‘Beech’s Choice’.
temperatures are much cooler, desiccants have proved unreliable and it is recommended that the crop be harvested and windrowed to dry.

The crop is harvested when 100% of the capsules have turned brown which should be about ten to fifteen days after desiccation. At this stage the grain moisture content will be about 6 to 7% in northern Australia.

In temperate areas the grain moisture content is likely to be higher and require a longer time to dry down before harvesting.

Harvesting is most efficient at a ground speed of 4 to 6 km/hr using a harvester fitted with a Harvestair® air reel and an extended table which gives a knife to auger distance as large as possible.

Sesame seed is easily threshed and relatively delicate so drum speed should be reduced to about half of that required for cereals and the concave clearance made as wide as possible. Seed damage during harvesting affects both the viability of the seed, storage and the quality of the oil.

For safe long-term storage, sesame seed should be clean, have moisture content no more than 6% and be stored at a relative humidity of approximately 50% and at a temperature less than 18°C.

**Financial information**

The economics of sesame production will vary with location while the attractiveness of the crop to a potential grower will depend on the expected returns from alternative crops that can be grown.

Desiccation is a prerequisite to successful harvesting of sesame

The area sown to sesame is dependent on the area that can be harvested in 3 days by one harvester. Currently 90-100 ha is the recommended ‘unit’ area. A smaller area should be sown if the crop is being sown for the first time.

**Table 4: Gross margin budget for sesame production in the Northern Territory, Queensland and New South Wales**

<table>
<thead>
<tr>
<th>Item</th>
<th>NT Dryland</th>
<th>QLD Dryland</th>
<th>QLD Irrigated</th>
<th>NSW Dryland</th>
<th>NSW Irrigated</th>
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</thead>
<tbody>
<tr>
<td><strong>INCOME</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.48 tonnes @ $1,000/t</td>
<td>540</td>
<td>425</td>
<td>765</td>
<td>481</td>
<td></td>
</tr>
<tr>
<td>0.50 tonnes @ $850/t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.77 tonnes @ $1,000/t</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.60 tonnes @ $900/t</td>
<td></td>
<td></td>
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<tr>
<td>0.85 tonnes @ $900/t</td>
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<tr>
<td>Fertiliser subsidy</td>
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<td></td>
<td></td>
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<tr>
<td><strong>A. Total Income</strong></td>
<td>$558</td>
<td>$425</td>
<td>$765</td>
<td>$481</td>
<td>$765</td>
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<tr>
<td><strong>VARIABLE COSTS</strong></td>
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<tr>
<td>Channel maintenance</td>
<td>-</td>
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<td>10</td>
</tr>
<tr>
<td>Land preparation</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10</td>
</tr>
<tr>
<td>Sowing and seed</td>
<td>19²</td>
<td>8</td>
<td>45</td>
<td>55</td>
<td>50</td>
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<tr>
<td>Irrigation</td>
<td>13</td>
<td>-</td>
<td>14</td>
<td>-</td>
<td>50</td>
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<tr>
<td>Fertiliser</td>
<td>-</td>
<td>-</td>
<td>132</td>
<td>-</td>
<td>180</td>
</tr>
<tr>
<td>Weed control</td>
<td>148</td>
<td>66</td>
<td>100</td>
<td>65</td>
<td>100</td>
</tr>
<tr>
<td>Insect control</td>
<td>-</td>
<td>69</td>
<td>35</td>
<td>40</td>
<td>30</td>
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<tr>
<td>Desiccation</td>
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<td>-</td>
<td>40</td>
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<tr>
<td>Harvesting</td>
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<td>16</td>
<td>38</td>
<td>28</td>
<td>25</td>
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<tr>
<td>Cartage &amp; cleaning</td>
<td>39</td>
<td>30</td>
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<td>40</td>
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</tr>
<tr>
<td></td>
<td>63</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>75</td>
</tr>
<tr>
<td><strong>B. Total Variable Costs</strong></td>
<td>$348</td>
<td>$189</td>
<td>$446</td>
<td>$236</td>
<td>$590</td>
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<tr>
<td><strong>GROSS MARGIN (A-B)</strong> $/ha</td>
<td>$210</td>
<td>$236</td>
<td>$319</td>
<td>$245</td>
<td>$175</td>
</tr>
</tbody>
</table>

1 Indicative price for Australian Number 1 grade sesame seed according to variety
2 Zero tillage land preparation
3 Seed is sold at the farm gate and seed supplied free by contractor.
Key references


Acknowledgements

This paper has been largely prepared from papers presented at the First Australian Sesame Conference held at Darwin and Katherine in 1995, (Australian) Sesame Growers Guide and Grade Standards for Sesame Seed and Sesame Oil. The assistance of Don Beech, Chris Cole and Brett Clift is particularly acknowledged for editing this paper.

Key statistics

- In 2001, world production of sesame seed was 3,150 mt
- Australia imported 6,100 t of sesame seed in 2002 (worth $A9 million), with China, Mexico and India the main suppliers
- Australian production of sesame seed decreased from 620 t in 2000-01 to 170 t in 2001-02
- Australia imported 1,116 t of sesame oil and sesame products in 2002 (worth $A4.2 million)

Key messages

- Suitable to sorghum growing regions
- High value oil seed crop
- Extensive local and overseas markets

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Capers

Jonathon and Samantha Trewartha

Introduction

A global cuisine appears almost inevitable as the world’s diverse foods are increasing available internationally. The caper plant is a drought–tolerant, perennial bush that grows in semiarid areas, requires very little water, has a favourable influence on the environment, stabilizes eroding slopes, provides medicinal and cosmetic compounds and is an essential and unique component of many meals.

The demand and consumption of capers is growing as lifestyles focus increasingly on healthy and sustainable food. Food tastes are expanding and as Mediterranean flavoured foods spread internationally, unique specialized products are increasingly sought out. In 1999 Steve Hubbard, worldwide Marketing Manager for Griffith Laboratories, a global manufacturer of food ingredients, commented on capers as one of several “potential celebrities in the culinary world” (Food Product Design magazine).

Capers have a long history of use by humans; the first evidence of consumption dating back to around 18,000 years ago in Upper Egypt, with evidence that they were eaten in Iran and Iraq in 6000 BC, in ancient Greece, in Rome in the middle ages and, in the last several centuries, in Spain and France.

The caper of commerce is in fact the immature flower bud and left to grow it increases in size and opens into a flower, which then ripens into a caper berry, which can also be pickled for use as a condiment if picked before it ripens and bursts open.

Caper plant, buds, flower and berries

Equivalent to latitudes where capers are grown commercially in the Northern Hemisphere
Capers also have a long history of use in medicine and cosmetics. Hippocrates wrote about the medicinal properties of different caper plant tissues and they are still sought after today for their medicinal value and in particular the health giving properties of the anti-oxidant bioflavinoid rutin which the plant contains in considerable amounts.

Today, global trade in capers involves around 60 countries and average annual production is estimated around 10,000 t.

Capers are hand harvested and growers would need to be able bodied or in a position to employ casual labour over the summer harvesting period. The Australian industry is young and while this presents an opportunity to build a cohesive, co-operative Industry and Marketing body, participants would need to persevere and consider their investment over the medium term.

**Markets and marketing issue**

Morocco and Turkey lead world production, but in both countries capers are largely harvested in the wild. The major cultivated plantations are in Spain (2,600 ha) where the industry has received considerable government support and research assistance and in Italy (1,000 ha) where caper farming has a long tradition.

Quality is determined by size, the smallest capers being the most prized, uniformity (difficult to ensure similar shape and color with wild harvesting) and flavour influenced by preserving technique.

Production has been increasingly exposed to the competitive influence of Turkey and Morocco and prices have been on a downward trend, however, caper quality and presentation are recognized by traders and higher prices are paid for Italian products. Recently capers from Morocco were rejected in some EU countries when they tested positive for high levels of toxic insecticide residues. Even higher prices are paid for French and Greek products where capers are generally produced in very small amounts for sale to those concerned with securing a high-quality supply.

Australia currently imports all caper products and although the customs data for imports of foods in this category is non specific it is estimated that around 600 t of product is imported with a wholesale value of approximately $AUD 7-9million.

The local market is relatively immature but an opportunity...
exists for a niche market initially targeting discerning consumers concerned with the image, freshness and quality of their food. Restaurants, gourmet supermarkets and grocers, produce markets and wholesale to gourmet food producers all provide niche markets.

The caper offers product variety and value adding can occur by downstream processing into tapanades (‘tapana’ means ‘caper’ in French), pestos, sauces and pastes. The caper leaf is also edible and a niche market may develop for these either fresh or as an ingredient in pestos and pastes.

With an increasing focus globally on sustainable production systems and quality, Australia has an international reputation for "clean and green" food production and is positively positioned to take advantage of a high-end export market.

In addition Asia is increasingly enjoying Mediterranean flavored foods with a sharp increase in olive oil consumption over the last 15 years.

In order to compete with established low cost caper producers in countries with low labor costs the Australian industry would need to find ways to increase economies of scale and decrease the cost of production. Opportunities exist for the fledgling industry to combine resources limiting capital expenditure, ensuring supply and sustainable price points in the marketplace reducing competition between growers, as well as developing a quality system that maintains Australia’s commercial advantage as a quality producer.

Important for production.

The caper bush can withstand temperatures of over 40°C in summer but it is sensitive to frost during its growing period. It is a deciduous plant able to withstand low winter temperatures of up to −10°C in the form of a stump.

Capers have been found in the foothills of the Alps at altitudes of over 1000m but they generally prefer lower altitudes and are closely associated with the ocean growing wild over rocky cliffs and on dry coastal ecosystems and withstanding strong winds. They appear to have no specific topographical preferences although a gentle slope may assist drainage.

Deep and well-drained sandy to sandy-loam soils are preferable although the caper adapts perfectly to chalky soils and some clay as long as the drainage is good.

Soil pH between 7.5 and 8 are optimum though pH values from 6.1 to 8.5 can be tolerated. The caper plant is able to grow well in poor soils as it has the ability to maximize the uptake of nutrients.
**Varieties**

Few, if any breeding programs have been undertaken worldwide and given the existence of extensive variations within the cultivated varieties, it is difficult to define the genetic material available.

In Australia, the parent plants of original propagations are of unknown variety but of the five or six different types available several have shown the advantageous characteristics similar to those of commercial plants in Italy. These plants are members of the species *Capparis spinosa*.

There is considerable scope for further research to ensure that varieties are selected for high productivity, flower quality, (flavour and processed appearance), ease of harvesting, short and uniform flowering periods and resistance to water stress and pests.

Attempts have been made to propagate caper plants via tissue culture in a Queensland laboratory. Initial results were encouraging but owing to varied results with planting out and the inability to find a nursery willing to focus on this, the project has been aborted.

Caper seed germination is poor although germination rates can be improved by partially removing seed coats. Seeding direct into the field would give limited success (5%) and is not recommended.

The most important influence of successful germination appears to be seed freshness and germinated seedlings from Australian plants are available.

Caper bushes grown from cutting have an advantage over seed-propagated bushes, as they are genetically identical with their source. This avoids high variability of production and quality.

However, root systems in cuttings are very delicate and the plant may be more susceptible to drought in the first years after planting.

**Agronomy**

Caper plantings are productive for at least 25 to 30 years so site selection is important. Soil, water availability and climate are the main aspects to be considered with the caper growing best on non-stratified, medium textured, loamy soils.

The ground is prepared through moldboard plowing and harrowing or digging backhoe pits for each caper if the ground is rocky.

Plants are usually planted in a square design and spaced from 2 to 6 meters apart to accommodate their sprawling growth.

Fertilisation can take place 20-30 days before planting or applied at planting. The type of fertiliser used and application rates is related to plant age and soil nutrient content. Phosphate and potassium fertilisers are generally applied every two to three years.

First year plants can be mulched...
and in low rainfall areas approximately 200 litres of water is applied to plants over the first year. Over-watering must be avoided, as wet roots will kill the caper plant.

Water is the most limiting production factor and where possible plants should be drip irrigated to encourage productivity.

A yield from 1.5 to 5 kg per plant can be expected in three to five years.

Plants are heavily pruned back while dormant in winter to remove dead wood and watershoots. This is essential for production as flower buds arise on one-year-old branches.

Competition with weeds may be particularly serious while establishing young plants and some herbicide treatment might be required along with mechanical weed removal. Mulch is also effective in limiting weed growth. Once the caper is established most of the ground is rapidly covered by the caper bush canopy and weed development is largely suppressed.

**Pest and disease control**

The caper bush is not very sensitive to pest damage and insects do not appear to be a limiting problem. Nonetheless, it is related to the “Brassica” family and attractive to the white cabbage moth. The caper moth also damages caper leaves. Both these insects appear not to harm the flower buds but if left unchecked damage to the leaves would influence the general vigour of the plant.

An advantage to the regular hand harvesting of buds that takes place is that pests are readily observed and can be destroyed manually, thus avoiding the use of insecticides. This process is currently occurring on an existing organic and commercial farm and will continue to occur as long as there is no mechanised way to harvest. Any insecticide treatments would be restricted by the short interval between harvests, as toxic residues at harvest must be avoided.

Snails can damage and kill young plants by stripping them of foliage and young plants must be checked regularly and snails removed.

Since the caper is a very new crop in Australia there is a risk that as yet unidentified pests or disease may prove harmful. Further consideration should be given to the fact that no organic insecticides have been approved for use on the caper plant and biologically integrated pest management approaches should be tested.

**Harvesting and processing**

**Harvest**

Harvesting is the most costly aspect of caper production since it is done manually. Bud production is continuous throughout the summer and since mechanical harvesting is not currently an option, a harvester will visit the same plant every 8 to 12 days resulting in around 12 harvests per season. To avoid the heat of the day, buds are collected in the morning. Harvest frequency has a direct bearing on the final size and quality of the product and determining the optimum time interval is influenced by the market one is picking i.e. smaller buds require more frequent picking and result in lower kilograms per picking hour.

A harvester can expect to pick up to 1 kg per hour in a mature plantation.

**Post harvest technology**

Immediately after harvest, capers are sorted and graded to size. In Italy they are graded into 6 different sizes on a scale from >7mm to <13mm. Capers are then packed in brine or under layers of salt in order to remove the intensely bitter flavor and to preserve them.

Approximately 30-50 days later they are repacked in vinegar or salt and packaged in glass bottles for retail sale or in larger plastic containers (5 kg) for sale to restaurants or in bulk for wholesale.

Caper berries are similarly pickled for retail sale.

**Key messages**

- Grow in a broad range of soils
- Key is excellent drainage
- Roots of young plants are very delicate
- Once established plants are very hardy
- Plants survive high saline water
## Financial information

<table>
<thead>
<tr>
<th>Investment inputs</th>
<th>$/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Year 1</strong></td>
<td></td>
</tr>
<tr>
<td>Field investigations</td>
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<tr>
<td>Land</td>
<td>1,400</td>
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<tr>
<td>Infrastructure</td>
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<tr>
<td>Site specific - shed, fences, power</td>
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<tr>
<td>Pump and dripper lines</td>
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<tr>
<td>Plants</td>
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<tr>
<td>1,100 plants @ $8/plant</td>
<td>8,800</td>
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<tr>
<td>Tractor $35/hr</td>
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<td>Establishment</td>
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<td>Labour $12/hr</td>
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<td>Fertiliser &amp; other material</td>
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<td>Overheads</td>
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<td>Eg Management and office expenses.</td>
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<tr>
<td>Working Capital</td>
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<td>3 Years</td>
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### Recurrent Inputs

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<td>Pruning</td>
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<tr>
<td>Fertiliser</td>
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<tr>
<td>Chemicals</td>
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<td>Harvesting</td>
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<tr>
<td>Primary Processing</td>
<td>Salting</td>
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<tr>
<td>Transport to Secondary Processing</td>
<td>Site specific (high value, low volume product)</td>
</tr>
<tr>
<td>Overheads</td>
<td>Site management</td>
</tr>
</tbody>
</table>

**Yield (after 5 years)** (Kg/ha)/pa

| Primary Yields | Caper buds - 3kg / bush | 3,300 |
| Secondary Yields | Caper berries - 600g / bush | 660 |

**Demand**

| Demand Value | Ave. retail price over total crop (non processed) - $/kg | 25 |
| Quantified Demand | Estimated imported processed products – t/pa | 600 |

**Price Elasticity**

Medium term impact on the current market price with the introduction of Australian grown capers is expected to neutral. The growth rate in caper product consumption in Australia is assumed to absorb any local production.

**Projected Demand**

It is assumed that the Australian and USA markets are similar and USA data indicates an average growth rate of 6% pa over 14-year period ('89 to '02).

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It would be misleading to put a gross margin figure on a 'typical' production site, as this is still an emerging crop.

### Financial risks requiring management are:

- premium pricem
- harvesting costr
- quality control
- marketing
- reduction in overall cost.
About the authors

Jonathon Trewartha started experimenting with growing capers in Australia in 1998. He and his parents gradually built the plant stock from an initial 15 plants to a current trial of 1,000 plants. Samantha Trewartha has a background in marketing and writing, and together Jonathon and Samantha are farming capers, processing and selling caper products, and researching and marketing the caper plant as a potential new crop for Australia.

Key statistics

- Export figures can be estimated at 3,500 t/yr for Turkey and 3,000 t/yr for Morocco
- World production is estimated to be around 10,000 t/yr
- Australia currently imports around 600 t/yr

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Coriander and fenugreek

Spice seeds

Introduction

The growing and use of Coriander (Coriandrum sativum L.) as a food is said to date back over 2000 years with a mention in the Bible. Originally named after a bug, which had a similar odour when squashed, it is believed to have originated in the Mediterranean region. As an ingredient in spice mixtures or as a leaf vegetable it is widely used throughout Europe, North Africa, North & South America’s and Asia. In the Pacific and Indian Ocean regions including Australia its spread has followed the migration of peoples from India to these countries.

The principal uses of this plant relate to its seed and leaf, both of which have found wide usage in Australia. The seed of the plant is crushed and used for mixing in curry powders and other spice mixtures. Crushing can also be used to extract the oil which is used in perfumes, condiment flavouring and alcoholic beverage manufacturing (along with juniper berry it gives gin its distinctive aroma).

The leaf with its characteristic strong odour is used a fresh vegetable in a wide range of foods particularly those with rice and of Asian origin. It has also been used as a medicinal herb.

Australia grows two seed types of coriander, these are the so called Moroccan type and the smaller seeded slow bolting type. The Moroccan seed is usually round, 3 – 5mm in diameter whilst the slow bolting types seeds are 1.5 – 3mm in size. Size is very much affected by the growing conditions with seed size differences reducing in dryland production areas. The larger Moroccan type is usually grown in Australia, North Africa, Middle East and India (Indian seed is more oval shaped than round). The slow bolting or later maturing types are grown extensively in central and eastern Europe.

Fenugreek (Trigonella foenum-graecum) originated much earlier than coriander. It was used as
Coriander plants

The harvest may prove hard to sell as the key markets in Indonesia (8-10,000mt/year), Malaysia, Sri Lanka, Fiji and South Africa are being supplied from Bulgarian and adjacent country production at prices well below those indicated as needed by Australian producers. Presently Fiji buys at $US670/t delivered ex Bulgaria versus Australian pricing of $US900/t or more. Even prices from Morocco into China, Japan and Vietnam are cheaper than Australian pricing today.

Markets in Europe were lost to Bulgarian and Russian production in the late 1990’s and Canadian production at that time displaced Australian and Morocco sales to the USA.

Large scale production in Australia will only be successful in the future if we can sell to China and regain market share in Indonesia, Sri Lanka, Japan and Malaysia for seed and crushing types as well as retaining markets in South Africa and the Pacific. Europe will continue to be difficult to penetrate.

Limited contracts from Australian companies exist for Moroccan coriander suitable for sowing and

In the last 3 years Australian Moroccan coriander producers have been selling into the markets of Japan, Asia, Fiji, Sri Lanka, Mauritius and South Africa. Sale price for crushing is best for seed with a bright golden brown colour and seed that is dark from rain damage at harvest time can be very hard to sell even at prices 30-40% below good colour lines. With production reduced due to drought the 1000 – 1500 metric tonne crops have been able to sell at values above $AU1200/t delivered Australian ports with prices reaching $AU1800/t in selected instances. Approximately 50% of this production was sold as sowing seed into overseas Asian markets. The harvest from the 2003/2004 growing season is estimated to have exceeded 1500t despite reduced crops in NSW. The harvest in WA has been estimated at 900mt. Approximately 50% of the harvest remains to be sold with our currency starting to work against the higher opening sales values despite good sales as seed for sowing.

Feedback to date from all main production areas indicates planting areas of Moroccan types will double in the 2004/05 growing season.

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Limited contracts from Australian companies exist for Moroccan coriander suitable for sowing and
Fenugreek plants growers should seek to find them before seeding if at all possible.

Slow bolting coriander is grown for seed for sowing usually under contract to vegetable seed companies selling into China and Asia. To date all production exceeding 70% germination has been sold and cleared in each year of production. Even seed grown without a contract has been sold. Production in 2003/2004 season is estimated to exceed 500 tonnes. New markets in India and increased demand from China will allow increased production this year but not all at the price levels of $AU1800 to 2000/t delivered Australian port as has been possible over the last 2 years as the strength of our currency is working against Australian sellers. Growers must ensure the stockseed they use to grow these crops is well known to the buyers as they will not buy unless they have had experience with the growth and leafiness of the variety.

Fenugreek production in Australia has always relied on overseas buying because of limited demand by Australian spice companies. Australian consumption is estimated to be in the range of 150–200t/year.

Small lots are used for seeding as green manure crops in cereal and orchard rotations.

Production in Australia up until 1999 was in the range of 400–500mt per year with most going overseas to Europe and USA. However in the past 4 years production in Victoria is believed to exceed 3000mt based on industry estimates, with smaller areas in SA, Queensland, WA and NSW.

It is estimated at publication time over 50% of this production remains unsold. Our growers have not been prepared to accept world price levels.

The largest world producer is India and their pricing of $US400-495/t delivered Europe main ports (Europe is the largest market) has not been attractive to Australian producers.

Markets in New York have always been at risk because of USA quarantine requiring freedom from wheat seeds however current requirements to satisfy USA counter terrorism procedures on foodstuffs has made exporting to this market very costly.

Seller offers of $AU475/t delivered Australian ports are well above buyer bids of $AU400/t.

Because of the large Indian crop, Australia will always find fenugreek a low return crop in the range of $AU250 – 300/t ex farm.

Production requirements

Coriander is best suited to areas with a temperate climate however in Australia it has been successfully grown in the sub tropical areas of northern NSW and the Darling Downs of Queensland. Outside of temperate areas, production usually faces a high risk of rain damage at harvest time from tropical downpours.

Plants grow best in deep well drained loamy soils with pH levels of 6.0 to 8.0 which are not prone to waterlogging and receive between 400 – 600mm of rainfall in the growing season. Generally wheat areas can successfully grow the crop. Rainfall below 400mm will usually reduce yields to an uneconomic level compared to cereal crops. Crops can be grown under irrigation, both flood and centre pivot.

Fenugreek is best grown on deep loamy free draining soils in pH range 6.0 – 8.0 which are not prone to waterlogging and receive 500–650mm of rainfall in the growing season. Being a legume it does not do well on very acid soils or those with a high aluminium concentration. It has been known to tolerate mildly saline soils.

Both coriander and fenugreek should not be sown on soils which easily compact after seeding.

Varieties/cultivars

Since 1978 when the first seed lots of the Moroccan type were commercially grown there have been numerous importations of stockseeds from Morocco, India and Egypt. These did not have any variety designation so no name can be directly placed on seed of these lines. Growers sell their seed...
after testing for Bacterial Wilt freedom as “Moroccan type”. This lack of variety identification has not been an impediment.

Slow bolting coriander seems to have two variety/cultivar streams. Early contracts for seed production were of the ALS or American Long Standing cultivar supplied from vegetable seed companies from USA and Europe for re-export to Asia and even Brazil. Taiwan buyers sent stockseed of their own selection to Australia for seed increase and it is believed they originated in China which may be the *microcarpum var* sub species. Germplasm of this type seems to be the main stockseed now used with variety/cultivar designation being fixed by the buyer without any recourse to a bred variety like ALS.

Production of central European lines has not featured in Australia. Indian varieties have been tried but not widely adopted as they usually perform as Moroccan types.

Fenugreek is very similar in that seed came from India and the variety stream was lost in the 1980’s. Seedco Australia Cooperative Limited undertook trialling of a wide range of cultivars/lines in 1990 but under Australian conditions found no significant differences in growth, seed production and plant appearance on most lines except in the larger seeded lines. This line was commercialised within Cooperative members. Later research at the Dryland Research Institute at Horsham selected cultivars that gave yield increases and two lines were released through the Lentil Company and were named “Might” and “Power”. These lines can be still grown under production agreements through Ausbulk Ltd in Adelaide. Most growers seem to use any seed with a known purity and germination.

**Agronomy**

Across Australia most coriander sowings occur in the May – June period with some crops in southern Australia being seeded in July depending on rainfall patterns. Crops seeded after the end of June in most regions suffer yield loss. Irrigated crops can be sown as late as August in high rainfall areas. The slow bolting types have a longer growing period and are usually seeded before the Moroccan types unless irrigated or in high rainfall/long growing season areas.

Seeding rates of 8-12kg/ha are in general use and each seed drill row is sown. Experience shows no real yield advantage in lower seeding rates and wider row spacings, dryland or irrigated. Seeds can take up to 4 weeks to emerge.

Fenugreek is also sown at the same time as Coriander with 15-20kg/ha. When seeded as a green manure crop rates as high as 40kg/ha may be required for maximum effect. Legume inoculant treatment is recommended. Wide row spacings are not an advantage unless mounding is required due to soil moisture conditions.

Both coriander and fenugreek prefer weedfree, well-prepared seed beds as they grow slowly after emergence and pre-emergence herbicides like Trifluralin are necessary in most situations.

Linuron can give good broad-spectrum weed control in coriander even applications just before head emergence can be used to suppress competition. Hormone chemicals like 2,4-D have been used as a “last resort”. Herbicides used in carrot seed production can also be considered as coriander is a member of the carrot family. Products such as Prometryne, Diuron and Igran

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About the author

Max Jongebloed was instrumental in starting the broadacre seed production of coriander in Australia in 1978 when seed was brought from Thailand and sown in various regions of South Australia. As the General Manager of Seedco Australia Cooperative Limited (formerly South Australian Seedgrowers Cooperative Limited) from 1987 until 2000 he initiated many years of research on coriander, fenugreek and other spices in conjunction with the Waite Agricultural Research Institute (University of Adelaide) and with support funding from RIRDC. Max today continues his very active involvement with these crops, both production and marketing, as an International Seed & Grain broker with Teague Australia.
have also been used on occasions. Fenugreek can tolerate a range of grass control chemicals but being a legume it is susceptible to some hormone herbicides however 2, 4 DB has been used with moderate success.

Phosphorous fertilisers at rates used for wheat in the growing area are usually adequate for coriander and fenugreek. Nitrogen applications are beneficial to coriander at early tillering and just before flowering stems emerge. Fenugreek at seeding can obtain a benefit from a nitrogen application.

Slow to emerge and remaining a rosette during winter, Moroccan coriander will send up flower stems approximately 90-110 days after emergence (slow bolting lines 15 – 30 days later). Stems branch out during flowering and give a large number of white flowered umbels with 10-12 individual flowers in a circular pattern. Plants usually reach heights of 1.25 – 1.5 metres.

Fenugreek plants send up flowering stems in late winter to a height of approximately 1.0m and green seed pods form a very distinctive curved sword shape usually 10 - 12 cm long but can reach 20cm. Plants usually stay upright when mature.

**Pest and disease control**

Coriander crops usually require no spraying for insect pests as it seems the strong odour of the plants acts as a deterrent. Heavy infestations of Red Legged Earth mite at seedling emergence can affect plant survival. Bees and flies are attracted to the flowers and are most important in the pollination and seed set of the crop. Granary type weevils can invade seed after it has been stored for more than 6 months after harvest and it may require fumigation prior to sale.

Fenugreek is susceptible to a wide range of insect pests including Red Legged Earth mite. Lucerne Flea, cutworms, Heliothis, Cowpea aphids, thrips and Rutherglen bugs and an active crop monitoring programme must be employed over the life of the crop partcularly at seed pod formation.

Today one particular disease of coriander threatens the continued wide scale production of coriander and in particular the Moroccan type. Commonly referred to as “Bacterial Blight” this bacterial disease identified as Pseudomonas syringae pv coriandricola emerged in the early 1990’s and caused destruction of seed fields. Large areas in South Australia stopped growing this crop because of the losses. The slow bolting lines have shown high tolerance levels to this disease and production has continued to market demand. Research has not yet given us resistant plants nor chemical control methods for this disease in coriander. Tests have been developed to identify certain disease levels in seed and growers should only use seed tested as being negative for this disease.

However seed testing negative can still carry enough infection so that when frost strikes the crop the disease emerges and multiplies and within days can waste crops. Experience has shown that frost is the main trigger for crop infestation so production should not be undertaken in areas with regular frost occurrences. Bacterial Wilt usually occurs at flowering and seed set when seed stems seem to wilt and brown leaving a single main stem that eventually dies. Infection and plant destruction can happen in 3-5 days after severe frosts. Wind, irrigation, rain and vehicle movements through crops seems to aid the spread.

Fenugreek seems to be reasonably free of disease but can suffer badly from Powdery Mildew (Erisiphe polygoni). Blight disease (Cercospora traversiana), Rhizoctania solani, Fusarium oxysporum (Wilt) and Meloidogyne incognita (root rot) have also been recorded in crops.

Chemical control has relied on copper and Mancozeb fungicide sprays to slow the spread but these are not satisfactory. Last season a combination of these sprays with a pre - application of a liquid sterilising agent seemed to arrest the disease in some fields.

The slow bolting /smaller seeded types seem to show the disease but unless there has been a severe frost, spread seems to be slow and does not cause a great yield loss.

Another disease that must be watched is Alternaria alternata which affects flowering and seed set but has not killed plants. It causes flowers to abort. Again it appears seed borne. Regular fungicide applications with copper oxychloride or Mancozeb commenced before flowering seem to provide reasonable control of this disease. Septoria has been recorded in crops.

Fenugreek is susceptible to a wide range of insect pests including Red Legged Earth mite. Lucerne Flea, cutworms, Heliothis, Cowpea aphids, thrips and Rutherglen bugs and an active crop monitoring programme must be employed over the life of the crop partcularly at seed pod formation.

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**Harvest, cleaning, packaging**

All varieties of coriander must be harvested when the seeds are light brown to brown and the plant stems are brown and starting to become dry. Open front headers are recommended. Crop losses by seed head shattering can occur if growers wait until stems are completely dry. Windrowing has been used but the windrows must be heavy and left to lie deep in the stalks otherwise wind can move them across the field. Dessication has not been used
with success. Dryland yields of 1–1.5mt/ha are common and 2–3mt/ha when irrigated. Rainfall areas below 400mm usually yield 750–1000kg/ha.

As most coriander seed is used for crushing it should be harvested free of stones, soil and other unmillable contaminants. Once cleaned it should have a minimum purity of 99% to satisfy the majority of buyers. Packaging is usually 25kg nett polypropylene sacks.

Buyers value light brown coloured seed above brown and seed blackened by rain at harvest is of very low value in the market. Within Australia and in certain overseas markets seed must be tested free of Salmonella, E- coli, aflotoxin and coliform bacteria. Some in Australia want freedom from wheat or allergenic compounds. Seed sold for fresh leaf production must meet the purity and germination requirements of the buyer.

Fenugreek is ready for harvest when the long curved pods are brown and just starting to become brittle. Crop lifters will be useful if the crop is tangled and has lodged. Mature pods after rain can shatter and an open front header is best. Pods thresh quite easily and seed should not be overthreshed. Dryland yields range from 1–1.5mt/ha and have been as high as 3mt/ha. Little is grown under irrigation.

Colour is critical for marketing and seed should have an even light tan colour with no dark or shrivelled seeds. Cleaning into polypropylene sacks either 40kg nett or 25kg nett is usual. Again as for coriander the majority of seed is crushed so must be free of unmillable material and may need to test negative for the pathogens listed.

Seed for sowing must comply with buyer requirements of purity and germination.

**Financial information**

Most growers compare coriander and fenugreek with the returns they obtain from wheat and vetch respectively when budgetting.

They also attribute some non cash benefit in the production year to the nitrogen enhancement of the soil for following crops using fenugreek.

Costs of seeding, fertiliser and harvesting coriander are similar to wheat in all rainfall regions and cost savings are possible in the use of herbicides.

However any savings are quickly used in the significant chemical and post harvest handling of coriander versus wheat.

Fenugreek growing costs are very similar to vetch but again post harvest handling can be a significant impost depending on access to seedcleaners.

The simple estimated comparison below can be applied to a cereal farm unit in a medium rainfall zone of 350–400mm/year.

One factor that is not costed into this calculation is the sometimes long period growers may wait to sell their seed if markets are quiet or if quality is not acceptable to the market.

Seed then remains in growers’ hands long after all costs have been incurred.

<table>
<thead>
<tr>
<th></th>
<th>Wheat*</th>
<th>Coriander</th>
<th>Vetch*</th>
<th>Fenugreek</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Income</strong></td>
<td>165.00</td>
<td>850.00</td>
<td>180.00</td>
<td>385.00</td>
</tr>
<tr>
<td>- Price</td>
<td>165.00</td>
<td>850.00</td>
<td>180.00</td>
<td>385.00</td>
</tr>
<tr>
<td>- Yield / ha</td>
<td>2.5mt</td>
<td>1.0mt</td>
<td>1.4mt</td>
<td>1.25mt</td>
</tr>
<tr>
<td><strong>Gross income</strong></td>
<td>413.00</td>
<td>850.00</td>
<td>252.00</td>
<td>481.00</td>
</tr>
<tr>
<td><strong>Variable costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Seed</td>
<td>23.00</td>
<td>30.00</td>
<td>15.00</td>
<td>15.00</td>
</tr>
<tr>
<td>- Fertiliser</td>
<td>32.00</td>
<td>60.00</td>
<td>27.00</td>
<td>27.00</td>
</tr>
<tr>
<td>- Chemicals</td>
<td>42.00</td>
<td>100.00</td>
<td>51.00</td>
<td>51.00</td>
</tr>
<tr>
<td>- Operations</td>
<td>31.00</td>
<td>31.00</td>
<td>36.00</td>
<td>36.00</td>
</tr>
<tr>
<td>- Freight</td>
<td>36.00</td>
<td>45.00</td>
<td>20.00</td>
<td>30.00</td>
</tr>
<tr>
<td>- Cleaning</td>
<td>0.00</td>
<td>126.00</td>
<td>0.00</td>
<td>60.00</td>
</tr>
<tr>
<td>- Other</td>
<td>4.00</td>
<td>25.00</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td><strong>Total variable costs</strong></td>
<td>168.00</td>
<td>417.00</td>
<td>152.00</td>
<td>222.00</td>
</tr>
<tr>
<td><strong>Gross margin</strong></td>
<td>245.00</td>
<td>433.00</td>
<td>100.00</td>
<td>259.00</td>
</tr>
</tbody>
</table>

* Source: 2004 Farm Gross Margins Guide – Rural Solutions
Key references


Elder, W., (1999) Coriander seed production. WA Agriculture Agnote AG 0621

Agriculture note AG0826 (June 2000) Coriander Seed. Department of Primary Industries Victoria.


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**Introduction**

The Australian Culinary Herb and Spice Industry can be described as a maturing industry. Its peak industry body, AHSIA (The Australian Herb & Spice Industry Association Ltd), has been set up to co-ordinate research & development needs, and to provide a strong representative voice for the industry.

Consumption of herbs & spices continues to grow in Australia in line with global trends, fuelled by changes to traditional eating patterns and a return to healthier eating habits in developed countries. Innovative marketing, packaging and processing have also assisted in extending the knowledge and consumption of herbs and spices to a much larger percentage of the population.

The industry has a domestic farm gate value currently estimated at $62 million and a fresh market retail sales section which continues to grow at 20% per annum.

To maintain its growth however the Australian Herb & Spice Industry has to export. Considerable processing & marketing expertise has been developed in Australia, which is of a world class standard. This puts Australia in an excellent position to take advantage of burgeoning overseas markets and several new and innovative processors have entered the market to take advantage of this. The export industry is projected to grow at 100% per annum for the next 5 years giving an export farm gate value of $100 million by 2009. Australian businesses wishing to export must have sound, well managed, quality controlled, cost effective enterprises that are competitive with major processing countries such as Germany, France, the UK and the USA.

The biggest challenge to export, and to increasing domestic productivity, is the lack of sustainable Integrated Pest Management strategies, including minor use permits for herbs and spices, the poor quality and supply of Australian seed and rootstock and, with a small percentage of growers, a limited knowledge and acceptance of the stringent quality requirements of supermarket chains, processors and consumers.

There is considerable opportunity for organically grown product, which is not being met at the

**Key messages**

- Maturing industry, with defined QA systems
- Importance of supply chain management
- The need to be market driven
- Continuing growth in domestic market
- Increasing export opportunities
- Need for sustainable IPM systems
- Lack of quality seed/rootstock
moment. To meet market demand, just as with conventional growers, organic growers must have Integrated Pest Management strategies in place and meet current quality management program requirements. Program requirements are strict and must be adhered to by all producers, both conventional and organic. Just as incorrect use of chemical controls and subsequent unacceptable maximum residue levels puts conventional growers at risk, the organic industry is at risk of high microbial contamination of produce due to the use of incorrectly treated animal manure products.

Several other low-cost producing countries such as India, Egypt, Turkey and Morocco are major exporters to Australia of dried product. This is an entirely different market segment, with imports around $40 million (excluding chilli/garlic/paprika).

However, it is a very price limited market, with few niche opportunities for premium grade, higher priced herbs and spices, and best suited to larger vertically integrated operations. Products flow into Australia via agency agreements that various importers have with producing enterprises in most parts of the world. The importers decide the quality/price ratios that each commodity segment can bear amongst their customer base. They organise importation of those lines either on contract for specific customers, or to hold as stock.

### Marketing and marketing issues

#### Principal markets

**Fresh**

1. **Supermarket chains**: Fresh product being supplied to supermarket chains: a range of climates, producing a range of quality assured products (packaged or bunched), competing in a small market place, which

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**About the author**

Jane Parker has a background in dairy farming in Scotland, followed by cotton, lucerne and small crop farming in Queensland. She commenced research and development into herb and spice production in 1992 in order to diversify the local economy and make more sustainable use of available water. She has been involved in the industry since then, particularly in agronomic research and development and supply chain management of broad acre herbs and spices.

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### Major supermarket sales, 2003

#### Fresh Herbs & Spices

<table>
<thead>
<tr>
<th>Herb</th>
<th>Retail $’s</th>
<th>Kilograms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basil</td>
<td>$7,373,200</td>
<td>74,200</td>
</tr>
<tr>
<td>Chilli</td>
<td>$3,755,300</td>
<td>425,000</td>
</tr>
<tr>
<td>Chives</td>
<td>$2,225,500</td>
<td>18,400</td>
</tr>
<tr>
<td>Coriander</td>
<td>$8,860,600</td>
<td>73,900</td>
</tr>
<tr>
<td>Dill</td>
<td>$1,074,900</td>
<td>6,100</td>
</tr>
<tr>
<td>Garlic</td>
<td>$7,941,100</td>
<td>1,767,000</td>
</tr>
<tr>
<td>Ginger</td>
<td>$7,259,900</td>
<td>592,900</td>
</tr>
<tr>
<td>Lemon Grass</td>
<td>$950,300</td>
<td>17,400</td>
</tr>
<tr>
<td>Mint</td>
<td>$2,151,500</td>
<td>18,800</td>
</tr>
<tr>
<td>Oregano</td>
<td>$594,700</td>
<td>9,700</td>
</tr>
<tr>
<td>Parsley</td>
<td>$8,415,000</td>
<td>30,500</td>
</tr>
<tr>
<td>Rosemary</td>
<td>$1,169,700</td>
<td>15,200</td>
</tr>
<tr>
<td>Thyme</td>
<td>$693,300</td>
<td>3,600</td>
</tr>
<tr>
<td>Other</td>
<td>$9,104,000</td>
<td>845,800</td>
</tr>
</tbody>
</table>

#### Presentation types

<table>
<thead>
<tr>
<th>Fresh Herbs</th>
<th>Retail $’s</th>
<th>Kilograms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Herbs</td>
<td>34,121,700</td>
<td>263,400</td>
</tr>
<tr>
<td>Bags</td>
<td>8,907,900</td>
<td>105,800</td>
</tr>
<tr>
<td>Bunches</td>
<td>17,349,000</td>
<td>13,700</td>
</tr>
<tr>
<td>Loose</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Other, value added</td>
<td>7,864,700</td>
<td>143,800</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fresh Spices</th>
<th>Retail $’s</th>
<th>Kilograms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Spices</td>
<td>20,185,800</td>
<td>2,810,500</td>
</tr>
<tr>
<td>Bags</td>
<td>299,000</td>
<td>14,100</td>
</tr>
<tr>
<td>Bunches</td>
<td>329,000</td>
<td>200</td>
</tr>
<tr>
<td>Loose</td>
<td>7,860,600</td>
<td>1,484,100</td>
</tr>
<tr>
<td>Other, value added</td>
<td>11,697,100</td>
<td>2,011,500</td>
</tr>
</tbody>
</table>
must be supplied all year round. Grower manager deals with supermarket buyers. Terms & conditions are negotiated. Competition is fierce and prices governed by supermarket policies. Individuals/companies dealing with supermarket chains, require thorough understanding of product & category requirements including required support plans, quality requirements, and shipping chain.

2. Processing companies (large & small): Fresh, quality assured product being supplied and transported in bulk, often on a strict 5-7 day week schedule, at specified times of the year. Grower manager deals with company buyer. Contracts generally negotiated and price reflects bulk purchasing. Product often ex-farm gate.

3. State markets: Fresh product, with lower quality requirements than those of 1&2. Grower manager is price taker and subject to fluctuations in prices due to over/under supply. Grower manager responsible for transport to market. Commission paid to marketer. Most of this product makes its way to greengrocers.

4. Local restaurants: A range of products, often delivered to the door, with supply agreements in place. Prices tend to follow state markets + commission + a possible premium for quality.

5. Local markets: On a permanent stall or ad hoc basis. Can be quite successful in an area with popular markets. Price structure varies, but can command premium price.

6. Export fresh (bunched, bagged or loose): This requires excellent understanding of your product and markets, superior supply chain management and sound business backing. Often required as small mixed lots which are repackaged at destination points.

Dried

1. Retail chains: Packaged product sold under own brand name or house brand. Competes with major brands eg. Masterfoods, McCormick’s. Generally commands a commodity price only and is a fairly static market.

2. Speciality stores and internet sales: Product sold under own brand name or house brand. Commands a higher price. Uses ‘good name’ to carry out business.

3. Food Service/Industrials: Product sold in bulk and commands a commodity price. Quality of product less important to buyers, and grower competes with imported product.

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**Estimated major import tonnages**

<table>
<thead>
<tr>
<th>Dried herbs &amp; spices</th>
<th>Tonnage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garlic</td>
<td>2000</td>
</tr>
<tr>
<td>Chilli</td>
<td>1500</td>
</tr>
<tr>
<td>Paprika</td>
<td>500</td>
</tr>
<tr>
<td>Oregano</td>
<td>300</td>
</tr>
<tr>
<td>Parsley</td>
<td>200</td>
</tr>
<tr>
<td>Sage</td>
<td>200</td>
</tr>
<tr>
<td>Basil</td>
<td>80</td>
</tr>
<tr>
<td>Cumin</td>
<td>500</td>
</tr>
<tr>
<td>Fennel</td>
<td>50</td>
</tr>
<tr>
<td>Anise</td>
<td>50</td>
</tr>
<tr>
<td>Dill seed</td>
<td>30</td>
</tr>
<tr>
<td>Saffron</td>
<td>10</td>
</tr>
<tr>
<td>Vanilla</td>
<td>10</td>
</tr>
<tr>
<td>Cardamomon</td>
<td>10</td>
</tr>
</tbody>
</table>

---

**Major supermarket sales, 2003,**

<table>
<thead>
<tr>
<th>Dried herbs &amp; spices</th>
<th>Retail $’s</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garlic</td>
<td>$107,000,000</td>
<td>43,000,000</td>
</tr>
<tr>
<td>Wet Herbs &amp; Spice</td>
<td>$16,300,000</td>
<td>6,600,000</td>
</tr>
</tbody>
</table>

**Sydney Spot Prices for Dried Herbs & Spices**

<table>
<thead>
<tr>
<th>$/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Most herbs</td>
</tr>
<tr>
<td>Parsley</td>
</tr>
<tr>
<td>French Tarragon</td>
</tr>
<tr>
<td>Chives - freeze dried</td>
</tr>
<tr>
<td>Cumin</td>
</tr>
<tr>
<td>Anise</td>
</tr>
<tr>
<td>Dill seed</td>
</tr>
<tr>
<td>Fennel</td>
</tr>
<tr>
<td>Saffron</td>
</tr>
<tr>
<td>Vanilla bean</td>
</tr>
</tbody>
</table>
Successful grower/marketers

3 successful grower businesses were interviewed as to their reasons for success. The common threads were:

- Each company, and individuals within the company, had a vision for the future.
- Each company started out to satisfy market demand and incorporate some value adding component into their business.
- Each company had allowed themselves approximately 5 years to establish their business.
- Each company had accessed government funding to assist in their development (The major value of this exercise was not seen to be the dollars collected, but the strategic plan that had to be developed in order to access the money).
- Each company has invested considerable personal amounts in establishing their business.
- Each company has a considerable personal presence in the market place.
- Each company is market driven.

Production requirements and cultural practices

The category, herbs and spices, encompasses a large number of species, ranging from temperate to tropical crops and are grown in enterprises all over Australia, eg parsley in Tasmania, rosemary in Victoria, lemon grass in the Northern Territory and green peppercorns in North Queensland with concentrations of growers around all major cities/population areas. Given the range of climatic conditions within Australia, it can only be said that the best yields and economic returns will be achieved if these crops are grown in environmental conditions most suited to their optimum requirements (however a customer’s marketing mix might require a grower to grow a range of species – this could necessitate a single crop being produced in a less than optimum environment, or even being produced at a net loss, to maintain the customer business).

A potential grower should understand the environment in which he wishes to grow his crop and research the best crop for that environment (remembering that all crop choices should be market driven). The grower should understand his soil types, soil nutrient status, water availability, plant water requirements and have an integrated pest management strategy in place before commencing an enterprise. Trial areas should be set up so that a grower learns to understand the crop, and make an informed decision on whether or not he is willing/and or able to grow the crop.

A range of information about cultural practices/requirements of individual crops can be found in the references.

Various cultural practices, both organic and conventional are undertaken, and can be grouped under the following headings:

- Broad acre field cropping, using conventional machinery operations suitable for small or medium cropping enterprises. Enterprises diversify using a mixture of species or single crop with a range of end products. Crops are machine harvested.
- Protected cropping, with all crops grown in controlled environments. Crops may be grown hydroponically or in a medium. Crops are mainly hand harvested.
• Market garden/Mixed cropping, with herbs/spices grown as part of a mixed enterprise, generally lettuce or Asian vegetables. Crops may be machine or hand harvested.

• Opportunity cropping. This is normally part of a mixed cropping enterprise but is grown on an ad hoc basis and usually only applies to the more robust herbs eg parsley. Crops are mainly machine harvested.

• Cottage Industry. These are smaller type enterprises which retain the 'lifestyle' tag. Herbs are grown and harvested using hand labour or smaller garden type machinery. Some have diversified into successful tourist enterprises.

Processors, supermarkets and to a lesser extent regional markets, insist that producers have quality assured production systems, with traceability from seed/plant supply to point of delivery, including transport systems. This necessitates strict record keeping of all operational aspects and a yearly audit, either by the customer or an accredited auditor.

Components to be audited will include such checks as seed/plant supply, chemical, fertiliser and water applications, machinery maintenance and wash down/sanitising, chemical storage and application equipment calibration, buildings and vermin control, cold rooms including temperature control/calibrations and sanitising records.

**Pest & weeds & diseases**

Herbs & Spices are subject to a range of pest, weeds and diseases which tend to be area/production practice and crop specific eg protected cropping experiences few weeds but has to maintain very strict control over temperature and humidity to minimise fungal diseases. Field cropping in hot dry areas is less prone to fungal diseases, but can experience more rusts, than field cropping in more humid environments. Irrigation practices can influence fungal leaf diseases and soil types can influence incidence of fungal root diseases.

To maximise sustainable practices in the control of pests and disease, it is important that Integrated Pest Management (IPM) strategies are implemented. IPM’s are practical strategies which include a broad range of appropriate pest/disease management options, including the strategic application of synthetic and biological insecticides/fungicides, improved pesticide application techniques, insect scouting and crop monitoring procedures and the introduction, protection and fostering of naturally occurring beneficials. The following is true of all crops, but must still be said – healthy crops are less susceptible to insect and disease attack.

The following are common pests/diseases:

Aphis, thrips, jassids, whitefly, other sucking insects, mealy bugs, diamond back moth, heliothis and other lepidopterous pests, altenaria, bacterial blights and root rots, fusarium wilts, phytophthora, rhizoctonia, sclerotina and rusts and mildews.

Weed control is difficult, particularly for producers whose product is destined for export, as few chemical controls are currently available. (See APVMA website). Current management practices include implementing weed control in proposed herb paddock two years before proposed planting dates, row cropping to allow inter-row cultivation, good plant stands to minimise weed invasion and the good old fashioned chip hoe.

**Harvest/ handling/ storage/ post-harvest/ processing requirements**

A lot of the research and development of companies and individuals has focussed on this aspect of herb and spice production. This has benefited all producers, as there is now a much greater understanding of individual herb harvesting and storage requirements. The biggest...
difficulty remaining in this section of the industry is in the shipping, particularly of small lots eg basil has proven to be a major challenge as it has different storage/shipping requirements from the majority of other herbs.

**Harvesting**

For a long time there was a myth perpetuated that it was impossible to machine harvest herbs without considerable product deterioration through bruising etc. In the last 5 years there have been many major break throughs in harvesting techniques and equipment, and the majority of commercial operations are now mechanised. Harvesting temperatures are also critical with more rapid shelf life deterioration if crop is harvested above 25°C.

**Post harvest handling**

The time from the paddock to the cold room is another aspect which should always be kept in mind. To maintain optimum quality and shelf life it should never exceed 30 minutes.

Cold rooms are essential and forced air cooling is critical for bulk harvested product. Settings are very specific as the product should not have air drawn over it too quickly or it will cause product burn. Different crops have different temperature requirements, the most sensitive being basil. It is important to cool the stem as well as the leaf or heat will begin to be generated whenever product is removed from forced air environment. (Recommended cooling temperatures are available through AHSIA)

Many customers require product to be washed. Various commercial washing systems are available and the product also needs to be spun dried after washing, again to maintain shelf life.

**Packaging**

Bulk ex-farm gate is generally shipped in Chep PB7 or similar bins (herbs & spices). This requires growers to have the correct handling equipment eg fork lifts. This product is generally unwashed.

Bagged product – various types of bags are used and information can be obtained from many packaging companies. Major supermarkets have their own packaging which growers are required to purchase and use. Bagging is typically by hand though there are opportunities for mechanisation of some lines.

Bunched product – Twice as much bunched product is presently being sold through supermarkets as bagged product. Product is hand bunched, therefore it is an expensive operation. Fresh product presentation will continue to change driven largely by supermarket requirements.

Loose product – this generally applies to spices, eg chilli, ginger.

**Processing requirements:**

Individual customer requirements can be quite specific. Samples of customer requirements for fresh bulk, fresh bagged and dried product are available from AHSIA.

**Financial information**

Because of the wide range of species/cropping styles it is impossible to give a true picture of costs/returns. The following financial information is a snapshot of: a machine harvested, field cropped, annual herb - basil, a machine harvested, field cropped, perennial herb - rosemary, a machine harvested field cropped spice - cayenne pepper, a protected cropping operation and a herb drying operation.

---

Processing room – protected crop.
Inset: Cold room with harvesting bins
### Detailed financial analysis for machine harvested annual field crop, Basil. 10ha unit

<table>
<thead>
<tr>
<th>Cost</th>
<th>Annual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>$50,000</td>
</tr>
<tr>
<td>Sheds/coldrooms</td>
<td>$90,000</td>
</tr>
<tr>
<td>Machinery</td>
<td>$63,000</td>
</tr>
<tr>
<td>Irrigation</td>
<td>$55,000</td>
</tr>
<tr>
<td>Working Capital</td>
<td>$50,000</td>
</tr>
<tr>
<td>Investment Costs/unit</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$33,800/ha</strong></td>
</tr>
<tr>
<td><strong>Annualised</strong></td>
<td><strong>$3,380/ha</strong></td>
</tr>
</tbody>
</table>

#### Recurrent inputs/ha

<table>
<thead>
<tr>
<th>Amount</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>$266</td>
</tr>
<tr>
<td>1</td>
<td>$1,690</td>
</tr>
<tr>
<td>5</td>
<td>$440</td>
</tr>
<tr>
<td>200</td>
<td>$60</td>
</tr>
<tr>
<td>400</td>
<td>$208</td>
</tr>
<tr>
<td>2</td>
<td>$200</td>
</tr>
<tr>
<td>6</td>
<td>$108</td>
</tr>
<tr>
<td>6</td>
<td>$456</td>
</tr>
<tr>
<td>330</td>
<td>$4,950</td>
</tr>
<tr>
<td>6</td>
<td>$3,600</td>
</tr>
<tr>
<td>15</td>
<td>$1,950</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$17,428</strong></td>
</tr>
</tbody>
</table>

#### Financial analysis

- Revenue/ha ($4.00/kg) $0
- Less recurrent inputs -$10,686
- Gross Margin $-10,686
- Less annual investment -$1,749
- Net Margin/ha $-12,435

#### Year 2

- Revenue/ha ($4.00/kg) $8,000
- Less recurrent inputs -$8,433
- Gross Margin $-433
- Less annual investment -$1,749
- Net Margin/ha $-2,182

#### Year 3

- Revenue/ha ($4.00/kg) $10,000
- Less recurrent inputs -$6,234
- Gross Margin $3,766
- Less annual investment -$1,749
- Net Margin/ha $2,017

#### Year 4

- Revenue/ha ($4.00/kg) $12,000
- Less recurrent inputs -$4,541
- Gross Margin $7,459
- Less annual investment -$1,749
- **Net Margin/ha** $5,710

### Financial Analysis for machine harvested perennial field crop, Rosemary. 10 ha unit

**Total investment cost/unit $17,250/ha**

**Year 1**

- Revenue/ha ($4.00/kg) $0
- Less recurrent inputs -$10,686
- Gross Margin $-10,686
- Less annual investment -$1,749
- Net Margin/ha $-12,435

**Year 2**

- Revenue/ha ($4.00/kg) $8,000
- Less recurrent inputs -$8,433
- Gross Margin $-433
- Less annual investment -$1,749
- Net Margin/ha $-2,182

### Financial Analysis for machine harvested annual field crop cayenne chilli. 10ha unit

**Total investment cost/unit $35,000/ha**

**Year 1**

- Revenue/ha ($2.00/kg) $30,000
- Less recurrent inputs -$17,428
- Gross Margin $12,572
- Less annual investment -$3,380
- **Net Margin/ha** $9,192

**Year 2**

- Revenue/ha ($4.00/kg) $12,000
- Less recurrent inputs -$4,541
- Gross Margin $7,459
- Less annual investment -$1,749
- **Net Margin/ha** $5,710

**Year 3**

- Revenue/ha ($4.00/kg) $10,000
- Less recurrent inputs -$6,234
- Gross Margin $3,766
- Less annual investment -$1,749
- **Net Margin/ha** $2,017

**Year 4**

- Revenue/ha ($4.00/kg) $12,000
- Less recurrent inputs -$4,541
- Gross Margin $7,459
- Less annual investment -$1,749
- **Net Margin/ha** $5,710

### Culinary herbs
Projected costs and returns for a herb drying operation processing 3000kg raw material/day of premium product, operating 250 days/year Excluding cost of land, buildings and services.

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forklift</td>
<td>$15,000</td>
</tr>
<tr>
<td>Receipt system</td>
<td>$10,000</td>
</tr>
<tr>
<td>Wash</td>
<td>$33,000</td>
</tr>
<tr>
<td>Rinse</td>
<td>$10,000</td>
</tr>
<tr>
<td>Spin</td>
<td>$120,000</td>
</tr>
<tr>
<td>Dryer</td>
<td>$50,000</td>
</tr>
<tr>
<td>Chamber</td>
<td>$100,000</td>
</tr>
<tr>
<td>Conveyors</td>
<td>$100,000</td>
</tr>
<tr>
<td>Dehumidifier</td>
<td>$100,000</td>
</tr>
<tr>
<td>Controls</td>
<td>$20,000</td>
</tr>
<tr>
<td>Power system</td>
<td>$25,000</td>
</tr>
<tr>
<td>Post dryer</td>
<td>$25,000</td>
</tr>
<tr>
<td>Rubbing</td>
<td>$10,000</td>
</tr>
<tr>
<td>Sizing</td>
<td>$10,000</td>
</tr>
<tr>
<td>Grading</td>
<td>$20,000</td>
</tr>
<tr>
<td>Packing</td>
<td>$5,000</td>
</tr>
<tr>
<td>Storage</td>
<td>$10,000</td>
</tr>
</tbody>
</table>

Total plant costs $538,000

Daily operating costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wages</td>
<td>$1,000</td>
</tr>
<tr>
<td>Power</td>
<td>$350</td>
</tr>
<tr>
<td>Washing</td>
<td>$50</td>
</tr>
<tr>
<td>Crop</td>
<td>$600</td>
</tr>
<tr>
<td>Overheads</td>
<td>$540</td>
</tr>
<tr>
<td>Investment cost</td>
<td>$729</td>
</tr>
</tbody>
</table>

Total daily operating cost $3,269

Daily production costs and returns

<table>
<thead>
<tr>
<th>Crop</th>
<th>Dry matter</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parsley</td>
<td>150</td>
<td>$21.60</td>
</tr>
<tr>
<td>Chives</td>
<td>300</td>
<td>$10.80</td>
</tr>
<tr>
<td></td>
<td>255</td>
<td>$12.71</td>
</tr>
<tr>
<td>Basil</td>
<td>255</td>
<td>$12.71</td>
</tr>
<tr>
<td>Dill</td>
<td>210</td>
<td>$15.43</td>
</tr>
</tbody>
</table>

Projected costs and returns for a protected cropping operation

Note**serviced land with proximity to metro market; minimum 10ha

Greenhouse with ridge vent, twin skin poly single screen, auto climate, hydroponic growing system, air & hydronic heating (5000m²)
Packhouse, coolroom, workshop, processing equipment.
Water storage, treatment & nutrient management

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land</td>
<td>$150,000</td>
</tr>
<tr>
<td>Greenhouse</td>
<td>$1,000,000</td>
</tr>
<tr>
<td>Packing etc</td>
<td>$600,000</td>
</tr>
<tr>
<td>Water etc</td>
<td>$100,000</td>
</tr>
<tr>
<td>Working capital</td>
<td>$250,000</td>
</tr>
</tbody>
</table>

Investment costs/unit

| Total   | $2,100,000 |
| Annualised | $173,890 |
| Revenue  | $1,323,094 |

Recurring input costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning</td>
<td>$8,258</td>
</tr>
<tr>
<td>Depreciation</td>
<td>$97,310</td>
</tr>
<tr>
<td>Labour</td>
<td>$687,467</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>$11,375</td>
</tr>
<tr>
<td>Freight</td>
<td>$106,441</td>
</tr>
<tr>
<td>QA</td>
<td>$10,423</td>
</tr>
<tr>
<td>Power</td>
<td>$139,815</td>
</tr>
<tr>
<td>Insurance</td>
<td>$16,000</td>
</tr>
<tr>
<td>IPM</td>
<td>$34,655</td>
</tr>
<tr>
<td>Maintenance</td>
<td>$76,080</td>
</tr>
<tr>
<td>Motor vehicle</td>
<td>$8,358</td>
</tr>
<tr>
<td>Packaging</td>
<td>$82,026</td>
</tr>
<tr>
<td>R&amp;D</td>
<td>$21,926</td>
</tr>
<tr>
<td>Seeds &amp; plants</td>
<td>$7,206</td>
</tr>
<tr>
<td>Sundry</td>
<td>$13,132</td>
</tr>
<tr>
<td>Telecom</td>
<td>$15,492</td>
</tr>
<tr>
<td>Travel</td>
<td>$13,880</td>
</tr>
</tbody>
</table>

Total Expenses $1,349,844
Key references

General information
http://www.ahsia.org.au

Minor permits
http://www.apvma.gov.au

Overseas seed supply
http://www.richters.com
http://www.cnseeds.co.uk

Research information
http://www.rirdc.gov.au
http://www.agr.gov.sk.ca
http://www.organicaginfo.org

Directory of Specialists in Herbs, Spices and Medicinal plants

Dr Lyle. E. Craker
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Ginseng

Introduction

Opportunities and challenges for Australian ginseng production have been demonstrated in forest floor gardens at Gembrook Victoria since early 1985. Since 1992 many other trials have been started in various south-eastern and south-western locations of Australia with mixed results. Organic aged roots from Gembrook gardens have been exported and are part of retail products for Australian sales. The most comprehensive data for current production are from Gembrook and other Victorian gardens.

Ginseng, known as an ‘adaptogen’, helps to restore the balance in the pituitary gland which, in turn, encourages the system to cure itself. Research shows Panax ginseng (Asian) has a hot acid action while Panax quinquefolius (American) performs in a cool or alkaline way. Generally speaking, ginseng grown on the forest floor is more medicinally potent than that from intensive field cultivation.

Recorded Australian imports of ginseng exceed 28 t/yr, with an estimated value of more than $15 million. In the last few years, diligent efforts by Australian Regions with successful trials

Key messages

- Patience is a must
- Quality before quantity
- Never fast—never easy
- Grow with a conscience — grow green
- Slow but sure = good returns

Two kg of 7-year-old ginseng roots produced at Gembrook
**Key statistics**

- Imports = ca 28t.
- Exports = ca 65kg (to Dec '03)
- 150 growers are having continuing successful trials with anticipated combined harvests commencing in 2005
- The "gold rush" into planting that raged from 1992 - 1999 has settled to a realistic and sustainable level
- The total estimated planted area of Australian Ginseng Growers Assoc. gardens is about 100 ha. The area of non-member gardens is unknown
- About 80% of plantings are of American ginseng and 20% of the Asian species

Customs have lessened the amount entering the country undeclared, so this figure provides a more accurate picture of Australian consumption than previously available figures. It is considered that this figure will continue to escalate, due to the rising proportion of the population of Asian origin and heavier demands for natural health products in society in general.

With wild ginseng stocks from Asia and North America diminishing, plus growing demands for better quality, chemical-free products, there is clearly potential for Australian commercial ginseng production, as an export commodity and for import replacement.

Growers need patience and commitment to achieve results with this long-term crop.

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**Markets and marketing issues**

Ginseng is traded by weight as dried or fresh whole roots, with different prices paid for approximately 40 market grades. Some 95% of all ginseng production is consumed in Asia. In major Asian and Japanese centres American ginseng is the preferred choice. The Koreans prefer their own product. As little was available or known about American ginseng until recently, Asian ginseng has dominated Australian markets.

Little private trading occurs in China or Korea although this should change with new government regulations. Trading in North America takes place at the farm gate, although cooperative or network marketing is becoming popular there. This type of marketing is being considered by Australian growers. Successful profits can also be made by growers who manufacture and market retail products.

Australian grown 7 year old roots, both fresh and dried, have been sold to Singapore based on the Wild American price plus 20%. Smaller quantities of aged fresh and dried roots are also being sold at similar prices within Australia. These are mainly private sales to Asian residents.

Singapore buyers are keen to purchase more Australian-grown ginseng to satisfy client demands for top quality roots.

Market trends are best assessed from North American information. Similar information from China and Korea is difficult to correlate. In 2003, North American production exceeded 2,500 t at prices that ranged from as low as $60/kg for Artificial Shade 4-year-old-roots to $1,800/kg for Wild American roots. Oriental production dwarfs the North American production but prices start at $25/kg with no records for wild ginseng.

The Australian Ginseng Growers Assoc. Inc remains committed to assisting its members to market as an entity. Continual appraisal of world market trends pinpoint the ongoing need for top quality...
aged roots. This is a niche market which is not being supplied from the rest of the world’s ginseng production. Sales will be directed both within Australia and overseas. The staging of IGC 2004 in Melbourne gave further direction for achieving top sales within this niche market. Australian growers are very excited about their potential to realise these goals in the near future.

Production requirements

Ginseng will not grow in the sun. It requires 80-90% density shade, either artificial or natural; a nitrogen poor soil which can range in structure from sandy to heavy clayey loam; an acid soil with pH between 4.5 and 7; and a climate with four distinct seasons to encourage the plants to progress through their cycle in order to reach maturity. A cold winter is required for stimulation of the root to encourage the following year’s growth. A good rule of thumb is, ‘grow ginseng with apples, not with bananas’. While the plants can survive hot summer days, they do not cope well with high humidity. Tropical or sub-tropical climates are not suitable.

Ginseng is not a heavy drinker but requires a well-drained soil which needs to be kept moist and cool. In times of adversity, ginseng is known to withstand droughts better than floods. Land on river flats subject to flooding, or at the bottom of potentially wet gullies would not be suitable. If required, ground level drip irrigation is better than overhead systems.

Normally unproductive steep slopes and/or forest floor areas where shade is so dense little else grows, can be quite suitable. Easterly or southerly aspects are generally preferable to north- or west-facing land. Beds should be raised to ensure good drainage.

Varieties/breeds

Ginseng (*Panax* spp.) belongs to the Araliaceae family, and is a slow maturing, woodland plant native to Asia and North America. From eleven known ginsengs, the two species with greatest medicinal and commercial value are *Panax ginseng* C.A.Meyer (native to Asia and sold as Chinese, Asian or Korean ginseng), and *Panax quinquefolius* L. (native to North America and sold as American or Canadian ginseng).

Both types are under cultivation in Australia, with the estimated ratio being 80% American and 20% Asian.

Australian-grown seed is not yet available for purchase. New gardens are planted with imported seed and/or Australian grown one-year-old rootlets.

So far, world-wide attempts to clone ginseng have been unsuccessful. Tissue culture is proving useful in research directed at control of disease in the cultivation of ginseng. Australian growers have become quite competent at controlling the germination of northern hemisphere seed so that it becomes acclimatised for Australian seasons.

Agronomy

There are three cultivation methods recognised: artificial shade, woods grown and wild simulated. Each growing method produces different results and consequently different market prices. Approximately 95% of the world’s ginseng production occurs under artificial shade. Wild simulated is the cheapest growing method and produces the highest returns per dried weight yield.

Soil testing for pH and nutrient levels should be done as part of site selection and bed preparation. Minimal tillage should be employed whenever possible. No tillage is used with wild simulated planting. Planting space should be free of debris and weeds, and beds should be raised to provide good drainage. Beds should run down slopes, not across them. Normal farm tilling machinery may be used in open ground. Most site preparation in a forest setting is carried out manually with normal garden implements, although some small mechanical devices may be
useful, taking into consideration obstruction from trees and their roots.

Imported seeds are planted in spring/early summer. Australian grown seeds are planted in late autumn/winter. After planting, mulch is applied to conserve moisture and to protect the plants from hard frosts. If shade structures are being used, frames should be erected but covering is not required until seed has germinated. To prevent damage by heavy snow, shade covers may be removed during winter. If required, install irrigation systems after planting.

The plants are fully deciduous perennials with dieback in autumn and new growth each spring as the natural cycle.

Weeding, re-mulching and addition of soil conditioners are part of winter maintenance. Application of fertilisers should be minimal to ensure better value crops. New beds for planting can be prepared in advance at any time. Apart from site preparation, planting, harvesting and drying time, approximately 100 hours/yr for each hectare of forest cultivation is required for maintenance. Artificial shade maintenance can require less time if it is mechanised.

Plants reach maturity during their fourth or fifth year under artificial shade and after six or more years when grown under trees.

Pest and disease control

Potential pathogens including *Rhizoctonia* spp., *Fusarium* spp. and *Pythium* spp. can destroy young plants. Although soil fumigation or chemical treatments are available, the majority of Australian growers prefer organic methods. Growers should be mindful that chemical treatments have the potential to leave residue on the roots, causing a reduction in market price. More importantly, natural therapies should not contain synthetic substances. Intensive planting in a monoculture garden can leave plants weak and more susceptible to disease.

Less intensive plantings generally allow better air circulation and reduce the risk of foliar transfer of fungal problems.

With approx 70% of gardens in virgin bush soil where beneficial fungi appears to provide the appropriate mycorrhizal action required for healthy growth, there is little evidence of fungal disease being a major hurdle in Australia. Similarly, forest floor gardens have not yet experienced any problems with pests.

Trials in previously cultivated or grazed soils have not been as trouble free. Various treatments have been applied to infestations of reticulate slugs (*Deroceas reticulatum*), cockchafers (*Adoryphorus couloni* and *Aphodius* spp.), chevron cutworm (*Diarsia intermixta*) and corbies (*Oncopera* spp.) with mixed success. Rather than straw, “scratchy” mulches, such as rice hulls mixed with coarse sawdust, can be a deterrent, especially for slugs.

Animals such as possums, rabbits, kangaroos, wallabies and wombats are deterred by fencing. Growers with severe possum attack find it necessary to protect all plantings with small mesh wire enclosures or fully enclosed shade structures. Protecting ripe berries with netting prevents parrots from destroying seed production. Anchoring wire mesh firmly across the surface of planted areas prevents lyre bird problems.

Harvest and processing

Where planted grounds do not freeze, harvesting of the roots can take place throughout the dormant period, otherwise, all harvesting must be completed before the freeze occurs. Harvesting can be done either by hand or by mechanical methods, again depending on the chosen growing method. Mechanical harvest is
done with modified potato or bulb diggers. After harvest, roots are sorted, removing damaged or spoiled roots to avoid a reduction in sale price.

For dried root sales, each day’s harvest is washed, loaded onto mesh trays and placed on the bottom rack in the drying area. Each successive day’s harvest is added at the bottom level with previous trays moved up in sequence. Roots can be air dried in a temperature controlled heated building or in a kiln if quantities are larger. Dried roots are stored and transported in cardboard barrels and require dry atmosphere storage. Correctly dried roots can be stored indefinitely.

Fresh roots need to be harvested as close to sale as possible. They are washed and re-packaged in a growing medium, such as peat moss, for transportation. Fresh roots are stored under refrigeration and are marketable only during the dormant period.

Security measures should be taken to guard against theft of harvested, stored and transported roots.

Ginseng products need to comply with the Australian Therapeutic Goods Act (TGA) and must be manufactured and sold under special Australia List numbers (AustL No). TGA licensed consultants can prepare a listing for approval, although it is possible to do it yourself. Once TGA has granted the AustL No, it must appear on all packaging of the product.

Under the Convention on International Trade in Endangered Species (CITES) the U.S. government has listed *Panax quinquefolius* on Schedule 2.

Therefore, a CITES Permit needs to be obtained from Australian Wildlife Protection before any whole root product is exported, even though the roots are cultivated in Australia. This rule does not apply to export of *Panax ginseng*.

### Financial information

The formula for expenses (Table 1) uses a site comprising 100 beds, 18 m long by 1.5 m wide, which have been planted intensively (50 x 150 mm spacings) with 20 kg of seed. Shade is erected singly over each bed on a structure of posts and wire. The cost of the shade is listed as a total expense but should last for three successive crops. Mulch is spread at the rate of 3 bales per bed. Soaker hoses are used for irrigation and use of fungicides and soil additives is minimal. Costs for land, rates etc., machinery and tools are not included.

#### Table 1: Ginseng production - costs

<table>
<thead>
<tr>
<th>Description of item</th>
<th>1st yr</th>
<th>2nd yr</th>
<th>3rd yr</th>
<th>4th yr</th>
<th>5th yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed – 20kg @$550 per kilo</td>
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<td>Wire and miscellaneous hardware</td>
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<td>Mulch – top up 50 bales per annum @$2</td>
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<td>$15</td>
<td>$20</td>
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<tr>
<td>Soil improvers</td>
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<td>$300</td>
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<td>Sub totals</td>
<td>$22565</td>
<td>$415</td>
<td>$470</td>
<td>$470</td>
<td>$525</td>
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</table>

**Possible total expenses** $24445

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**About the author**

Charlene Hosemans is the wife of Australia’s first ginseng grower, Fred Hosemans. She is the Foundation and current Secretary of the Australian Ginseng Growers Assoc. Inc (see Key contacts for address). Charlene has been an invited presenter at major overseas ginseng conferences including IGC’94, Vancouver, B.C., Canada; ICG’95, Harbin, China; New Crops Conference, Gatton 1996; New Zealand Ginseng Seminars, 1997; IGC’99, Hong Kong; and was Conference Chair for IGC 2003, Melbourne, VIC, Australia.
Projected income (Table 2) is based on the anticipated sale of varying quantities of surplus seed from the end of the third growing season, plus the income from a yield of organically grown dried roots at the end of 5 years. Seed sales are calculated on the possible yield, amount kept for own use and consequent surplus sold. The price obtained for seed is expected to fall as more Australian grown seed becomes available. The production of seed for own use will reduce set-up costs for successive years and should be taken into account for any planning budgets. A harvest of 908 kg (2000 lb) of dried roots is considered to be a good average, with an excellent crop being about 1,589 kg (3500 lb). Some crops yield less than 908 kg per 0.4 hectare (approx. 1 acre).

### Key references

Hosemans, F. and C. Ginseng Growing in Australia, Published by Gembrook Organic Ginseng Pty Ltd.


### Table 2: Ginseng production - income

<table>
<thead>
<tr>
<th>Description of item</th>
<th>1st yr</th>
<th>2nd yr</th>
<th>3rd yr</th>
<th>4th yr</th>
<th>5th yr</th>
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<tr>
<td>Seed sales @ $650/kg Grown 45kg (100lb) – Sold 22.5kg (50lb)</td>
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<tr>
<td>Seed sales @ $600/kg Grown 136kg (300lb) – Sold 90kg (200lb)</td>
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<td>$54,000</td>
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<td>Seed sales @ $550/kg Grown 136kg (300lb) – Sold 90kg (200lb)</td>
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<td></td>
<td>$49,500</td>
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<tr>
<td>Root sales – 908kg (2000lb) @ $160 per kg</td>
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<td></td>
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<td>$145,280</td>
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<td>Sub totals</td>
<td>$14,625</td>
<td>$54,000</td>
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<tr>
<td>Possible total income</td>
<td>$263,405</td>
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</table>

### Key contacts

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Introduction

Jojoba (*Simmondsia chinensis*), pronounced ho-Ho-baa, produces a unique oil (or liquid wax) which has great potential for use in cosmetics and industrial applications. The oil is crushed from peanut-sized seeds that are produced from plantations of hedge-row grown shrubs. This desert plant is extremely drought tolerant, and is well suited to a broad area of inland Australia where it offers not only stable production, but environmental benefits not offered by existing landuse practices. These will ameliorate some of our land degradation problems.

Jojoba oil has many attributes that make it highly attractive to the cosmetic and skin-care industry. Not only does the oil have very acceptable skin-feel properties and excellent moisturising ability, but also it is very stable and gives products a long shelf life.

The industry in Australia is now based on the use of high yielding cloned varieties especially selected for our climate. Since 1993, the area planted has increased to over 400 ha and most plantations have reached production age and are now producing seed. There are at least 25 commercial growers, most of whom are active members of the Australian Jojoba industry Association (AJIA), the peak body for the industry. There are seven other countries that also produce jojoba. Their production is based on the use of ‘seeded’ material. Australia is well placed to become a major producer of jojoba oil because of our varieties, amenable climate and the good technical skills of our farmers.

While good husbandry is a prerequisite in any agricultural enterprise, the timing of many of the operations in jojoba growing is not as critical as for some other crops, eg., fresh fruit harvest. This
Key messages
Select:
• suitable climate
• well drained soils
• suitable varieties
• good management strategies

Key statistics
• Managed jojoba plantations in Australia have increased to over 400 ha of clonal material planted on 25 farms
• Seed production has approximately doubled in each of the past 5 years to about 48t at present.
• Production will continue to increase rapidly as the stands mature and new plantings reach production age.
• The industry will now rely on export markets for its products.

makes it a relatively easy crop to integrate with existing landuse practices as well as offering a reliable return to supplement farm income.

Markets and marketing issues
Sales are still limited to the high price, low volume markets that match the current low world production of about 1 500 t/yr. The cosmetics and skin-care industry buy most of present production and use the oil in its natural form or modify it to a cream or wax. The majority of oil is consumed in the USA and Europe. In 2003 the world trade in jojoba oil was estimated to be worth $AUD 135 million. Current Australian production now exceeds local demand for the oil and growers are now reliant on developing export markets for their product. Increased interest from Asia suggests there is great potential for expansion in the next few years. A small percentage of industrial grade oil comes from second pressings of seed or solvent extraction of meal carried out by a few large producers. This oil is used as an additive in special lubricants.

Typical of agricultural commodities subject to the cyclical nature of production and demand, the world oil price for jojoba oil has fluctuated greatly since commercial production commenced about 25 years ago. There are indications that pricing has become more stable over the past 5 years and jojoba oil currently sells on the world market at about $US 200 ($AUD 10 500)/t.

Production requirements
Much of the inland cereal growing area of Australia is well suited for jojoba production. Varieties that are well suited to the climate of these areas have been selected, but other factors such as soil type and rainfall must also be considered.

Jojoba requires soils that have good internal drainage and not subject to flooding. Apart from pH, the chemical properties are less critical, as fertilisers can be used. Soils with a pH of less than 5.0 are generally not suitable for jojoba because of aluminium toxicity problems. Aspect is generally not important on land with an altitude of less than 350 m, but for higher areas aspect needs to be considered to reduce the risk of late and severe frosts that can cause damage at flowering.

Jojoba is planted as hedge-rows and often on low banks to facilitate weed control and harvest. It can be planted on land with slopes of up to 3% provided the banks are contoured.

Jojoba should not be grown in areas receiving less than 450 mm rainfall annually unless supplemental irrigation is available or planting density reduced from the nominal density range of 1 000 to 1 250/ha. In areas where rainfall exceeds 600 mm per annum, the threat of fungal attack on leaves during wet winters increases dramatically.

Most cereal-growing areas are suitable for jojoba production.
**Varieties**

To ensure ease of management and to have only one crop annually, it is important that all plants in any crop follow a similar growth and fruiting cycle. This can only be achieved in jojoba by using cuttings from registered varieties. Seed should not be used for establishing a plantation.

Jojoba requires both male and female plants to produce seed. There are three female varieties (Barindji, Wadi Wadi, and Waradgery) suited to Australian conditions. They have been selected for their consistent high yields and are registered under the *Plant Breeders Rights (PBR) Act*. Two male varieties—Dadi and Guyambul—are prolific producers of compatible pollen, and are well suited for pollinating the selected female varieties. There is continued interest and activity within the industry to find new and improved varieties to add to the existing ones.

**Agronomy**

Field layout should be planned to ensure that the rows run on the contour on sloping land. This will minimise erosion, provide access and locate drainage areas, and ensure that the most efficient use of the land is made. Hence it is advisable to survey the site well in advance of any work. Jojoba is grown in hedge-rows on low banks spaced at least 5 m apart. The plants are spaced 1.6–2.0 m apart along the rows. Headlands of 5–10 m are needed at each end of the rows to permit machinery access.

Jojoba grows slowly in the first few years and has little competitive ability against fast-growing annual weeds. Good initial land preparation to reduce weed seed numbers assists in later management as it is much easier to work on a broad-acre basis than try to control weeds around individual plants. Small areas of jojoba can be established and maintained by using three point linkage machinery normally found on farms, but large plantations will require special equipment. Land should be fallowed at least 12–18 months before planting to build up soil moisture reserves and reduce weed seed populations. Banks should be constructed at least 3 months before planting to allow them to settle. It is advisable to limit the length of plant rows to 500 m as crop management may present problems, particularly at harvest. The initial fertiliser application should be banded along the rip lines at about the time of bank construction. Ideally it should be placed 15–20 cm below the plant line where it will be readily available to the jojoba but unavailable to weeds. Leaf tissue and soil tests should be used as a guide for subsequent fertiliser needs.

There are two main planting seasons each year. The first is in spring as soon as the soil temperature rises above 20°C at a depth of 10 cm. This gives the young plants maximum growing time before the onset of winter. The second is during autumn from late February until early March after the worst of the hot weather is finished. However, plants can be successfully planted during the heat of summer provided extra care is taken with watering during the initial part of the establishment phase. If the plantation is to be irrigated the layout should be designed to allow young plants to be watered by channels or from drippers.

Planting can be done by hand or with machinery. About 5% of plants need to be male and planted throughout the plantation to ensure adequate pollination of the female flowers. The newly planted cuttings need to be watered-in as soon as possible after planting. Follow-up waterings are most important to ensure the roots to grow out of the potting mix into the surrounding moist soil, especially so if planting occurs in hot weather.

Weed control is the most important operation after planting and it is critical that this is done effectively. Specially designed plant guards are now commonly used by growers to shield young plants and allow directed spraying of weeds. This is complemented by the use of residual pelleted herbicides on the inside of the pots. After the first seasons’ growth plant shaping can commence, using contact sprays and mechanical pruners to produce vase-shaped plants that can easily be harvested.

**Pests and disease control**

There are few pests and diseases in jojoba. Following planting, birds and rodents may be troublesome. Galahs and sulphur-crested cockatoos occasionally attack
young plants nipping them off near ground level, but rarely killing them. There have been several instances where white cockatoos have caused about 5% deaths in small plantings, but these problems are reduced by plant guards and by using scare guns. Rabbits and hares can do similar damage, especially when there is a shortage of green feed.

Aphid attack during spring has been recorded from several young plantings but has never been serious. Insecticides can readily control any outbreak, but experience has shown that natural predators do a better job. Spiders and birds have colonised some plantations and between them control most insect pests. Following fruit set, caterpillars (*Helicoverpa spp*) can attack the developing fruit. The caterpillars appear to invade over a short period of time, soon after flowering, before the capsule becomes too hard for the grubs to penetrate. Only isolated outbreaks have been recorded and, to date, none of the attacks has been serious.

Some plant deaths have occurred that have been attributed to soil borne pathogens, notably *Fusarium oxysporum*, attacking the roots. Research projects are currently being undertaken with Charles Sturt University and the Rural Industries Research and Development Corporation to deal with this problem. Black spot periodically infests new growth at some locations and these outbreaks mostly occur after periods of extreme wet.

Frost can affect the reproductive potential of the plant as well as the vegetative parts. The recommended varieties have been selected to minimise loss of yield potential. Vegetative damage can occur on new growth of all varieties and at all ages, especially in dry winters when severe frosts are more common. Frost damage is usually restricted to new growth made just before winter that hasn't hardened off before the onset of winter dormancy. While it looks bad no lasting damage is done. The flower buds survive and the frosts have the effect of tip pruning, encouraging new lateral growth in the following spring.

**Harvesting and processing**

Off-the-ground harvesters are used overseas. In 2003 companies in Israel and the USA had developed commercial harvesters. Harvesters for Australian conditions will be similar, with several prototypes based on brushing the seed into windrows and then picking it up with either a tray or vacuum being tested. After harvesting, the seed is cleaned of leaf and other debris, washed and dried, then stored until required for crushing. Crushing is carried out using standard oilseed presses. Once crushed, the oil is filtered and may be pasteurised and bleached before storing in sealed drums until required, or sold.
Industry development

The Australian Jojoba Industry Association (AJIA) was formed 10 years ago and attracts members from all aspects of the industry, but has a majority of grower members. The association is active in promoting the industry through newsletters, meetings seminars and field days where there is a free exchange of ideas. The association also acts as the peak body for the industry and collects voluntary plant and oil levies from growers. This money is then appropriated for production and marketing research as directed by the members.

Marketing is a key factor in the success of any industry, more so in a new industry such as jojoba. The growers have formed a co-operative marketing company to oversee the operations from seed crushing to final distribution of the oil, ensuring the highest standards are maintained and that growers receive the highest returns for their product.

Financial information

A well managed plantation set out with properly selected varieties using 1 250 plants/ha will yield about 1 t of seed/ha after 10–11 years under rainfed conditions, and up to 2 t if irrigated. The main cost is the purchase and establishment of the seedlings (about $4 500/ha) with land preparation, planting and tree guards costing another $2 250. Further costs will be incurred if irrigation is used, the cost varying according to delivery method. Following establishment, plantation management costs should be budgeted for weed control and plant shaping until the crop starts production in year 4 or 5. Harvest costs are about $2.5/kg for hand picked seed from small plantations but should drop to $0.20–0.30/kg when machine harvested from larger plantations. Seed yields will increase from year 5 until to about year 12 when they will plateau. Indicative returns from a mature stand are given in Table 1.

Table 1. Projected gross returns for jojoba ($AUD/ha)

<table>
<thead>
<tr>
<th>Yield (kg/ha)</th>
<th>Seed sales ($/t)</th>
<th>Oil sales ($/L)</th>
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<td>2 000</td>
<td>9 000</td>
<td>5 000</td>
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Key references


Key contacts

NSW Agriculture has been responsible for most of the recent research leading to the development of suitable varieties and offers advice. Other State Departments of Agriculture or Primary Industries also have advisory officers to assist.

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Private consultants.
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Secretary: Mr Ian Smithers P O Box 1204 DUBBO NSW 2830 Phone/fax 0268 872647

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**Introduction**

Herbal medicines are today well established in a number of market channels, and there exists widespread familiarity with the names of various common herbal remedies.

This is quite a different situation to that of 15 years ago, when Echinacea for example, never featured in mass market advertising.

As the trend continues towards a more health conscious aging population, herbal medicine is likely to continue to gain an even wider acceptance within the community.

In year 2000, the Secretariat of the Convention on Biological Diversity, estimated that global sales for all herbal products, totalled US$60 billion.

In 2002, import replacement value for the herbal medicine industry in Australia was estimated at $A400 million (Rich B, Cheras P, Myers S., 2002). This suggests there is an opportunity for an Australian herbal medicine industry to become a major export earner, in a premium quality market niche, differentiated from the general global supply.

**Markets and marketing issues**

Medicinal herbs have been traded around the world for many years. Botanical (herbal) raw materials are comprised of the plant parts: roots, barks, leaves/stems, flowers, seeds, fruits, resins. These materials are presented in either a whole or cut form and sifted to a consistently even particle size.

Market prices are usually determined by supply and demand, but generally tend to be stable. Most traded European herbs are priced at source in the range US$2.00 to US$6.00/kg. However, prices paid by end users of raw materials (manufacturers) would vary according to where in the supply chain the material is procured. There could easily be two ‘middlemen’ between the source of raw material and manufacturer of raw material. ‘Middlemen’ may simply be trading herb material sourced from various growers and collectors or in addition may add value by sorting, cleaning, cutting, and testing materials for supply to manufacturers. Prices for imported organic medicinal herbs may range from US$10.00 to US$20.00/kg, due to the more limited supply market. Prices for difficult to grow or rare herbs, may be as high as US$120.00 at source (or higher).

The principal primary market for these raw materials is to industry which manufactures:

- essential oils
- liquid extracts and tinctures
- herbal teas
- concentrated extracts (the form required for the manufacture of tablets)
- plant derived pure pharmaceutical drugs.

Leaving aside the essential oil and pharmaceutical drug market, there are at present in Australia, about six manufacturers directly using dried herbal raw materials for the manufacture of liquid extracts. There are a number of manufacturers using mostly imported concentrated extracts for the manufacture of tablets, functional foods and personal care products. There are also a number of herbal tea manufacturers using...
As the expected Australian domestic and export market for herbal medicine develops, opportunities will arise for the development of a primary industry to supply and support the growth of this market. Access to export markets may be facilitated by the ‘clean green’ image that Australian agriculture presents to the world.

There are three other factors, which if considered in conjunction with the increase in demand for herbal medicines, also suggest that there will be future opportunity for the development of an Australian herbal primary industry.

1. Increasing unsustainability of wild harvesting. Up until the late 1990s, probably close to 70% of traded medicinal herbs (by number of herbs), were harvested from wild plant populations. Some harvesting practices known as ‘wildcrafting’ are defined by accepted harvesting protocols to ensure continuing viability of plant populations. However, many herbs are just gathered, without regard to the ongoing sustainable future supply. In a situation of an ever growing world demand for medicinal herbs, sooner or later, various plant species will become ‘endangered’. Examples of enforceable prohibitions already applied to the trade in wild harvested plant species include: - *Prunus africana*um (Pygeum) and *Hydrastis canadensis* (Golden Seal).

2. As the market grows for herbal medicine, so too will the market and regulatory requirement for herbal raw materials to meet quality standards of safety and efficacy. As the international trade of substandard raw materials has long been a feature of this industry, there will be a greater opportunity for a primary industry in Australia to lift the bar on the quality of raw materials that is available.

3. The Australian Quarantine regulations for importing raw herbal materials into Australia are a significant barrier. It is now getting to the stage where it is very difficult to import raw botanical material without some form of Quarantine prescribed treatment. This results in an increase in costs, time delays and possible compromise to the quality of the raw materials. In a situation of an expanding market, this again suggests a greater opportunity for an Australian import replacement primary industry.

In supplying a consignment of herb to a manufacturer, a herb grower must follow certain steps, which are as follows:

![Supply chain diagram](image-url)
Purity – Is the level of extraneous matter within specification?

Efficacy – Determination of the presence and quantification for the active chemical constituents or marker compounds, through analysis such as– HPLC, Gas Chromatography, Mass Spectrophotometry.

Production requirements

Most medicinal herbs from Europe and North America will do best in temperate climatic regions. Within a climatic region there will be an optimum microclimate for a particular plant species.

Medicinal herbs generally do best in moderate to highly fertile, light textured soils with good moisture retention and drainage. Heavy soils may be acceptable for some crops but tend to be unsuitable for most root crops because of the extra difficulty (and cost) in harvesting and cleaning.

The various geographical and climatic regions in Australia will offer the growing conditions required by most medicinal plant species in demand, although almost everywhere in Australia herb production will need irrigation. Certain herb crops may be unsuitable for summer growing because of heat, lack of rain or, conversely, the intensity of summer rain.

Agricultural practices

Stringent quality requirements apply to the acceptance of medicinal herbs as raw materials for the manufacture of herbal medicines. The quality requirements are prescribed by the Australian Therapeutic Goods Administration through the code of Good Manufacturing Practice.

Three key standards against which herbal raw materials are assessed are:


2. **Purity** – herb and plant part must not be contaminated by extraneous matter including– moulds, foreign plant matter, incorrect plant parts of the specified plant, soil, stones or animal matter, pesticides and heavy metals.

3. **Efficacy** – the herb must possess the required level of medicinally active constituents.

The identity, purity and potency of a herb crop are affected by all cultivation and on-farm processing practices.

All herbal materials are exposed to a wide range of possible contamination sources on farm. To minimize such potential contamination, at the primary producer level, producers of medicinal herbs should be aware that in 2003, the World Health Organisation (WHO) published a code of Good Agricultural Practice (GAP) in a publication entitled *WHO guidelines on good agricultural and collection practices (GACP) for medicinal plants* (Geneva, 2003).

Medicinal herbs

- All packaging must be clearly labeled with: - herb botanical name, batch number, gross/net weight, name of supplier
- The contents of all bags of herb from one batch must be of uniform colour and appearance
- All herb supplied must be properly dried and free of extraneous material (see above). The code of Good Manufacturing Practice designates that there should be no more than 1% extraneous vegetable matter and nil soil or animal matter
- A certificate of identity must be supplied with each product, with material identified by botanical name, plant part and batch number. This certificate should also designate if the herb is organically grown (details of organic certification should be supplied), or details of chemical if used.

Acceptance of a herb consignment by a manufacturer is contingent to the herb consignment conforming to specifications. These typically cover the following–

**Identity** – Does the herb comply by macro identification assessment, TLC fingerprint analysis, HPLC profile?
Elements of this code of practice when adopted into an on-farm crop management system, would assist in the consistent supply of medicinal herbs which meet requirements for identity, purity and efficacy.

The main elements addressed in this code document are as follows:

**Site Selection**
- conduct soil tests to ensure soil is free of chemical residue contamination
- select climatic area and soil type conducive to growing the proposed medicinal herbs
- the soil type, drainage, moisture retention, fertility and pH should be optimal for the herb selected to be grown. eg heavy clay soils are generally unsuitable for root crops. The application of fertilizers should be used sparingly, ideally as part of an organic management system. The ideal is to optimize the development of active constituents in plants rather than heavy vegetal growth
- medicinal herbs of the same species, grown at different sites may have significant differences in either growth habits, harvest yields and/or active constituents, due to the influences of soil and farm microclimate.

**Buildings & Equipment**
- all buildings and areas used for the handling of medicinal plant material must be of an appropriate standard (refer to the Code GAP)
- all equipment must be kept clean to prevent contamination of herb crops and harvested plant material.

**Documentation**
- all on farm processes (eg cultivation, planting, crop maintenance, irrigation, harvesting, post harvest preparation) should be documented
- every batch of dried herb must be assigned a unique batch number

**Personnel**
- all personnel engaged in the cultivation of medicinal herbs must be proficient in plant identification and crop management practices
- all personnel involved in the handling of medicinal plant produce should in all processing procedures, comply with applicable health regulations.

**Seeds and propagating material**
- the start of the raw material chain is the selection of correct seed, plant variety, cultivar and genotype, to ensure the correct primary identity of plant material and potential potency of the herbal material.

**Cultivation**
The cultivation of medicinal herbs is mostly undertaken on cultivated areas of less than 20ha, and often on areas of less than 1ha. The general principles of good plant husbandry including crop rotations should be followed.
- in terms of the intensive management required, herb production is somewhat similar to horticultural production. However, whereas the life cycle of a horticultural crop may be 3 - 6 months, herb crops usually have a much longer growing period, which increases the cost of crop maintenance. Different herb species may be annual, biennial or perennial and need to be managed accordingly. Annual crops may be harvestable within 12 months, whereas the other perennial type crops may need 12 - 20 months before the first optimum harvest time.

**Irrigation**
- in general, medicinal herb crops require irrigation, the extent of which depends on the climate soil type and rainfall. Overhead and drip irrigation systems have been successfully used, however overhead irrigation may lead to an increased problem of weed control.

**Crop maintenance and plant protection**
- specific herb crops may benefit from pruning, or topping at different stages in the growth cycle. In organic crop management systems, weed control is the largest component of crop maintenance.

**Harvest**
- medicinal plants should be harvested during the appropriate season to ensure the presence of active constituents within the herb
- the herb crop should be harvested at the optimal time of day and climatic conditions: avoiding periods of heavy dew, excessive humidity, or rain
- damaged plants or plant parts and extraneous plant materials and soil must be excluded
- freshly harvested plant material must be delivered as quickly as possible to the primary processing facility, to prevent the build up of heat and potential thermal degradation.
<table>
<thead>
<tr>
<th>Botanical name</th>
<th>Common name</th>
<th>Part used</th>
<th>Currently grown in Australia</th>
<th>Potential for growing in Australia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albizzia lebbek</td>
<td>Albizia</td>
<td>Stem Bark</td>
<td></td>
<td>♦</td>
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<td>Common name</td>
<td>Part used</td>
<td>Currently grown in Australia</td>
<td>Potential for growing in Australia</td>
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<td>Seed</td>
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</table>
Primary Processing
- harvested plant material should be shielded from direct exposure to the sun or rain
- freshly harvested medicinal plant materials should be inspected and checked for quality, ie appearance, size, colour, odour and taste
- prior to drying, plant material should be hand sorted, cleaned by vibration and/or washed to remove any extraneous plant parts and soil.

Drying
- the optimum way to dry herbal material is in a kiln, where heat and humidity can be controlled. The drier may be a closed de-humidification system or simple flow through hot air drying system. Other more sophisticated (and expensive) drying systems are available
- hot air should delivered through a heat exchange system. Herbal material should not come in contact with hot exhaust gases
- herbal material must be uniformly dried, to evenly remove moisture and prevent mould formation. A common way of ensuring uniform drying is to thinly and evenly spread plant material on racking which allows for the even circulation of drying air through the plant material
- final moisture content in herbal material should be no more than 10 - 12%
- ideally herb crops should be dried in a system where there is minimal potential for mould growth. This will require adequate ventilation, control of heat and humidity.

Storage
- packaged dried medicinal herbs are best stored in a dark, well ventilated building, off the floor, where daily temperature variations are limited and where the maximum temperature does not exceed 25°C.
- to prevent potential insect infestation due to the hatching of eggs, and assuming fumigation is not an option, packaged medicinal herbs should be frozen at -18°C for a minimum period of three days. eg dandelion root, angelica root are root crops which are particularly susceptible
- storage on pallets, away from walls.

Packaging
- processed herbal materials should be packaged as soon as possible after drying/processing, to prevent potential deterioration of product and protect against unnecessary exposure to potential pest attacks and other sources of contamination.
- appropriate packaging of herbs will prevent the herbs from re-absorbing atmospheric moisture. Best packaging materials are lined woven poly produce bags. For certain herbs, packaging in new wool bales is acceptable.
- if lined produce bags are used, herb material should be sufficiently dried, otherwise herb material will turn mouldy.

Key messages
- Strong growth forecast for herbal medicines
- Meeting well defined quality parameters essential for herbal raw materials
- Opportunities for Australian primary producers

Key statistics
- Global sales for all herbal products valued at US$60 billion (2000)
**Financial information**

A full financial analytical model for medicinal herb production, using Echinacea purpurea as an example, is provided in the accompanying chapter on financial models. An analysis of this type should be conducted for each proposed medicinal herb crop.

The model presented, is based on a production area of 1ha, although the comment is made that this level of investment for 1ha is impractical. The investment presented in this model could probably facilitate larger scale herb production, up to about 6 ha. For less than one ha of production, less mechanisation (and capital investment) with greater labour input may be manageable.

Using the example of Echinacea purpurea, an estimate of yield depends on the planting rate per ha and the dried herb mass per plant. For example, assuming a planting rate of 50,000 plants/ha, a yield of 1.2–2.0 t/ha may be achievable, based on dry root mass per plant of 20–40 g, in the second season. Flowering tops, harvested in the first season, may yield up to 5.0 t/ha, based on a dry plant mass of 100 g/plant. The yield based on these calculations is somewhat lower than that assumed by the model.

It is probably useful to adopt a conservative approach to such calculations until an actual yield is achieved.

Examples of various risks which may impact on assumptions about yield and revenue are as follows:

- actual yield may vary according to the soil and regional ‘microclimatic’ conditions for the land to be cultivated
- unfavourable climatic conditions may result in plant loss within any growing season directly impacting on yield, which may, for Echinacea purpurea root be as low as 400kg/ha
- the lead time to the first harvest may be longer than 12 months, due to insufficient plant root growth to justify a harvest. Consequently, revenue return may be unachievable within this period
- the market for Echinacea flowering tops may be oversupplied as has been the case in recent years, revenue may be only a small proportion of total potential yield.

**Key references**

American Herbal Pharmacopoeia, Monographs.
Pleasance A. ‘Instruction in Commercial Herb Production’ (course notes), Pleasance Herbs, 1999.
Rubin H, Purbrick P. ‘Audit of Medicinal Herbs Currently Grown in the Northern Rivers Region’ Northern Rivers Consultative Committee, 1999.
About the author

Peter Purbrick joined MediHerb Pty Ltd in 1987 to assist with general production operations. From the early 1990s in the role of Purchasing Manager, Peter has specialized in sourcing herbal raw materials, liaising with growers and suppliers within Australia and overseas and has experience in establishing long term supply arrangements. Over the years Peter has contributed to publications and addressed conferences on a range of aspects of the emerging Australian herb industry.

Disclaimer

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Peter Sharp

Introduction

Paprika is a potential new crop for production in Australia. It is from the genus Capsicum that includes capsicums (bell peppers) and chillies. Condiment paprika is Capsicum annuum covar. longum and it is characterised by having long, smooth, intensely deep red fruit with high dry matter content. The fruit is free of the pungent component of “hot” chillies, the chemical capsaicin.

The fruit can be harvested and sold as a vegetable, a sweet chilli. However, the major world uses are for the production of condiment paprika, which is the dried fruit that is milled to a fine powder, or for the production of oleoresin (pigment) by extraction from the condiment paprika. With increased consumer and regulatory demand for use of natural food colouring and flavouring the market for condiment paprika and oleoresin can be predicted to grow. Condiment paprika is a spice and colouring agent used in home cooking and in food manufacture, while paprika oleoresin is widely used in the food canning and smallgoods processing industries. Paprika oleoresin can also be used as a colouring agent in cosmetic and pharmaceutical products. Paprika seed oil is a highly valued seed oil in Asian cuisine.

Key messages

- Paprika is a potential new crop for Australia
- Australia needs to aim at high mechanisation and quality
- RIRDC is supporting breeding of cultivars for Australia
- PVR cultivars will be available in the next few years
- Processing and marketing needs to be developed

Key statistics

- Australia currently imports over 600t of condiment paprika at a cost of over $5 million
- A conservative estimate is that Europe, North America, Japan and SE Asia consume over 20,000t/year
**Markets and marketing issues**

Australia currently imports over $5 million of paprika products, including over 600 t of milling condiment paprika, from about 400 t in 1991. This rapid increase in Australian imports reflects current global demand, which is conservatively estimated to be over 20,000 t/year, in Europe, North America, SE Asia and Japan.

Production statistics from the FAO for 1999 indicate the major producers. It is likely that the total figures for both China and North America include hot chilli production as well. The traditional condiment producing countries of Morocco, South Africa, Israel, Slovenia and Spain have relatively constant production, but production in Zimbabwe is likely to have fallen greatly due to the political problems there. Hungary also had some problems with product quality.

**Condiment paprika production of major producing countries**

<table>
<thead>
<tr>
<th>Country/Region</th>
<th>Production in 1999 (Mt)</th>
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<tr>
<td>Morocco</td>
<td>12,000</td>
</tr>
<tr>
<td>South Africa</td>
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<tr>
<td>Zimbabwe</td>
<td>23,000</td>
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<td>China</td>
<td>200,000</td>
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<tr>
<td>Israel</td>
<td>2,600</td>
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<tr>
<td>North America</td>
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</table>

Paprika is traded as the “half-product” — the dried fruit after the removal of the caylx, or as the milled condiment paprika. The level of colour in these is a key specification, measured as ASTA (American Spice Trade Association) levels, a spectrophotometric measure of extractable colour.

As there is not yet a paprika industry in Australia, markets and marketing will have to be developed. Both condiment paprika and oleoresin from experimental growth and processing in Australia has received very favourable comment from both potential local and Japanese customers.

**Production requirements**

Capsicums and chillies are grown as field crops in several areas of Australia, in South Australia (Adelaide Plains and Riverland), NSW (especially the Sydney basin market gardens, and Narramine), and in various areas of Queensland (Bowen–Burdockin, and Bundaberg regions). These areas will be suitable for paprika, as will be processing tomato areas of the Murray basin.

Paprika is a warm season crop that requires about the same growing conditions as tomatoes. The plants are very susceptible to spring frosts, and grow poorly in the 5-15°C temperature range. Sowing too early in cool soils (September and early October) gives slow germination, and growth.

Seedlings can also be produced for transplanting to enable earlier establishment and reduced seed use. High yields come with daily temperatures of 18-32°C during fruit set. High temperatures do not affect fruit set if moisture supplies are adequate. A deep, well-drained, medium textured, sandy loam or loam soil is best, as is a slightly alkaline soil pH (7.0-8.0). Saline irrigation water (>1200 µS/cm) is not well tolerated, especially by seedlings.

**Varieties/cultivars**

Hungarian cultivars of paprika such as Szegedi 80, as well as US cultivars (not all of which are sweet), such as PapriQueen and PapriKing, have been used for trials in the Sydney basin and in the Hunter Valley by the University of Sydney.

There are currently no Australian-bred cultivars of paprika. However, the RIRDC-funded paprika breeding program at the Plant Breeding Institute, University of Sydney will be releasing a number of cultivars shortly, after Plant Breeders Rights are obtained. Important selection criteria in the breeding program are aimed at providing cultivars that will be suitable for Australian conditions, and also for possible production systems here, the most important being mechanical harvesting, to reduce costs. Selection is for semi-determinate growth habit, high productivity, synchronous early ripening of hanging fruit, resistance to diseases, high germination (for direct sowing) and a detachable pedicel or calyx (for mechanical harvesting), high dry matter, and high ASTA (colour content) with good aroma and taste.

**Cultural practices/agronomy**

Crop establishment and husbandry for paprika is very similar to that for field capsicum. Preparing soil involves various tillage treatments, followed by smoothing and listing and formation of raised beds. Irrigation should be before planting, of either seedlings or seed. High quality seed should be planted, aiming at 200,000 – 600,000 plants/ha, depending on the cultivar. Seed is planted 1.5-2 cm deep. Experience overseas
suggestions that further covering with a further protective 7-10 cm cap of soil that is removed at the crook stage of seedling emergence can be beneficial. Seedlings are planted like tomato seedlings. Shallow inter-row cultivation may control weeds and increase soil aeration, and pre-emergent herbicides may also be useful. Advice from a weed specialist is important for this.

Paprika greatly prefers trickle or furrow irrigation to overhead irrigation, which can burn the leaves and fruits on hot sunny days, and overhead spray irrigation also contributes to disease spread. Fertilisation should follow recommendations for capsicum, with pre-plant application of nitrogen and phosphorous before tillage, or by banding 10 cm below the seed at planting. As the crop grows, a steady supply of nitrogen is needed during fruit set to produce high yields.

**Pest and disease control**

Thrips, leafhoppers and aphids can infest emerging seedlings, while fruit fly and heliothis can attack fruit, and leaves and fruit respectively. Systemic insecticides give good protection against thrips, leafhoppers, aphids and fruit fly. BT sprays are effective against heliothis. All chemicals used should be labelled and licensed for capsicums.

Common diseases of capsicums include *Phytophthora* root rot, *Verticillium* wilt, *Rhizoctonia* root rot, and bacterial leaf spot. Seed fungicide treatments are effective against the three fungal soil-borne diseases (*Phytophthora*, *Verticillium*, and *Rhizoctonia*). Rotations help control of these diseases, so growing paprika after cereals (but not sorghum) or legumes is recommended, only repeating paprika after 3 or 4 years. Tomato crops also have a similar range of diseases and pests, so growth after tomatoes should be avoided.

Viruses are also likely to be important, with curly top virus, tomato spotted wilt virus, lucerne mosaic virus, and capsicum mottle virus known to occur. Control of the insect vectors of the virus will reduce the incidence of infection, as will rotations, and control of solanaceous weeds in the area.

**Harvest and processing**

Fruit can be harvested fresh like vegetable capsicums and sold as fresh sweet chillies in markets. However, for the industrial purposes of producing condiment paprika and oleoresin, mechanical harvesting will be vital for the economics of the industry. There is at present little experience with this. It may be that processing tomato or green bean harvesters can be modified to harvest paprika. One of the breeding aims of the RIRDC-supported program at the University of Sydney is synchronous early ripening, which will facilitate mechanical harvesting. Ethephon® can be used to stop flowering, hasten fruit maturity and defoliate the plants before mechanical harvesting, and fruit can be left on the plants to partially dry before harvest.

The harvest must then be dried (without overheating), slightly crushed and the calyx removed (half-product), and then milled to produce condiment paprika. The machinery and processes for these steps are still under development. Oleoresin production is a specialised process unlikely to be undertaken by producers.

**About the author**

Peter Sharp is the Director of the Plant Breeding Institute of the University of Sydney. He is an expert in the area of cereal molecular genetics, but has in the last few years collaborated with Nickolas Derera AM in developing paprika cultivars, with funding from RIRDC.

A RIRDC-supported PhD student is also developing a hybrid seed production system for paprika under his supervision.
Financial information

As there is not yet an established industry in Australia, complete information in this area is difficult to provide. However, crop establishment and husbandry costs are likely to be similar to those of capsicum, which are about $10,000-12,000/ha.

The cost of mechanical harvesting, drying and production of half-product and then condiment paprika by milling in Australia is not known at present. Trials in NSW indicate reasonable yields of 25t/ha of raw paprika, which will produce about 4,000 kg of milled condiment paprika with a store value of about $25,000. This would produce about 350kg of oleoresin with a value of about $35,000.

It must be emphasised that the price of condiment paprika is highly dependent on quality, as measured by ASTA. In New York recently, Hungarian product at 120 ASTA was about $US 3,900/t while South African product at 80 ASTA was about $US 1,800/t. Clearly, the breeding and production of paprika in Australia will need to concentrate on the high ASTA market (ASTA over 200).

Key references


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Alternative oil seeds for Australia

Clive Francis and Margaret Campbell

Introduction

The Australian oilseed industry is almost solely dependent on canola (Brassica napus) despite the diversity of soils and climates and the threats from disease and insects. The disease blackleg (Leptosphaeria maculans) builds up rapidly and prevents close rotation even with cultivars bred for improved resistance. Canola is not adapted to poorly drained soils and needs high levels of fertility for its success. A single oilseed system based on B. napus is unlikely to be the best fit for all environments and disease exposures. For long-term stability other oil seed crops are needed in the system to satisfy the increasing demand, particularly if the ‘new’ oil seeds have oils of different and better qualities than canola, either for culinary, pharmaceutical or industrial purposes. To be an acceptable alternative or compliment to canola, any new oil seed will need to have a readily marketable, higher value oil and or produce equivalent or better yield in a given environment. There is now a range of alternatives of varied market prospects.

Research is being conducted on a range of alternative oilseed species suitable for Mediterranean environments in Australia. The species are being evaluated as

The plants

The Mustards
Indian or Oriental, Brown Mustard, Brassica juncea and Ethiopian Mustard, Brassica carinata are closely related to canola, with a very similar habit but often taller. Mustards tend to have a higher tolerance to water stress, insect pests and diseases. Yields have often been better than canola especially in drier areas. The highly variable Ethiopian mustard is almost completely immune to blackleg but has been neglected as a crop species in Australia.
The oil from the yellow seeded Oriental mustard is a mainstay of Indian cooking. Main use elsewhere is as a condiment in a wide range of mustards. Dijon mustard employs seed of brown mustard. They have potential for the medium to low rainfall environments of Australia. The oil of some of the lines contains a very high proportion of erucic acid, which gives them potential as industrial oil or for biodiesel fuel.

Ethiopian Mustard produces a lot of biomass, more than any of the other mustards. The leaves are often used as a vegetable in Ethiopia. The colour of the leaves can vary between a bluish green and a deep burgundy.

**White or English Mustard** *(Sinapis alba)*: The ‘hot dog mustard’ of USA, has a niche market as a condiment. Generally the seed yield is lower than the other mustards due to less seeds per fruit, although the seeds themselves are bigger.

In their current high glucosinolate, high erucic forms, there is restricted local opportunity for production of mustard seed for condiments or mustard oil but there is a future potential for export and as biodiesel. Ethiopian mustard, being highly resistant to blackleg, is a candidate for crosses with canola quality *Brassica napus*, as has already been done in Canada and Germany. It appears worthy of a program for reselection for low glucosinolate and reduced erucic acid within the best yielding genotypes of the species.

**Crambe**
*Crambe abyssinica* is established as an industrial oil crop in USA with an exceptionally high concentration of erucic acid (>60%). Tolerant of a range of herbicides and easy to grow, the crop has potential in the medium rainfall areas but seed yields, as distinct from the husked harvest product, have been generally lower than canola. The lightweight pod makes transport expensive and hence the need for an oil extraction plant in the near vicinity to the farmer sources.

The small round Crambe fruit contain just one or two seeds. The whole fruit is harvested as a unit with the pericarp intact.

**Camelina or False Flax**
*Camelina sativa* has a high level (35%) of Omega 3 fatty acid (Alpha Linolenic acid) combined with higher antioxidant levels than other oilseeds. The crop is low maintenance, adapted to sandy soils where it is capable of outyielding canola. Its early vigour makes it competitive with weeds. It has considerable potential, as in Europe, as a food and health oil but is currently mainly used in the cosmetic industry as a base for skin creams and lotions.

Camelina oil, seed and seed meal are marketed in Finland by *Camelina Pty Ltd*. For further information on their camelina products see their web site at http://www.camelina.fi/.

**Golden Linseed**
*Linum usitatissimum* is grown for the health food market and is sold both as seed and as Flax oil. The high Omega 3 content of the oil (> 55%) makes it desirable as a health food supplement but detracts from its keeping quality. High lignan content is an added health benefit. Well adapted to southern Australia, earlier flowering varieties are needed.
Linseed is typically more tolerant of waterlogging with a greater tolerance to herbicides than the other species in this study. Linseed flowers can be white or shades of pale blue. The stems of the plants can be used for fibre and to make linen.

**Garden Stock**
*Matthiola incana,* more commonly known as an ornamental garden plant, is a perennial and relatively slow growing. Weed control early in the growing season is essential. Once established, it is hardy and can be long lasting but its yield potential is not yet clear. It is drought tolerant and some lines appear adapted to salinity. More than 60 per cent of the total fatty acid content of the seed consists of Omega 3. It is potentially very valuable as a health food supplement. Omega 3 fatty acids are reported to confer a low incidence of arteriosclerosis and heart disease in humans, as is the case of ethnic diets containing fish oils.

**Noog or Niger**
*Giuzaotia abyssinica* is more suited to subtropical; warmer areas but has potential as a spring or summer crop in certain areas of southern Australia. *Niger* oil sells for a premium over other food oils in Ethiopia due to its preferred taste and pale yellow colour. In Nepal, the ground up seed is used as a condiment. The whole seed has a strong US market as birdseed. Yields in tropical Australia can exceed 1.5 t/ha but maximum yields require the presence of a pollinator.

**Borage and Echium**
*Borago officinalis* has limited potential in other than cool high rainfall areas. It shatters badly and harvesting can be a problem. The oil in the seeds of Borage contains 22% Gamma Linolenic acid (GLA), a valuable fatty acid essential for good health. The seed oil of Evening Primrose, the more commonly known source of GLA contains only around 10% GLA. Borage oil is currently sold in capsules as ‘Starflower Oil’ in health food shops. The near relative, Salvation Jane (*Echium plantagineum*), a common weed, contains even better health oil characters with both GLA and Omega 3 fatty acids and as a bonus, the anti inflammatory, stearidonic acid. Like Borage, shattering is a problem and being a cross fertilising species a high bee population is needed for maximisation of yield.
Salvation Jane or Patterson’s curse: *Echium plantagineum* is a common sight in many places in Australia. The seed oil is potentially valuable for its anti inflammatory properties and as an aid in wrinkle reduction.

### Markets and marketing issues

The projected marketing study will provide definitive answers to likely prices in dollar terms and will define more accurately the potential area of production. The project is expected to result in the release of new oilseed opportunities for Australian farmers.

### Oil content and quality

The oil content and quality are vital ingredients in defining the value and end use of the alternative oilseeds.

Oil colour can be a selling point for cold pressed oils and in this respect Camelina and Niger produce attractive pale coloured first press oils.

### Health foods

The health food market favors oils high in the essential fatty acids, Omega 3 (Alpha linolenic acid) and GLA (Gamma linolenic acid).

### High Omega 3 oil

There could be a new and better health product for Australian consumers. Cold pressed Camelina oil with 36% Omega 3 and unique antioxidant (tocopherol) levels. This represents a big potential market but may require considerable input to satisfy the Australian food standards agencies, though accepted as a food oil in Europe.

Levels of Omega 3 in linseed are over 50%. This coupled with high lignin content make the seed itself a highly marketable product. Golden seeded lines, especially if organically grown, attract high prices $1300–$2000/t on the UK market. Linseed has an increasing market. Oil from brown seeded varieties is usually put into capsules, the golden seeded varieties are either sold for oil or the whole seed is sold as a health product. Golden seeded varieties attract a premium of approximately $150/t, but it must be organically grown. This year 8100ha will be sown to linseed in UK with the biggest market in organically grown linseed of both types.

The Garden Stock (*Matthiola incana*) has even higher levels of Omega 3 fatty acids with some 60% of its oil comprising this essential fatty acid.

### Table 1. Oil and fatty acid contents

<table>
<thead>
<tr>
<th>Species</th>
<th>Niger</th>
<th>Camelina</th>
<th>Linseed</th>
<th>Stock</th>
<th>Crambe</th>
<th>Borage</th>
<th>Echium</th>
<th>Canola</th>
<th>Ethiopian</th>
<th>Oriental</th>
<th>White</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil content (%)</td>
<td>36.0</td>
<td>35.0</td>
<td>37.0</td>
<td>24.0</td>
<td>28.5*</td>
<td>35.0</td>
<td>20.0</td>
<td>40.0</td>
<td>38.5</td>
<td>38.5</td>
<td>31.0</td>
</tr>
<tr>
<td>Palmitic (16:0)</td>
<td>9.3</td>
<td>4.8</td>
<td>6.3</td>
<td>8.6</td>
<td>1.9</td>
<td>11.5</td>
<td>7.1</td>
<td>4.3</td>
<td>3.1</td>
<td>4</td>
<td>2.6</td>
</tr>
<tr>
<td>Stearic (18:0)</td>
<td>3.3</td>
<td>2.8</td>
<td>5.2</td>
<td>4.3</td>
<td>0.7</td>
<td>4.0</td>
<td>2.9</td>
<td>2.1</td>
<td>2.1</td>
<td>2</td>
<td>1.1</td>
</tr>
<tr>
<td>Oleic (18:1)</td>
<td>14.1</td>
<td>16.1</td>
<td>17.4</td>
<td>14.0</td>
<td>14.3</td>
<td>16.2</td>
<td>14.7</td>
<td>59.0</td>
<td>10</td>
<td>34</td>
<td>14.5</td>
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<tr>
<td>Linoleic (18:2 n-6)</td>
<td>75.5*</td>
<td>16.2</td>
<td>18.3</td>
<td>11.8</td>
<td>9.5</td>
<td>36.7</td>
<td>18.0</td>
<td>20.2</td>
<td>16</td>
<td>27</td>
<td>10.3</td>
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<tr>
<td>Linolenic (18:3 n-3)</td>
<td>36.1</td>
<td>56.2</td>
<td>61.5</td>
<td>6.5</td>
<td>4.1</td>
<td>34.1</td>
<td>10.1</td>
<td>13</td>
<td>12</td>
<td>10.4</td>
<td></td>
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<tr>
<td>Omega 3</td>
<td></td>
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<tr>
<td>Linolenic (18.3 n-6)</td>
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<tr>
<td>GLA</td>
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<tr>
<td>Eicosenoic (20:1)</td>
<td>14.2</td>
<td>1.2</td>
<td>1.0</td>
<td>5.0</td>
<td>4.3</td>
<td>3.1</td>
<td></td>
<td></td>
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<tr>
<td>Erucic (22:1)</td>
<td>2.8</td>
<td>60.1</td>
<td>3.6</td>
<td>47.2</td>
<td>11</td>
<td>36.0</td>
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<tr>
<td>Stearidonic (18.4)</td>
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</tbody>
</table>

* Our best line is a moderate erucic acid selection of Indian Mustard - normally at least 30% erucic

### Table 2. Oil colour and cold press extraction results

(Oil extraction – first press of 1000 gm of seed)

<table>
<thead>
<tr>
<th>Species</th>
<th>Oil extracted (ml)</th>
<th>% extracted (first press)</th>
<th>Oil colour *</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canola</td>
<td>350</td>
<td>83.3</td>
<td>7 A, (Yellow)</td>
</tr>
<tr>
<td>Niger</td>
<td>310</td>
<td>86.0</td>
<td>6 D (Pale yellow)</td>
</tr>
<tr>
<td>Camelina</td>
<td>300</td>
<td>81.1</td>
<td>5 D (Pale straw)</td>
</tr>
<tr>
<td>Linseed</td>
<td>275</td>
<td>88.0</td>
<td>8 A (Yellow)</td>
</tr>
<tr>
<td>Crambe</td>
<td>225</td>
<td>72.5</td>
<td>7 B (Yellow)</td>
</tr>
</tbody>
</table>

* Colour grading RHS color chart of the Royal Horticultural Society. Kew Gardens, UK.
Health benefits of Omega 3 consumption
- improved regulation of blood pressure
- reduced risk of cardiovascular disease and blood clotting
- lower risk of bowel and prostate cancers
- improved foetal and infant development
- treatment of rheumatoid arthritis and some forms of depression.

Source: CSIRO Division of Plant Industry

High GLA oils
Borage marketed as Starflower oil, has significant levels (20-25%) of GLA (gamma linolenic acid) - twice as much as the widely marketed Evening Primrose oil (9-12%) GLA. Echium oil contains not only as much GLA as Evening Primrose oil but 30 % Omega 3 as well. As an additional bonus it contains the valuable anti-inflammatory Stearidonic acid with reports of 10-14 %.

Health benefits of GLA 3 consumption
- atrophic eczema
- reduction of cholesterol levels
- treatment of mild hypertension
- reduction of premenstrual tension

Source: Horrobin (1984)

The mustard market
A relatively small market for seed for condiment mustard production exists in Australia. Mustards in South East Asia however, are a major industry, with India and its neighbours, Bangladesh and Pakistan importing more than 100,000t annually from Canada. This could well represent an opportunity for Australian farmers if the market could be established with a reliable supply chain.

The industrial oil market
Crambe oil is used as an industrial lubricant. *Crambe abyssinica* has potential as an industrial fatty acid feedstock as a source of erucic acid. Erucic acid is used mainly as erucamide, an effective non-stick agent in polyolefin films for wrapping food, plastic bags, shrink-wraps, lubricants, plasticisers and foam suppressants. It can also be converted to nylon 1313, or hydrogenated to behenic acid, which also has many applications in the manufacture of rubber, pharmaceuticals, cosmetics, fabric softeners, hair conditioners and rinses.

Crambe oil is a very effective lubricant, and is much more biodegradable than mineral oils, so it may be used alone or as additives for the textile, steel and shipping industries. It is based as an industry in North Dakota USA but has proven unstable in terms of grower interest. A UK market for 30-50,000t exists established by John K Kings and Sons. This would entail the oil extraction and import into UK. This could be met from Australia as refined oil. The seed export and handling is made more expensive by the adherence of the fruit coat, doubling the volume of seed for transport and undoubtedly making container shipping too expensive.

In recent years, the production of Crambe in North Dakota has fluctuated as the commercial players involved in the industry have changed and supply has proven unreliable. Its future will depend upon both the future of bio-renewable resources together with innovative research to develop additional markets for the crop. It faces competition from easier to handle HEAR cultivars of *B napus* and potentially from *B. juncea* selections.

New quality oils
Niger is highly prized for its edible oil qualities in Ethiopia, India and Nepal. Polyunsaturated with some 80% linoleic acid, its composition closely resembles that of sunflower oil but is more attractive in colour. In addition, there is a substantial birdseed market in the USA. Despite the availability of markets in Australian and a good overseas demand for this tropical or subtropical crop, it has yet to be fully exploited in Australia except by a Kununurra producer seed RB Des(s)ert Seed Co. Tapping into the USA birdseed market is an attractive aim.

Production requirements
Niger is regarded as a tropical or subtropical species. It is frost sensitive, but was tested in these experiments under winter rainfall conditions in southern Western Australia. The Ethiopian lines are more vigorous, slightly later, and more tolerant to cooler temperatures than the Indian subcontinent lines. It is tolerant of poorly drained soils and but prefers relatively fertile loams. The presence of bees is important.
to sustain adequate yield and if possible production should be coupled with a commercial honey producer.

The mustards are more widely adapted than canola and will out yield it in lower rainfall areas (350 mm or less). Like canola, loamy, relatively fertile soil is preferred. Shorter growing lines especially for the white mustard are the preferred type for harvesting. They are relatively non-shedding compared to Canola and can be directly machine harvested.

Camelina, despite its small seed, nevertheless establishes quickly on a range of soil types and rainfall regimes in southern Australia as a winter-sown crop. It is frost resistant. Our research indicates an adaptation to sandy soils not favored for the production of canola or the mustards.

Linseed is well adapted to southern Australia over medium to high rainfall, but current cultivars tend to be later maturing than the other oilseeds. It has some special properties being tolerant of a much wider range of herbicides than the other alternative oilseeds. This is important, as good weed control is most import for a species which lacks early growth or seedling vigour. It is also far more tolerant of poor soil drainage than the Brassicas in this study.

Crambe grows aggressively in Southern Australia on both loams and sandy soil. Its seedling vigour and spreading habit allows it to compete well with weeds and it is one of the easiest of the oil seeds to generate a vigorous crop. It retains its seed husk at harvest and in comprising some 50 % the weight, makes transport over any distance an expensive exercise relative to the other alternative oil seeds.

**Varieties**

The emergent varieties are yet to be named. Current advanced generations include two selections of Camelina, an Indian (oriental) mustard selection, two Ethiopian mustards and a golden linseed.

Seed of Niger is commercially available. As of the end of 2004 commercial quantities (sufficient seed for 100 hectares plus) of Camelina, Indian and Ethiopian mustards are planned to be available to interested parties. Similar quantities of the golden linseed selection would be available in the following year.

**Crop agronomy**

Seed yields confirmed the highly variable nature of the harvestable yield of the oil seeds. This is a consequence of the diversity of environments chosen for the preliminary yield trials and the fact that oil seeds are sensitive to biotic as well as edaphic and climatic factors. The poor yield of canola sown at 5 kg/ha near Meckering in 1999, reflected aphid damage on the one hand whilst the sandy relatively infertile soil of this site produced a low yield of all species. Crambe is vigorous and well adapted, but yields (seeding rate 15 kg/ha of husked seed) include the pod husk, which does not separate from the seed on harvest with conventional machinery so that actual seed yield, is some 50% of the figure in table 1. Amongst the species it was the most prone to shattering and the yield figure

**Table 3: Alternative oilseeds mean yield (kg/ha)**

<table>
<thead>
<tr>
<th>Species</th>
<th>Niger</th>
<th>Camelina</th>
<th>Linseed</th>
<th>Crambe</th>
<th>Borage</th>
<th>Canola</th>
<th>Ethiopian Mustard</th>
<th>Indian Mustard</th>
<th>White Mustard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seed yield (kg/ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northampton 1999</td>
<td>300</td>
<td>167</td>
<td>1761</td>
<td>902 *</td>
<td>396</td>
<td>1,428</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meckering 1999</td>
<td>60</td>
<td>188</td>
<td>592</td>
<td>715 *</td>
<td>455</td>
<td>197</td>
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<td>Miling 2000</td>
<td>180</td>
<td>1940</td>
<td>1850</td>
<td>2535 *</td>
<td>95</td>
<td>1883</td>
<td>2486</td>
<td>2755</td>
<td></td>
</tr>
<tr>
<td>Wagen 2000</td>
<td>56</td>
<td>1290</td>
<td>952</td>
<td>1438 *</td>
<td>99</td>
<td>850</td>
<td>1777</td>
<td>2330</td>
<td></td>
</tr>
<tr>
<td>Miling 2001</td>
<td>1000</td>
<td>1590</td>
<td>1900 *</td>
<td>55</td>
<td>2460</td>
<td>1900</td>
<td>2350</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>Wagen 2001</td>
<td>1015</td>
<td>700</td>
<td>1700 *</td>
<td>68</td>
<td>Shatter</td>
<td>1200</td>
<td>2370</td>
<td>830</td>
<td></td>
</tr>
<tr>
<td>Northam 2001</td>
<td>920</td>
<td>730</td>
<td>1220 *</td>
<td>68</td>
<td>830</td>
<td>870</td>
<td>1110</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meredith 2001</td>
<td>1920</td>
<td>440</td>
<td>1840 *</td>
<td>1540</td>
<td>1210</td>
<td>1340</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mingenew 2002</td>
<td>590</td>
<td>210</td>
<td>660 *</td>
<td>780</td>
<td>710</td>
<td>550</td>
<td>666</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mingenew 2003</td>
<td>1050</td>
<td>1300</td>
<td>1870 *</td>
<td>1390</td>
<td>1310</td>
<td>1440</td>
<td>690</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Norcia 2003</td>
<td>420</td>
<td>1,300</td>
<td>1630 *</td>
<td>2130</td>
<td>2190</td>
<td>2020</td>
<td>850</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best yield</td>
<td>729</td>
<td>2360</td>
<td>2003</td>
<td>2685 *</td>
<td>455</td>
<td>2460</td>
<td>2746</td>
<td>2755</td>
<td>890</td>
</tr>
</tbody>
</table>
Alternative oil seeds for Australia

is likely to be conservative. With crops new to the Mediterranean environment, more research is needed on optimisation of seeding rate, harvesting methods, weed control strategies and time of sowing. Despite the limitations of the field trials, it is nevertheless clear that both linseed on poorly drained soils and Camelina (on deep sandy soils) can be the equivalent or better in yield than canola. There is every indication that Indian and Ethiopian mustard are capable of out yielding canola as they did quite significantly ($p < 01$) at the two lower rainfall sites sown in 2000. The non-shattering character of the mustards obviates the need for windrowing and is an important cost saving ($25/ha) advantage.

The yields of the small seeded *Camelina sativa* were particularly promising at recommended seeding rates of 4 kg/ha. Although in this case not significantly better than canola, the figures do indicate that, particularly on sandy soils, the species has significant potential. Given that there was no real basis on which to select from the available restricted germplasm base for this species, it is well worth more intensive investigation with additional genotypes now at our disposal. Where blackleg is a problem, it may be that Camelina could prove to be a highly profitable cleaning crop given the attractive qualities of its oil in terms of its potential food quality and health benefits.

The Borage selections used were local garden types. It did not yield well even when hand harvested in quadrats. This is not to say other higher yielding lines might not be found. The species however is an obligate out crossing species and thus needs bees. It will as a consequence always be highly variable in yield. A more important difficulty is the highly shedding nature of the seed head whereby the seed begins to shed well before the stems and branches are mature. This will mean heavy yield loss with conventional harvesting even when windrowing is employed. It can be expected that Échium would encounter the same problems. Losses of more than 60% are reported in USA (Simon et al 1990). Despite its valuable oil profile in terms of its gamma linolenic acid content, its yield is always likely to be unreliable and difficult to harvest. However if prices are anything like those in USA (around US$3.20 kg), it may still find a niche market as it has in the UK where it is a regular part of the rotation of some farms (Nicholls 1996).

Niger was not adapted to the colder winters at most sites but the normally frost-free environment of Northhampton (729 kg /ha yield) showed that there is some potential for a winter rainfall crop. Such a yield is consistent with average yields (approximately 500 kg/ha) in the centers of its cultivation in Ethiopia, Nepal and India (Getinet and Sharma 1996). Some cultivars are reported by these authors to have a margin of cold tolerance. Such lines are to be found from the highlands of Ethiopia and Mid-Hills of Nepal. Being a cross-fertilised species, bees are important and were in abundance at Northampton. Depending on the premium for the oil and the high value, albeit restricted birdseed market, further evaluation of the now extensive gene base is indicated in the subtropical areas of Australia as a winter sown crop in Northern Australia or as spring-sown crops in the winter rainfall areas where supplementary irrigation may be available.

Farmer groups like the Western Australian No Till Farmers (WANTFA) see alternative crops suitable for no till agriculture as environmentally friendly. The Mustards, Camelina and Crambe are well suited to no till farming as has been demonstrated at the farmer group field days. Fertiliser requirement can be closely aligned with those for canola. The lack of Triazine resistance now so popular with Canola growers is however a disadvantage in no till systems which in fact are often dependent on the use of herbicides.
No adverse changes to the farming environment are foreseen. A potential benefit is a weed-inhibiting (allelopathic) characteristic reported for Camelina, a useful character if it applies to common weeds in our agricultural areas. It is known as a minor weed in flax but not recorded as a problem in other crops. It does not have seed dormancy.

**Pests and disease control**

Blackleg, *Leptosphaeria maculans*, is the most serious soil borne disease of the Brassicas. Rotation, sowing onto clean land and resistance are the only practical controls. The new mustards and Camelina are far less susceptible to black leg than Canola. This is especially the case with Camelina and the Ethiopian mustards, which appear immune. This provides the opportunity for shorter rotation than currently practiced for Canola to be used should they prove profitable.

Canola and the mustards are susceptible to attack by diamond back moth (*Plutella xylostella*) the caterpillar stage of which attacks both the leaves and developing fruit. Again the mustards, especially Ethiopian mustard, are less susceptible than commercial Canola varieties. Insecticides containing cypermethrin are proving useful in Canada. The use of synthetic pyrethroids is not proving very effective and resistance can quickly develop occasioned by the frequency of spraying necessary to control the caterpillars.

Aphids are an occasional problem with all the species but again the mustards, perhaps related to the spicy glucosinolate levels, are less prone to attack. Recommended sprays like Pirimor will greatly reduce the infestations whilst remembering that spray and application cost $15-25/ha and if used too frequently, development of resistance may prove a problem.

**Harvest and handling**

With the exception of Matthiola, all the winter growing oil seed crops can be direct headed with conventional machinery provided the harvest is timed to be as soon as the crop is ripe. For the mustards the screens and machinery settings should be as for Canola whilst finer screens may need to be on hand for the small seeded Camelina. Delays can result in harvest losses in the Indian mustard lines and Camelina is also prone to seed loss and sometimes lodging if harvest is delayed. Despite the vigilance needed, the harvesting does represent a cost saving on the need to swath. Of the oilseeds under test the maturity ranges over one month from early November to mid December.

Matthiola, a perennial, may not set seed until year two although the varieties selected for further evaluation have all produced seed in their first year of production albeit somewhat late in the season (mid January)

The large scale crops can be delivered in bulk or packaged in bags for container shipment. Oil milling would of course relate to bulk and subsequent package in bottles for market of Camelina or mustard oils. Species with a high value heath food market, such as linseed, would normally be in sealed bags. The product would then be repackaged by the health food chains. The oil of this species for health food use needs to be

### Table 4. Approximate maturity of lines available

<table>
<thead>
<tr>
<th>Species</th>
<th>Approximate maturity, Miling, WA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oriental mustard</td>
<td>Early November</td>
</tr>
<tr>
<td>Camelina</td>
<td>Mid November</td>
</tr>
<tr>
<td>Early Canola (Karoo)</td>
<td>Late November</td>
</tr>
<tr>
<td>Crambe</td>
<td>Mid November</td>
</tr>
<tr>
<td>Ethiopia mustard</td>
<td>Early December</td>
</tr>
<tr>
<td>White mustard</td>
<td>Early December</td>
</tr>
<tr>
<td>Golden linseed</td>
<td>Mid December</td>
</tr>
<tr>
<td>Matthiola</td>
<td>January</td>
</tr>
</tbody>
</table>
encapsulated due to instability resultant from the high level of Omega 3 fatty acid or after careful cold pressing, kept refrigerated in dark bottles. If the ultimate use is for furniture oil or cricket bats such a precaution is of course unnecessary.

Financial information

Start up costs of mustards or Camelina can be closely equated with a TT canola for bulk trade. Such comparison, as in the table, must however be treated with caution as the price may well depend on the scale of production. It is unwise to compare profitability of an initially small crop like Camelina or golden linseed initially perhaps a few hundreds of tonnes with larger crops of 500,000t like canola. The results may also be soil type specific.

The table is constructed based on a medium rainfall 350–500 mm rainfall canola growing area in WA. Mustards may well be more profitable than Canola in drier areas and on wet soils linseed is likely to be relatively more profitable. The important issue is however that a range of oilseeds can be grown profitably provided the markets are in place.

Details of the gross margin analysis is available on the farm budget guide http://budget.farmonline.com.au/search.asp

A typical gross margin for 375 mm rainfall in the Central wheat belt of WA at $375/t for Canola less freight, handling and other levies ($35), results in a nett on farm price of $340/t.

For Camelina and the linseed which might be handled in bags the freight and handling is estimated at $50.

Table 5: Estimated costs and gross margins for some of the alternative oilseeds and canola

<table>
<thead>
<tr>
<th>GROSS INCOME</th>
<th>Treatment</th>
<th>Oriental mustard</th>
<th>Golden linseed</th>
<th>Golden linseed organic</th>
<th>Camelina</th>
<th>Canola</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain yield (Net price/t)</td>
<td>1.5 t/ha @ ($290)</td>
<td>0.80 t/ha @ ($450)</td>
<td>0.60 t/ha @ ($1400)</td>
<td>1.0 t/ha @ ($430)</td>
<td>1.4 t/ha @ ($340)</td>
<td></td>
</tr>
<tr>
<td>Total Income /ha</td>
<td>$435</td>
<td>$360</td>
<td>$840</td>
<td>$430</td>
<td>$476</td>
<td></td>
</tr>
<tr>
<td>VARIABLE COSTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed</td>
<td>20.00</td>
<td>60.00</td>
<td>60.00</td>
<td>25.00</td>
<td>24.75</td>
<td></td>
</tr>
<tr>
<td>Fertiliser</td>
<td>Agstar 43.50</td>
<td>43.50</td>
<td>43.50</td>
<td>43.50</td>
<td>43.50</td>
<td></td>
</tr>
<tr>
<td>Urea</td>
<td>38.50</td>
<td>38.50</td>
<td>38.50</td>
<td>38.50</td>
<td>38.50</td>
<td></td>
</tr>
<tr>
<td>Organic</td>
<td></td>
<td></td>
<td>150.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cartage</td>
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<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
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<tr>
<td>Sprays</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knockdown</td>
<td>Roundup 5.23</td>
<td>5.23</td>
<td></td>
<td>5.23</td>
<td>5.23</td>
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</tr>
<tr>
<td>+ chlorpyrifos insects</td>
<td>4.46</td>
<td>4.46</td>
<td></td>
<td>4.46</td>
<td>4.46</td>
<td></td>
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<tr>
<td>Treflan</td>
<td>17.60</td>
<td>17.60</td>
<td>17.60</td>
<td></td>
<td></td>
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<tr>
<td>Pre-emergent</td>
<td>Atarazine 11.25</td>
<td>11.25</td>
<td></td>
<td>11.25</td>
<td>11.25</td>
<td></td>
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<tr>
<td>+ Treflan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Post –emergent</td>
<td>Select for grass</td>
<td>11.25</td>
<td>11.25</td>
<td>11.25</td>
<td>11.25</td>
<td></td>
</tr>
<tr>
<td>+ Atrazine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lontrel</td>
<td>6.16</td>
<td>6.16</td>
<td>6.16</td>
<td>6.16</td>
<td>6.16</td>
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<tr>
<td>Fastac for moths</td>
<td>9.35</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Machinery operating</td>
<td>Fuel and oil</td>
<td>22.00</td>
<td>22.00</td>
<td>30.00</td>
<td>22.00</td>
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<tr>
<td>Repairs and maintenance</td>
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<td>23.00</td>
<td>30.00</td>
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<tr>
<td>Contractors</td>
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<td></td>
<td></td>
<td>20.00</td>
<td></td>
</tr>
<tr>
<td>Harvesting</td>
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<td>25.00</td>
<td>25.00</td>
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<tr>
<td>Seed bags</td>
<td></td>
<td>28.00</td>
<td>28.00</td>
<td>36.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>On farm</td>
<td>10.00</td>
<td>15.00</td>
<td>15.00</td>
<td>15.00</td>
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<tr>
<td>Insurance</td>
<td>Fire and hail</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
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<tr>
<td>TOTAL</td>
<td>237.00</td>
<td>306.00</td>
<td>344.00</td>
<td>278.00</td>
<td>291.00</td>
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<tr>
<td>MARGIN</td>
<td>$198 /ha</td>
<td>$54 /ha</td>
<td>$496 /ha</td>
<td>$152 /ha</td>
<td>$185 /ha</td>
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Key references


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Coffee

James Drinnan & David Peasley

Introduction

The advent of machine harvesting triggered the reestablishment of the coffee industry in Australia in the mid 1980’s and the Australian industry is now making its mark on domestic and export markets. However, continued investment is required to maintain a high quality and consistent product capable of competing successfully in a highly competitive world market.

Coffee growing in Australia appears an attractive proposition at first glance. We import virtually all of our 48,000 tonnes of raw coffee (called dry green bean (DGB)) into a domestic market worth over $600 million; we can produce a distinctive high quality Arabica coffee suitable for the rapidly growing roast and ground market which has grown by 28% over the last 5 years; we do not have the major pests and diseases of other coffee producing countries, and can therefore produce a “clean” product; we have drastically reduced our production costs by harvesting mechanically; and we have enjoyed a price premium (over double the world price) on our domestic market.

However, as the production volume increases there are significant issues facing the industry as our product starts to compete in the highly competitive world coffee market. Australian producers will have to overcome industry fragmentation and become highly efficient in their production costs and produce an internationally accepted grading system and specifications if they...
are to be successful in the long term. Whether the price premium can be maintained will depend on the ability of the Australian industry to produce a consistent high quality product and the success of marketing strategies to exploit the comparative advantages and market opportunities for the “new” product. A price premium is seen as essential for the viability of the Australian industry.

There are now four coffee growing regions in Australia – the tropical tablelands of Far North Queensland, the central Queensland coast, subtropical south-eastern Queensland and north-eastern New South Wales (see Table 1).

Australia imports around 12,000-15,000t of Arabica coffee annually for the Roast and Ground market. Australia’s total production of 500t DGB (dry green bean) in 2002 is only 1% of the total volume of coffee imported or 6% of the total volume of Arabica imports.

Markets and marketing issues

The world coffee market is enormous. Almost 8 million tonnes of the raw product, Dry Green Bean is traded annually, worth over $US10 billion with a retail value (roasted) of over $US50 billion.

At present the world is awash with cheap coffee, largely Robusta and low quality Arabicas. As a result of continuing unsustainable prices, in order to survive, many producing countries are improving the quality of their coffee to target the upper, ‘boutique’ or gourmet end of the market where price premiums are significant. Specialty coffees such as single origin, shade grown, ‘Rainforest Alliance’, ‘Fair Trade’ and various accredited organic and ‘natural’ grown coffees are attracting price premiums because of their social and environmental appeal. This category is gaining momentum internationally, but from a very small production base and it is this expanding but highly competitive market that Australia’s fledgling industry has the capacity to target in both the domestic and export markets. Our ‘disease free’ status and natural production systems already in place are attractive comparative advantages which could be exploited in marketing Australian coffees on the world market.

Competing in this market will not be easy and Australia faces major challenges with its very small production volume (500t) and a fragmented industry. Gaining credibility as a reliable and consistent supplier is paramount in this highly competitive international market. A few larger producers in Australia have already successfully initiated export development programs through brokers to Europe, Japan, USA, New Zealand and Hong Kong.

The current rate of growth in demand for Roast and Ground coffee in Australia is 6%. This equates to approximately 1,000t of extra volume each year for Arabica coffee on the Australian market. This volume far exceeds the expected total Australian production in 2007/08 of just 1,600t.

Australia’s domestic market is still highly attractive for high quality Australian grown Arabica.
coffee. A standard price of $8-$9/kg DGB has operated for over 10 years, compared to the average price for imported high quality Arabica of $3-$5/kg DGB. As production increases over the next five years these price premiums will be challenged.

Internationally, coffee is traded as Dry Green Bean (DGB) as a commodity, and prices are set in New York based on an international grading system. The NY commodity price sets the price for all trading around the world; however individual sellers, brokers, buyers and roasters will negotiate the price for individual lots based on its quality versus the benchmark of the NY stock price.

The negotiated price for individual lots of DGB coffee is based on a sample of coffee supplied to the buyer. Price is determined by the quality of the sample on visual appearance and the number of defects (size of bean, colour, broken beans, extraneous matter, etc) and the cupping quality.

Currently most of the locally produced coffee from smaller producers is ungraded and sold within the region through local roasters and labels directly to retail outlets. Trading of DGB and roasted coffee outside the region is being undertaken by the larger producers who are exploring new domestic and export markets as supply exceeds local demand.

**Production requirements**

Coffee originated as an understorey plant in the highland tropical rainforests of Ethiopia. These areas are frost-free, have mean daily temperatures of 20°C and an average annual rainfall of 1800-2000mm well distributed but with a dry season of 3-4 months. The important factors in site selection in Australia for coffee production based on machine harvesting are as follows:

**Temperatures**

The cultivars grown today in Australia prefer a relatively mild frost free subtropical climate with mean temperatures between 15°C and 25°C and as a consequence coffee does well in elevated tropical areas. Temperatures below 7°C and above 33°C slow growth and reduce production. Small diurnal variations in temperature (that is day/night) are also preferred. Coffee is highly susceptible to frost and even short periods below 0°C will defoliate the bush.

**Rainfall**

The rainfall pattern is probably one of the most critical requirements in the choice of a suitable site for coffee production based on mechanical harvesting. For machine harvesting to be successful a reasonable synchronisation of flowering and fruit ripening is required. The rainfall and irrigation pattern control the flowering pattern to a large extent. In Far North Queensland with a reliable dry season during flowering
(winter/spring) and where there is irrigation, flowering can be controlled by deliberately water-stressing the trees and then heavily irrigating. Controlling flowering is not practical in the subtropics because of the lack of a distinct dry period and the extended maturity period for coffee on the tree. A reliable dry season and cool temperatures during fruit ripening (winter for Far North Queensland and spring for the subtropics) are also required to aid machine harvesting (see Figure 1). Wet and warm conditions during fruit ripening can dramatically reduce harvested yields (because of fruit drop). For the rest of the year reasonably well distributed, high rainfall is preferred. This allows for good fruit growth and the development of large beans. Good irrigation can overcome the need for high rainfall.

**Soil**

The soil needs to be well drained and aerated, as coffee does not tolerate waterlogging. A free draining depth of at least 0.5-1.0m is preferred. Where coffee is grown on more fertile volcanic soils, irrigation and fertilizer management is much easier than on sandy soils.

**Altitude**

Overseas literature recommends an altitude of 900-1200m for arabica coffee cultivation. However, this altitude really relates to suitable temperature and rainfall patterns. Research in Australia and growers’ experience has shown that good quality coffees can be grown at altitudes from 15-900m and the higher latitudes of the subtropics above frost level.

**Slope**

Flat ground is preferred for machine harvesting, but hydraulic levelling on the machine allows it to harvest up and down slopes of up to 15% and side slopes of up to 6-8%.

**Shade**

Shade is not required for coffee production. Where adequate nutrition and irrigation are provided, yields are greater without shade.

**Wind**

Coffee trees are very sensitive to wind damage which can severely reduce productivity; therefore, windbreaks are essential. Wind can cause ringbarking in young trees and also cause them to lean over, which interferes with the harvester.

Given these climatic requirements many areas along the Queensland and Northern New South Wales coast are suitable for coffee production.

**Varieties**

Initial plantings were based on the local cultivar Kairi Typica and Bourbon, Arusha, Caturra and Blue Mountain imported from PNG. Yields were disappointing with only 0.5-1 t/ha green bean. Some newer cultivars have now been evaluated by QDPI and NSW Agriculture. The recommended cultivar for North Queensland is Catuai Rojo, because of its high yield and quality, dwarf stature and late maturing time. For the cooler subtropical areas of Southern Queensland and Northern New South Wales, K7 is preferred for the warmer sites and a local selection CRB is suitable for cooler locations. These varieties produce high yields of good quality, large beans and are tall growing.

**Agronomy**

Being highly self-pollinated, coffee is propagated by seed and therefore does not need grafting. To avoid the risk of “off-types” resulting from cross-pollination, seed should be selected from proven trees in blocks of the one variety. Seedlings are available from
Coffee

specialist nurseries, particularly for mechanical planting. However, most growers raise their own seedlings. Seed is available from existing growers or the QDPI.

Seedlings are raised in seed germination beds under 50% shade and then transplanted into polythene planting bags at the 2-3 leaf stage. Seed takes 4-8 weeks to germinate. The plants are then gradually sun hardened and are ready for field planting at 20-30cm tall in about 8-12 months. Some growers have planted seedlings bare rooted from seed beds to reduce costs. Planting is usually carried out at the start of the wet season.

Trees are planted in hedgerows for ease of machine harvesting, weed control, fertilising, irrigating, spraying and mowing. Trees are spaced between 0.75m and 1.0m apart within the rows and 3-4m apart between the rows (depending on the cultivar and the climate). This gives plant densities of 2500-4400 plants/ha. A ground cover is usually established between the rows to reduce erosion.

Before planting the ground is usually deep ripped and cultivated along planting lines. Trees are planted into mounds (30-40cm). It is important that rocks, sticks and stumps are cleared from the field to enable the harvester to operate smoothly.

Windbreaks should be established before field planting, as trees are sensitive to wind damage. *Pinus caribaea* and Bana grass (*Pennisetum* spp.) have been used successfully as windbreaks in Far North Queensland. In the subtropics Sorghum provides excellent protection for the first two years when planted within 1m of each coffee row on the windward side.

Coffee trees are fairly slow to establish in the field for the first 12-18 months because of inherently slow growth rates and poorly developed root systems. Therefore weed control in the early establishment period is critical. The planting rows should be mulched and kept weed free 50cm either side of the plants. Pre-emergent and post-emergent herbicides are used but young trees are sensitive to spray drift.

Once trees are established heavy shading from the trees canopy reduces the need for herbicides. Some problems have been experienced with climbing vine weeds (eg. *glycine* (*Glycine clandestina*) and sirato (*Macrotilium atrapurpureaem*). Trees start to crop after 2 years but cannot be machine harvested until 3 years of age (because of size). Full production is not reached until year 4 or 5. Yields of 1.5-2.0t/ha dry green bean (DGB) could be expected in Far North Queensland and up to 2.3t/ha in the subtropics.

Coffee beans nearing time for harvest

Coffee trees grown intensively under full sun have a very high nutrient requirement. Before planting, fertilisers are incorporated into the planting strip (especially phosphorus) and soil pH is adjusted to 5.5-6.0. Fertiliser is then banded along the rows at 4-6 week intervals. As trees come into full production (year 4 and 5) 300-400kg of N and K/ha and 15kg P/ha are needed. Foliar fertilisers are often applied in times of peak need. Common nutrient deficiencies experienced in Australia have been Zn, Fe, Cu and Mg. Fertigation is proving cost effective in supplying the required nutrients to the coffee plant with minimal waste. Special mixes have been formulated for use in coffee.

Coffee requires a plentiful supply of water all year round except during the late stages of floral development (September- November) when a period of water stress can be used to manipulate flowering in far north Queensland under tree and overhead irrigation have been used. Overhead irrigation has been used to protect young trees from frost on small plantations. The irrigation requirement is around 3-7ML/ha/year. Under subtropical conditions monitoring moisture
use by the tree using hand held electronic sensors is recommended to assist in scheduling irrigation according to plant needs. Yield increases of 25% have been achieved with strategic irrigation as well as an increase in bean size. Irrigation requirements of 1-2 ML/ha/year have been required under subtropical conditions. Full details of research results are available from the RIRDC project publication titled ‘Irrigation of Coffee in the Subtropics – Best Management Guidelines’.

**Pest and disease control**

Australia is fortunate to be free of the two most serious and widespread coffee diseases, coffee berry disease and coffee rust. Coffee trees in Australia have only a few pest and disease problems and these are not serious. Green coffee scale (Coccus viridis) and mealy bug (Planococcus spp.) are the two most common pests. Both attach themselves to leaves and young branches and draw nutrients from the tree. In large numbers they cause a general decline in tree health, affecting yield. Ants are often associated with scale and mealy bug infestations. Sooty mould grows on the sticky residues produced by the scale and mealy bugs and covers the leaves, reducing photosynthesis; this also contributes towards the decline in tree health. In warm, dry environments, scale and mealy bug can become widespread and may need to be controlled chemically. White oil, refined water miscible oil and Lorsban (in Queensland only) have been used successfully. Research trials have shown that where there are only minor infestations, natural predators (parasitic wasps) and the disease (Verticillium) usually keep populations under control. In the subtropics natural predators and good management (nutrition and irrigation) are usually adequate to control these pests. Control spraying with paraffin oil may be required for heavy infestations.

The only significant disease in coffee trees is cercospora (Cercospora coffeicola), a fungus which causes leaf spotting and defoliation and attacks fruit, causing premature ripening. It is most prevalent in warm wet weather, in nurseries and early field establishment, usually where nutrient levels have not been adequately maintained. In severe attacks repeat sprays of foliar copper will control the fungus.

**Harvesting and processing**

The harvester is a large self propelled three or four-wheel machine which straddles the rows of coffee. Within the harvester frame are two vertical shafts which carry hundreds of fibreglass fingers (40-50cm in length). The fingers vibrate and rotate through the bushes as the harvester moves forward down the row (3ha/day). The fruit is dislodged from the branches by the action of fingers and is caught on a catching frame which transports the fruit to storage bins on the harvester.

An Australian developed (QDPI) coffee harvester is now commercially available (manufactured by CASE International in Brazil) and the American built Korvan harvester is the latest machine currently in operation in Northern NSW. Other machines for use on smaller plantings and steeper land have been evaluated, including a tractor drawn harvester and hand held harvesters which remove cherries from individual branches. But these have not proved very successful. High labour costs generally make it uneconomic to harvest coffee by hand ($6/kg vs. $0.60/kg for machine harvesting).
As ripening commences, the coffee fruit changes from green to red, then to dark red-purple and eventually black when over-mature. There are two processing methods to obtain green bean which is used for roasting, both require specialist processing equipment including a mechanical drier. The simplest method is ‘dry processing’ where coffee is harvested over ripe and then dried to 10-12% moisture. The dried skin and parchment is then removed by hulling, leaving green bean coffee. This method is commonly used to process robusta coffee and produces a lower quality product than ‘wet processing’. In wet processing, coffee is harvested as ripe red fruit. The fruit is pulped to remove the two seeds from the skin (Figure 1). The seeds are then fermented or passed through a demuscilager to remove the sticky mucilage layer around them and then washed and dried to 11% moisture. The parchment and silver skin are then removed by hulling and polishing, leaving green bean coffee. The bean is referred to as ‘green bean’ because of its colour. It normally takes between 6-7kg of fruit to produce 1kg of green bean coffee. This method of processing produces the best quality coffee. Most of the coffee produced in Australia is processed using the ‘wet’ method. The problem with this method has been that all immature green cherries must be removed to produce top quality coffee.

When machine harvesting is used (as opposed to hand-harvesting), cherry samples for processing often include various amounts of over and under-mature fruit as well as mature ripe, red cherries. These samples when processed using traditional processing equipment produce very poor quality coffee. Until recently this was the major problem of the newly established Australian coffee industry. New processing systems have now been developed. One developed by QDPI uses flotation, size grading and selective tyre pulping to separate fruit of different maturities, so that top quality coffee can be produced even from samples with mixed fruit maturities. Another system being imported uses a cherry classifier which separates cherry of different maturities by selectively pulping fruit through a screen. Care must be taken not to pollute the environment from the waste produced in the factory.

Coffee growers usually process their coffee to the dry green bean stage. Equipment to colour sort and size grade is required for this. The green bean is then sold to processors for blending and roasting. However, some of the Australian growers roast, grind and package their own coffee and do some of their own marketing. Quality is assessed by bean size, freedom from defects and liquor quality. Prices are significantly better if you sell the bean as speciality or gourmet coffee. No central marketing group body or co-operative exists so individual growers must develop individual marketing plans. There have been some attempts at group marketing, although these have not been very successful.
Financial information

An economic assessment of coffee production in North Queensland was undertaken (Hosegood et al 1988, Hosegood 1991 and Hassall and Associates 2004). These economic studies estimated farm profitability for machine-harvested coffee, establishment costs, rates of return and break-even yields and prices.

Hosegood investigated the profitability of a new 20ha plantation and a 10ha plantation on an existing farm, with both farms using contract harvesting.

Both studies found that these plantations were marginal for the yields and market prices at that time.

The conclusion from those reports was that a yield of 2t green bean/ha and a price of $4/kg are required to make coffee production profitable.

In the report by Hassall and Associates, they found a 20 ha plantation required a capital outlay of $410 000 (year 1). Establishment costs were around $10 000/ha and operating costs $3000/ha (year 2 & 3) and $5000/ha thereafter. Using a yield of 1.6 t/ha and $6/kg they found an internal rate of return of 13%.

For the subtropics the following budget summary is based on the costs and returns of establishing and growing 1ha of coffee on the North Coast of New South Wales.

The study by Planning and Management Project Pty Ltd (1999) was sponsored by RIRDC. The report estimated establishment costs at $22,000/ha; this includes a technology fee, land preparation, irrigation, seedlings and planting. If the technology fee is removed industry leaders indicate this figure may be reduced to $15,000/ha (or $5/tree at 3000 plants/ha).

Maintenance costs were $5,000/ha, harvesting (contract) costs were $1,200/ha, and processing (contract) costs were $2,300/ha. A yield of 1.15t/ha in year 4 and 2.3t/ha from year 5 on with an 80% recovery was used. A selling price of $8/kg for DGB was assumed. This study estimated a gross margin of $2,300/ha, which rises to $3,600/ha if the reduced establishment cost is used.

First commercial yields are expected in the third-fourth year after transplanting. Full commercial yields are expected five years after transplanting where conditions are good. Some form of tree rejuvenation (pruning) will be required in years 7-10, depending on variety, to maintain the trees in a productive and manageable state for harvesting.

There is a reduction in yield in the year following pruning. Stumping (pruning to 30cm above ground level) may be required after year 10 depending on climatic conditions, production history and management. No production occurs for two years after stumping, which should be done on a rotational block basis to maintain cash flow.

Key references


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David Peasley, (WDA) is a Horticultural Consultant based in Murwillumbah. Since 1984, David has evaluated coffee varieties, harvesting systems and irrigation strategies for coffee in the subtropics. He organised the first coffee marketing summit in 1990 to determine the market potential for Australian coffee and has undertaken overseas consultancies on coffee. He is Chair of the Australian Coffee Industry R&D Advisory Council.

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Coffee
Japanese green tea

Audrey Gerber

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Introduction

Green tea (*Camellia sinensis* var. *sinensis*) is traditionally consumed in Japan as a beverage renowned for its health giving properties. The Japanese market represents approximately 20% of the world green tea market. In recent years the per capita consumption of traditional green tea has declined, forcing companies to investigate alternative marketing strategies to attract the younger generation. Significant growth has consequently occurred in the canned beverage market which now occupies close to 15% of the market. In addition, the individual components in green tea are undergoing analysis and extraction to assess their potential for use in cosmetics, as nutrition supplements, as flavours and fragrances and as disease cures and preventatives.

Projected consumption in Japan of green tea as a beverage vastly outweighs potential domestic production. Consequently many Japanese companies are sourcing production outside Japan. Japanese markets for green tea however are very demanding and high quality product is required.

Traditional bulk agriculture markets such as Africa and China are considered unsuitable due to inferior tea quality. Australian agribusiness has a reputation among Japanese markets for professional management and high quality products.
Research and development programs funded by RIRDC have been carried out over many years in Tasmania and elsewhere and interest in R&D on this crop has come from a number of states over the years. Commercial green tea production in Australia currently takes place in NE Victoria, initiated by the Japanese beverage marketing company, Ito En. Ito En perceives a rapid and continued increase in the demand for prepared green tea sold in PET bottles or cans by vending machines in Japan.

Investigation by company sponsored agronomists indicated that the climatic conditions of NE Victoria are suitable for commercial production of Japanese style green tea. The significant progress of the green tea industry in Victoria can largely be attributed to the contribution of the Australian Green Tea Growers Association (AGTGA), assisted by Commonwealth funding. In addition, Ito En Australia Ltd has a strong financial and personal commitment to the growth of a sustainable industry.

Interest in green tea production is increasing in Western Australia and New South Wales due to the attention of another Japanese company seeking to develop the crop in Australia. The Manjimup and Pemberton area in Western Australian and the area inland from Gosford are considered suitable. In both areas commercial plantings have yet to occur, although production of rooted cuttings and assessment of suitable areas is occurring in anticipation.

Green tea production for the Japanese market is an intensive horticultural enterprise. Once established, plants can continue to produce commercial harvests for 30 years. During the establishment phase, however, maintenance of the young plants is labour intensive. In order to optimise economies of scale a 10 ha production unit is considered economically viable. To manage this size unit mechanical production techniques are required. The opportunity exists, and is being implemented in NE Victoria, for neighbouring farms to share equipment.

Markets and marketing issues

Japan currently consumes approximately 100,000 t of green tea per annum, 90,000 t of which are produced domestically. The balance is imported and any future expansion of consumption in Japan must be met by an increase in imports as domestic production cannot expand.

In the current situation green tea produced in Australia is designed for Japanese markets. The fresh leaf will be processed locally into crude tea and shipped to Japan for final grading, blending, further processing where required, and packaging. A processing factory requires significant capital to establish and run. Consequently fresh leaf is the marketed commodity and it is unlikely that individual farms will process the fresh leaf and market a finished product.

Small-scale production for niche domestic markets may be possible using mini-processors designed for experimental work. Established black tea companies in Australia have begun marketing green tea, based largely on imported product.

Current commercial plantings in Australia consist of 50 ha in NE Victoria with the first harvest due in spring 2004. Strategic planning within the industry aims at a total of 250 ha planted by the end of 2006. Projections of Japanese consumption indicate that the leaf from 10,000 ha will be required within the next 10 years to fill Ito En’s markets. Other Japanese companies are also showing interest in Australian production of green tea to fill projected market expansion.

Key messages

- Domestic consumption of Green Tea in Japan exceeds production
- Market growth requires new production areas
- Japanese companies have confidence in Australian agriculture
- Traditional production techniques require modification for Australian conditions
- Minimum production size for economic viability
- Processing requires specialised equipment

Key statistics

- 50% increase in Japanese consumption expected over the next decade
- 50 ha commercial green tea currently established in Victoria
- 250 ha required in Victoria by 2006
- Market share of canned green tea to rise to 40% of Japanese domestic consumption

Japanese green tea

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Production requirements

Green tea plants require a period of cold induced dormancy to produce the chemical compounds which contribute to the health giving properties. A long summer growing season encourages shoot growth enabling repeated harvesting. Although the plant can withstand cold conditions during winter the young tissue is sensitive to frost, and early spring frosts will ruin the first harvest. High temperatures during the growing season may inhibit growth thus reducing yield. Plant growth in NE Victoria is considered satisfactory despite summer temperatures over 35°C.

Active growth occurs through summer and, unless summer rainfall exceeds 1,000 mm, irrigation is required. In the establishment phase (from planting to first harvest) more frequent irrigation is required due to the shallow root of the young plant. Preliminary estimates indicate that green tea requires 4-ML water per ha during the growing season. Drip irrigation is considered the most efficient system, although use of overhead sprayers may also be suitable. The latter tends to encourage inter-row weed growth.

Green tea plants require deep, well-drained acidic soils. A soil pH of 4.5-6.0 (H2O) is considered ideal, with a useable soil depth of 60 cm. The requirement of green tea plants for good drainage tends to suggest that gently sloping sites are ideal, however, provided soils are well drained, flat sites are also suitable. Steep slopes should be avoided due to manoeuvrability and safety issues involved with the specialised machinery required. Pruning or skiffing and harvesting techniques result in the formation of a continuous horizontal canopy thus eliminating the need for specific row orientation. In general north-facing slopes will provide a longer growing season, however, depending on local climate, the cooler conditions provided by south and south east facing slopes may be advantageous. Coastal areas may present problems with wind blown sand and spray causing damage to tea plants.

Varieties

Cultivars currently grown in Australia are Yabukita, Sayamakaori and Okuhikaori. Cultivars vary slightly in their growth rate and, therefore, time of harvest. This information is used, together with local climatic and topographic variation, to spread the harvest between farms in NE Victoria. This strategy enables equipment to be shared. The precise interaction of growth rate and harvest time with climate in Australia has yet to be quantified. Both Japanese companies currently interested in Australian green tea production have a number of other cultivars and seedlings undergoing trials for suitability to local conditions. Access to plant material is largely restricted to growers linked with specific companies.

Cultural practices/agronomy

Experience in Victoria indicates that standard site preparation a year before planting significantly reduces the weed problem experienced during the establishment phase. The use of appropriate herbicides or annual crops reduces the seed bank of weeds in the soil.

Where sub-surface compaction needs to be broken to facilitate root growth and drainage, deep ripping may be required. Soil analysis will indicate amendments needed prior to planting, eg pH amendment, phosphorous addition. For mechanical planters to operate effectively the surface soil must be light and friable. Equipment currently used for mechanical planting is either a modified vegetable seedling planter or a modified...
tobacco planter. In both cases rooted cuttings in plug trays are manually fed into a feeder chute. Equipment is commonly shared between farms. Plant spacing is either 40 cm apart in single rows 1.8 m apart (14,000 plants/ha), or in double rows (22,000 plants/ha). Individual farm equipment directs the choice of planting density. Initial yields may be lower due to a longer time taken to form a complete canopy, but estimations are that mature yields will not differ with a lower planting density.

Young plants have shallow roots and require immediate watering following planting and frequent watering until established.

In Victoria planting is done either in spring when the soils are first dry enough to work or in autumn after the first rains (autumn break).

During the establishment phase weed control requires vigilant attention. Strategies vary between farms, depending on equipment available, but most use a combination of targeted herbicide treatment, manual removal and inter-row mowing.

Canopy management during the establishment phase involves repeated, well-timed pruning or skiffing.

New growth is cut back to promote branching which encourages the plant to form a low, spreading bush. A two-man hand held sickle-bar trimmer is suitable, although specialised ride-on equipment is available in Japan.

Nitrogen is required both to support the vigorous new growth that is harvested and to form leaf chemical compounds which contribute to quality. Fertilisation through irrigation lines enables targeted and well-timed nitrogen application for optimum growth while restricting run off or leaching. Phosphorous and potassium are also required as part of a balanced nutrition programme. Any fertiliser addition should be based on leaf and soil analyses.

The first harvest from green tea plants is possible four years after planting, leading up to a mature size harvest in the 6th year and every subsequent year.

Depending on plant vigour 3–5 harvests are possible in a growing season, spaced approximately six weeks apart from late spring/early summer. Harvesting is done mechanically using specialised equipment that straddles the plants.

DPI Victoria is currently managing a series of R&D projects, funded by HAL and Ito En, with the long-term aim of developing best practice management strategies.

Many of the current agronomic uncertainties relating to commercial production of green tea in Australia will be clarified to

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**About the author**

Audrey Gerber is an Industry Development Officer for the Primary Industries Research Victoria (PIRVic) branch of DPI Victoria, based at Ovens in North East Victoria. She works with New and Innovative Industries to identify barriers to industry growth and help to find ways to overcome them. The Green Tea industry and the Wildflower industry in Victoria are currently offered assistance. Roles include organising and presenting training sessions, managing and conducting R&D and promoting interaction within the industry.
enable optimum yield and quality of green tea to be produced in a cost effective and environmentally sustainable manner.

**Pest and disease control**

Strict AQIS quarantine regulations and procedures prevented the simultaneous importation of known green tea pests and diseases along with plant material into Australia.

Commercial plantings of green tea introduce a new plant species (*Camellia sinensis var sinensis*) into agricultural areas where other crops undergo attack by known pest and disease elements.

It is unreasonable to expect that new host/plant interactions will not occur. Programmes are in place in Victoria to monitor pests and diseases and implement appropriate IPM strategies.

Table 1 lists the insects identified in green tea plantations in Victoria, many of which are beneficials. Currently no agrochemicals are registered in Australia for use on green tea.

In the first year following planting young plant deaths were reported due to African black beetle (*Heteronychus arator*) and white fringed weevil (*Naupactus leucoloma*)

Appropriate soil treatment prior to planting would eliminate deaths due to these pests.

**Harvest, postharvest requirements and processing**

Green tea leaves are harvested repeatedly through summer when sufficient new leaf growth has occurred. In NE Victoria it is anticipated that 4 harvests will be possible, spaced approximately 6 weeks apart starting from mid-November.

Harvesting starts four years after planting, reaching maximum yield at 6 years, and continues for up to 30 years (with correct management). The new growth is harvested using specialised equipment that rides over the tea plants.

Fresh green tea leaves deteriorate rapidly following harvest. In Japan it is recommended that fresh leaves arrive at the factory for processing within one hour of harvest. On arrival leaves are steamed to inhibit chemical processes that would otherwise occur resulting in deterioration of the fresh leaf and subsequent quality of processed tea.

The distances in Australia limit compliance with this recommendation. In addition, climatic conditions in Australia are significantly different from Japan to anticipate that post harvest deterioration may differ in rate and pattern. Current practices in Japan need to be assessed and refined where appropriate. A transport and storage strategy suitable for Australian conditions is currently under consideration, investigating storage and transport under conditions of low temperature and high humidity.

Processing of Japanese green tea involves 6 steps and requires specialised equipment for steaming, rolling and drying. During this process the weight of tea reduces by 70-80%. A processing factory, financed and managed by Ito En Australia Ltd, will be established in NE Victoria in time for the first commercial harvest. The initial equipment has the ability to process the leaf from 130ha, and the factory will expand with additional units of equipment to keep pace with the anticipated growth of the industry.

**Financial information**

The key factors in an economic analysis are price and yield. Yield data from different sources varies greatly as does price, which is dependent on quality and market destination. Until this information is available from commercial green tea production in Australia any financial information is only an estimate. An economic analysis produced by Department of Natural Resources and Environment (now DPI Victoria) assesses cash flow scenarios of different combinations of price and yield. Yields ranging from 8.6 t/ha to 18 t/ha was matched with prices for fresh leaf of $1.17/kg to $0.40/kg. For economies of scale a 10 ha plantation was analysed.
The capital required for establishment of ten hectares of green tea is estimated at $130,000. This includes the purchase of general farm equipment (including a second-hand tractor), purchase and installation of irrigation equipment and fencing. It is assumed that the green tea buyer will supply specialised harvesting equipment. Annual running costs are higher in the first year (approximately $6,500/ha), decreasing to approximately $3,500/ha in year four and subsequent years. Owner/operator labour is costed at $15/hr.

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Olive oil

Susan Sweeney and Gerry Davies

Introduction

Olive oil is an international commodity. The development of a local industry must therefore be considered in an international context. Australia has the climate, physical resources, horticultural infrastructure and expertise to support a modern olive industry. However, other southern hemisphere countries also have the resources and have also started developing their own olive industries. In addition, the production resources are in demand by other horticultural industries within Australia.

Despite this, olives, particularly for oil production, have become a substantial horticultural industry based on existing domestic demand and the potential for the development of export markets.

The health benefits of olive oil and the continuing interest in Mediterranean cuisine, ensure that it is a popular choice for consumers across the world. Nevertheless, locally produced olive oil must be able to compete against other vegetable oils with similar chemical characteristics and alternatives, including imported olive oils, which may be cheaper.

Markets and marketing issues

Olive oil markets are dominated by Spain, Italy, Greece and Tunisia which account for approximately 85% of world production and a similar percentage of consumption.

World olive oil consumption has risen by almost one million tonnes over the past twelve years. The perceived health benefits, a continuing interest in Mediterranean cuisine and promotion by the controlling body
of the industry, the International Olive Oil Council, are all stimulating market demand for olive oil, particularly in countries not traditionally associated with olive oil such as the USA and Japan.

In 2002/3, Australia imported 32,748 t of olive oil (30% extra virgin) valued at $139 million. The average annual growth rate of olive oil imports has been 17% for the past ten years in Australia. There are no accurate figures for local production of olive oil but it was estimated at about 1,500 t in 2003 (D. Taylor, pers. comm.). This figure will grow rapidly as the estimated 8 million trees planted in Australia in the last 10 years come into full production (Sweeney, 2002).

Strong local demand and the potential for exports have seen a renaissance in the Australian olive industry. It has been estimated that output from recent plantings can provide most of the demand for olive oil on the domestic market within five to ten years. It is important therefore for the local industry to quickly develop both the domestic and export markets for Australian olive oil.

The growth in interest in olive oil production is undoubtedly driven to some extent by the high prices ($22 to $65/l) which are currently being achieved by some locally produced oils. In contrast, lower quality imported oils are retailing at $8 to $12/l in supermarkets. This implies that the import price is around $4/l or less. Australian extra virgin oil either needs to compete with this low import price or differentiate itself sufficiently for consumers to pay a higher price.

A reasonable price, acceptable taste and reliable supply of sufficient volumes of consistent quality oil are all required to gain acceptance and shelf space in supermarkets. This is important in underpinning the growth of the industry.

Economies of scale and modern production techniques based on worlds’ best varieties and practices can place Australia in a strong competitive position. Even so, it must be recognised that there is competition from other southern hemisphere producers, and from other vegetable oils such as canola.

**Production requirements**

The olive originated in the Mediterranean region and will grow well in areas of Australia with a similar climate ie cool, wet winters and warm dry summers. They will produce in other areas as long as they have the correct chilling requirement (winter temperatures fluctuating between 1.5°C and 18°C) and summers long and warm enough to ripen the fruit. The trees can suffer severe damage at temperatures less than -5°C. Hot dry winds or rain at pollination in late Spring may reduce fruit set. As well, significant rain at harvest-time, may reduce the extractability of oil from the fruit due to the higher water content in the fruit. This appears to be particularly problematic for fruit normally grown for table olive production, such as Manzanillo.

The shaded areas on the map show regions in Australia with similar climatic regimes to traditional olive growing areas in Europe. There are other areas not indicated on this map where olives are grown successfully. However, long term economic viability is yet to be determined. Recent results from the National Olive Variety Assessment Project, funded by RIRDC, show that olives grown in the cooler, more southerly latitudes in Australia, produce higher levels of oleic acid in the oil, a positive...
characteristic, than olives grown in the more northerly latitudes of Australia.

Olives will grow in most soil types as long as they are well drained and have a subsoil pH range between 6.5 – 8.5. Steep slopes should be avoided if it is intended to use machinery, especially mechanical harvesters, which may not operate efficiently at slopes greater than 17°C (30%).

Tree spacing is generally around 250-300 trees/ha to optimise yield and light interception at maturity. Some growers are experimenting with higher density hedgerow plantings with the aim of increasing early yields and straddle harvesting the trees, much like wine grapes. These high density plantings require greater management input and as mentioned are still in the experimental stage.

Olives can be grown without irrigation but water stress will significantly reduce yields. Californian research has shown they need approximately 1000 mm of irrigation plus rainfall annually to produce maximum yields. Good yields are possible using less water but this requires careful irrigation management to ensure minimal water stress during critical growth stages.

**Varieties**

There are many different oil varieties available in Australia although DNA typing is showing that some varieties with different names are actually the same. Some of the more commonly known varieties include Arbequina, Barnea, Californian Mission, Coratina, Frantoio, FS17, Koroneiki, Leccino, Nevadillo Blanco, Pendolino and Picual. All have their own particular characteristics such as oil yield, organoleptic (taste and smell) characteristics, resistance to stress, productivity, tree vigour, time of ripening and ease of harvest and all of these characteristics should be thoroughly researched before a choice is made. Probably the best advice though is to research what your market wants and then determine whether these varieties will grow in your particular environment.

Nearly every olive variety will benefit from some form of cross fertilisation with another olive variety to optimise yield. Experimental work is still determining which varieties pollinate other varieties best. In general, it is best to have at least 3 to 4 different olive varieties to optimise cross-pollination. Different olive varieties should be within at least 30 m of each other, preferably closer.

Due to the current confusion in olive variety identification in Australia, planting stock should only be purchased from reputable nurseries with good quality control and DNA certified varieties. Any waiting period should be spent developing a business plan and preparing a site.

**Agronomy**

Although olive trees are hardy, to yield well they require the same high level of management as other commercial tree crops, particularly in their first few years of growth.

Soils should be tested for their nutrient status before planting, as many corrections are easier to make without trees in the ground. Olive trees will respond to fertilisers and it is important to take regular soil and/or foliar samples for nutrient analysis. As well as ensuring a correct balance of trace elements, a combination of NPK should be applied half in autumn and half in spring.

Young trees are vulnerable to strong winds and should be staked or trellised, particularly if a single straight stem is required for mechanical harvesting. Protective

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*Portable catching frame for small scale harvesting of olives*
paper or foil wrapping around the trunk will protect the young tree from sunburn and herbicides. Competition from weeds can be a major problem for young trees but is easily managed by using herbicide along the tree row leaving a strip of pasture in the middle of the row which is regularly slashed.

The young tree will need to be pruned to encourage it into the correct shape (usually vase or conical) to optimise efficient removal of olives by mechanical shaking. Once this is achieved the tree should be pruned every year to maintain the shape and tree health by allowing air and light to enter and circulate through the tree canopy. If the trees have been planted specifically for straddle harvesting, protruding limbs that may obstruct the harvester will need to be controlled. Olive trees are biannual bearers and pruning at the correct time during “on” years will encourage more shoots and subsequent fruit growth in the following “off” year.

The time from planting to first harvest is variety dependent and also dependent on management techniques. Some varieties will come into commercial bearing at only 2-3 years of age. Most olive varieties though will take at least 4-5 years and even longer if not cared for properly. Maximum production is generally achieved by years 7-8. Young trees can be induced to yield earlier by correct irrigating, fertilising and pruning.

The olive knot bacterium which produces galls on trunks and branches, has recently been identified in Australia on isolated properties. Sound orchard management and hygiene should keep this disease under control.

**Pest and disease control**

A major advantage of olives is that they are relatively pest and disease free in Australia. Very few chemicals should be needed for successful olive cultivation and it has good potential to be grown organically, particularly in drier areas. If pesticides must be used, the National Registration Authority has information on which chemicals are permitted for use on olives and under what conditions they can be applied.

The most common pest is black scale which also affects citrus. Olive Lace Bug (not to be confused with beneficial lace wings) can also be a problem, particularly in the Eastern states. The Curculio beetle or weevil is a common pest in new plantings that were formerly pasture.

All of these pests can be controlled but they should be positively identified and expert advice sought to minimise indiscriminate spraying of broad spectrum insecticides which will also kill beneficial insects.

The main fungal problem is peacock spot which results in leaf fall and poor fruit set. It is more common in humid areas and correct pruning to allow adequate air flow through the leaves will help keep it under control. Anthracnose, or fruit rot can also affect olives. Copper sprays can be used for both of these fungal diseases.

Olives are also harmed by some soil borne pathogens such as phytophthora, verticillium and nematodes common to other fruit trees. If the site has been previously used as an orchard the soil should be tested for these organisms and fumigated if necessary.

The olive knot bacterium which produces galls on trunks and branches, has recently been identified in Australia on isolated properties. Sound orchard management and hygiene should keep this disease under control.

**Harvest, handling, packaging, storage, post-harvest treatments and processing**

Olives have traditionally been harvested by hand but for an economically viable large scale operation mechanical harvesters are essential. Mechanical shakers can either shake olives off individual limbs or vibrate the whole trunk.

Over-row harvesters similar to grape straddle harvesters can also be used on small trees. Other mechanical harvesters that comb the foliage are being developed by enterprising local engineers. Correct training and pruning of trees is crucial for mechanical harvesters to be able to operate efficiently.

Fruit should be transported to the processing plant under optimum conditions and processed as soon as possible.
as possible after harvest to reduce oxidation and fermentation which will produce faulty oil.

Impeccable hygiene is vital at the processing plant to produce a fault free oil. Modern processing plants that crush the fruit, mix the resulting paste and then separate the oil from the paste in one continuous process are usually employed. Traditional mat presses are generally not recommended as it is extremely difficult to keep the mats scrupulously clean. A continuous process system with a capacity of 1.5 t of fruit per hour, will cost around $500,000 although smaller, cheaper machines suitable for boutique operations are also available.

Olive oil has a quality grading system based on chemical and taste tests. Virgin olive oils (extra virgin, virgin and ordinary virgin) are obtained solely from the fruit by mechanical or physical means without using chemical extractants or excess heat (greater than 28°C) that will alter the characteristics of the oil. Extra virgin olive oil is considered the best quality grade and is the primary focus of most olive oil producers in Australia.

Refined olive oil is obtained from virgin olive oil by refining methods used to improve the odour, flavour and taste. Olive oil (sometimes labelled pure olive oil) is a blend of refined and virgin olive oil. The olive pomace (solid material left after the first oil extraction) can be treated with solvents to extract the remaining oil to produce olive pomace oils suitable for human consumption.

Olive oil should be stored in air tight and light proof containers at a constant temperature below 22°C to slow down the onset of oxidation which causes the oil to go rancid. Even under ideal storage conditions though, olive oil quality will deteriorate over time and it should be consumed within 1-2 years after production.

Financial information

Establishment costs will vary considerably for each site. To simplify matters in the following example the price of land, irrigation headworks and special soil preparations are not considered. These costs though, particularly irrigation headworks, may be significant. After these, the major establishment costs are the trees and irrigation system. Trees cost between $5 – $10 each depending on age and source.

Irrigation reticulation varies from $1,000 to $4,000/ha depending on system design and labour costing. Professional soil surveys and irrigation system designs are highly recommended to optimise irrigation efficiency. With a further $1000/ha for ripping and soil amendments, establishment costs lie in the order of $3,000 to $7,500/ha (assuming a standard planting density of 250 trees/ha).

Annual gross return for a mature grove (maturity reached by about year eight for an intensively managed grove) is determined by tonnage, oil percentage and price. Assuming a planting density of 250 trees/ha; 50 kilograms of fruit/tree with 20% oil (specific gravity 0.91):

Key statistics

- World olive oil production (2002/03) 2,515,000 t
- World olive oil consumption (2002/03) 2,641,000 t
- Australian olive oil imports (2002/03) 32,748 t ($139 million)

Key messages

- Maximise productivity by variety selection and management
- Minimise costs through mechanisation and economies of scale
- Understand and develop markets
- Nurture industry growth through coordinated organisation
• 250 trees x 50kg = 12,500 kg of fruit
• 12,500kg x 20% = 2,500 kg of oil
• 2,500kg / 0.91 = 2,750 L of oil (approx.) = 140 drums (20L drums) of oil.

Production costs (pesticide, pruning, fertilizer, irrigation, herbicide picking and processing) are between $6,000 and $8,500/ha depending on whether the fruit is hand picked or mechanically harvested.

By substituting the ‘world parity’ price for oil of $4/L into the equation above, the gross return is $11,000 giving a gross margin of between $2,500 and $5,000/ha. The gross margin does not include capital costs which may make the overall venture unprofitable unless a large enough area is planted to achieve economies of scale.

The yield figures given above are reasonably high under Australian conditions and can only be consistently achieved by carefully managed groves. However, niche or speciality marketing may achieve higher prices for the oil. Sensitivity analyses on yield and price should always be done to determine what could be realistically achieved in your situation.

The important issues are to use the best varieties and management practices eg irrigation, to ensure high fruit and oil yields and design the grove to accommodate mechanical harvesting to reduce costs. Throughout the production and processing system attention to quality is essential.

Key references


Germplasm of Olive in Tuscany. Institute for the propagation of woody plants, CNR, Scandicci, CNR Florence research area. www.area.fi.cnr.it/olivo/indiceng.htm


International Olive Oil Council www.internationaloliveoil.org


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Plant fibre crops

Tanya Jobling

Acknowledgement is given to Ian Wood and Stuart de Jong, the authors of this chapter in the first edition of this publication.

Introduction

Plant fibre crops produce cellulose, which is used in a wide range of manufactured and industrial products. Cotton is the dominant plant fibre crop globally. Other plant fibre crops produced and traded globally are Flax (Linum usitatissimum), Hemp¹ (Cannabis sativa), Jute (Corchorus spp.), Kenaf (Hibiscus cannabinus), Roselle (Hibiscus sabdariffa), Ramie (Boehmeria nivea), Coir (Cocos nucifera), Sunn Hemp (Crotolaria juncea), Abaca (Musa textilis), Sisal (Agave sisalana) and Henequen (Agave fourcroydes). Many other plants are used for fibre on smaller scales or for particular applications in the countries of production. In addition, fibrous by-product of many other crops is used for fibre, such as cereal straws and bagasse (the fibre of the stalk of sugar cane after pressing).

Most of the plant fibre crops are “bast fibre” crops, meaning that the valuable fibre is derived from the bast (bark) fraction of the stem. The inner part of the stem is the “hurd”, a softer woody core. The bast fibre crops include Hemp, Kenaf, Flax, Jute, Ramie, Roselle and Sunn Hemp.

The plant fibre crops discussed in this chapter are those relevant to ongoing development in Australia: primarily Flax, Hemp, and Kenaf. Other crops that may be of interest or potential but have not undergone significant research or development effort are included here but in less detail: Ramie, Sunn Hemp, Roselle, Sisal, Henequen and Jute. Cotton is now a major crop in Australia, with an approximate annual value of $1.2 billion. Other plant fibre crops are less suitable to Australia due to limited production areas or relatively high labour requirements.

Plant fibre crops, particularly Hemp and Kenaf, have recently received renewed attention for production in Australia and overseas with the identification of increasing fibre demand globally, particularly in the manufacturing industries. Whereas, synthetic fibre production, wood fibres and cotton dominate the market, these sources are finite and in some cases environmentally damaging. The demand, therefore, for sustainable plant fibre crops is set to increase dramatically due to population increases and manufacturing substitution.

Markets and marketing

Plant fibre crops have traditionally been marketed internationally for a number of long-standing uses including carpets, furniture, pulp and papers, textiles, cordage, canvas, building products, non-woven textiles, insulation materials and fuel. More recently, newer markets have emerged for bast fibres, including plastics, poly-composites and glass fibre replacement. These applications have opened new markets in the building sector, automotive components and plastics industries. Hurd product has achieved considerable market share in absorbency and animal bedding markets.

Traditional markets for other plant fibre crops continue, with some development into the automotive markets as well. Jute for example, is used extensively in non-woven textiles and carpets. Traditional international markets tend to remain for plant fibre crops

¹ Hemp, in this chapter, refers to “Industrial Hemp” or “Industrial Cannabis”. Industrial Hemp has been bred to contain low levels of THC, the drug component of marijuana. Levels of THC permissible in Australian Hemp crops vary according to state legislation. Industrial Hemp in Australia is grown under state government licence.
produced in areas with variable supply and very low costs of production relevant to low quality end uses, such as geotextiles or non-woven materials.

Flax, Hemp and Kenaf have undergone significant research and development internationally as a source of bast fibre for these new and existing markets. Currently, these markets are developing rapidly with projected shortfall in supply of bast fibre internationally within the next five years.

In the European automotive market, for example, natural fibre usage is currently 40,000 t annually. Demand is expected to increase to 150,000 t over the next five years, in the automotive manufacturing industry alone. Of this demand, the hemp market share is expected to increase from 12% currently to about 65%, equating to 100,000 t of hemp fibre required annually. It has been estimated that European production capacity for hemp fibre is capped at about 60,000 t annually due to land availability and production costs. Further shortfalls in bast fibre requirements for alternative industries are projected but are not clearly quantified.

The paper pulp market globally only uses approximately 10% non-wood pulp sources due to the historical availability and cheapness of wood sources internationally. With the shift to sustainable resources for manufacturing and the near depletion and increasing costs of available wood pulp sources, paper-manufacturing industries, especially in Asia, have moved to increase non-wood pulps for paper production.

In the Australian context, while research has identified these markets and private companies are actively pursuing them, supply capacity remains critical to secure contracts to these markets. Supply capacity depends both on production and processing.

**Production requirements**

Hemp is well adapted to both temperate and subtropical climatic zones as an annual summer crop. Kenaf is a spring-summer crop in tropical and sub-tropical regions and flax is predominantly a temperate summer crop or sub-tropical region winter crop. Most of the other plant fibre crops are adapted to the semi-arid or wet tropic climates. These are discussed individually below.

**Hemp:** Hemp is a genetically diverse species, with varieties adapted to a wide range of latitudes and climatic zones. It is a summer annual, short-day flowering plant. Until recently, all developed fibre varieties in the world were bred in Europe and therefore adapted to longer summer daylengths than in most of Australia. This meant that fibre varieties flowered prematurely in all but the highest (i.e. farthest south) latitudes of Australia, limiting productivity and yield. Recently, plant breeding and selection in industrial hemp in Australia by private companies has focussed on developing varieties suitable to Australian production, particularly the sub-tropics where higher summer rainfall and summer temperatures implies higher production capacity. These varieties have consistently achieved much higher fibre yields than previous trials of European varieties.

Hemp requires well-structured soils with high nutrient and water availability. It has been grown in trials in most states of Australia with varying success depending on varieties and agronomy. Best production conditions rely on well-prepared seedbed, well-fertilised soils, regular irrigation or rainfall and good sunshine conditions. The fibre crop grows for approximately 100–120 days. In temperate regions, hemp can only be grown in the summer months, in subtropical and tropical regions there may be scope to extend this with varietal development. Hemp is intolerant of waterlogging and trials with flood irrigation in various areas of Australia have shown reduced yields compared with overhead irrigation.

**Kenaf:** Kenaf is a subtropical and tropical plant capable of high biomass production over summer growing period. It prospers under high rainfall and sunlight conditions. It is a relative of cotton...
and hibiscus and is a short day (autumn) flowering species. It is more diverse than hemp in its tolerance of soil conditions and could be grown under a range of dryland or irrigated conditions in northern Australia. It is highly drought tolerant with a broader harvest window than hemp.

**Flax:** Flax fibre is produced in Australia largely as a by-product of linseed (grain) production. Production is therefore limited by the market capacity for linseed grain. Flax can be grown solely for fibre in both temperate regions in summer and subtropical regions in winter. Flax varieties specifically for fibre have been developed and are available overseas, growing taller and less branched than linseed varieties. Flax requires good soil moisture and nutrient availability and is susceptible to dry periods.

**Sunn hemp:** Sunn hemp has been trialled recently in southern and western wheatbelt areas as a summer leguminous cover crop rather than as a fibre crop. It generally requires moderately rich lighter loam soils for fibre production but it will tolerate heavier soils.

Other fibre crops that may be of interest to Australia have been or are being trialled. Sunn hemp, roselle and ramie are typically similar to kenaf in their adaptation to subtropical areas with some tolerance of drier conditions. Roselle is listed as a significant weed species in Western Australia and the Northern Territory and is naturalised across large areas, which may cause problems for adoption as a crop species. Other bast fibre plants such as henequen and sisal are adapted to drier climates such as semi-arid northern Australia. They are intolerant of waterlogging, with shallow root systems preferring lighter well drained soils.

### Varieties and cultivars

The availability of seed remains a hurdle for most growers of new bast fibre crops.

**Hemp:** Hemp seed is available in Australia only where imported or grown under relevant state licence. Varieties and cultivars imported from Europe or Canada, the only commercial sources of industrial hemp cultivars, are generally unsuited to Australian conditions except far southern Australia. Imported seed can be poor quality and expensive. Private researchers have recently been developing varieties suitable for Australian cropping, however seed stocks are generally limited.

One grain variety of industrial hemp "Finola" has recently been granted PBR in Australia but is primarily suitable for Tasmanian climatic conditions. Other European varieties such as Futura 77 and Kompolti have achieved reasonable yields in Tasmania and Victorian trials. Subtropical varieties developed by Ecofibre Industries Limited in Queensland have achieved viable yields in trials in Victoria, New South Wales and Queensland, significantly improving on yields of European varieties.

**Kenaf:** Kenaf varieties predominantly grown in Australia are Everglades 71 and Guatemala 4, both well adapted to Queensland tropical and subtropical conditions. Both varieties have performed well in Queensland and northern New South Wales trials over the last few years.

**Flax:** The flax industry in Australia has used residue from linseed grain varieties and has not developed or imported fibre flax varieties commercially. While specialised flax fibre trials are available internationally (Europe and Canada), in Australia the flax industry remains dependant on the residual fibre from linseed crops and therefore varieties are those selected for linseed production (eg Argyle, Glenelg, Linola). Trials using European flax cultivars in Tasmania in the early nineties showed increased bast fibre yields over traditional varieties. Factors to consider for flax varieties include time to maturity, disease resistance, branching and susceptibility to lodging.

Adaptation to local climatic and edaphic conditions will be imperative in the choice of varieties of bast fibre crops for Australia. Maturity time relative to local daylength is the key determinant
of yield, therefore varieties suited to local summer daylength conditions will need to continue to be developed for the bast fibre industry.

**Agronomy**

**Hemp:** Industrial hemp grows in both temperate and subtropical through to tropical climates, requiring high light, nutrient availability and moisture conditions. Hemp is intolerant of waterlogging and prefers well-structured soils with high organic matter and near neutral – slightly alkaline pH. Hemp is intolerant of compaction and anaerobic soil conditions at germination and establishment, which has caused poor results in Australian trials including trials under flood irrigation.

Plant population is critical to crop structure, total stalk yield and bast fibre yields. Trials on optimum plant populations in Australian conditions have been inconclusive, although showing yield reductions at higher rates recommended by European trials. Current recommendations are between 100 and 200 plants/m². Sowing rates in kg/ha depend on the seed weight count, which may be between, for example, between 15 and 30 g for 1,000 seed count. Recommended sowing rates (e.g. 45 – 65 kg/ha) need to take into account 1,000 seed weight and Australian cropping conditions for yield relative to density.

Industrial hemp is typically a summer crop that is harvested after onset of flowering. Earlier trials in Australia using European varieties have generally flowered early, thus limiting stalk yield. Choice of variety is critical to yield in any location and sowing date will depend greatly on the daylength response of varieties relative to local summer conditions. Later flowering varieties enable longer planting windows for the same period of vegetative growth. Varieties may flower prior to mid-summer if planted too early in the spring, with limited yield due to reduced temperatures, moisture availability and onset of flowering. Researchers in Queensland have focussed on developing and trialling suitable subtropical varieties with a view to achieving higher stalk yields.

Nutrient availability is a major determinant of biomass yield and hence fibre yields. Hemp is a nitrophilic crop and trials have shown increased yields up to 250 kg/ha of N, 120 kg/ha K and 40 kg/ha P. Comprehensive trials for detailed nutrition and fertiliser requirements need to be conducted for Australian production.

**Kenaf:** Kenaf grows best in tropical and subtropical conditions where daily mean temperatures are above 20°C. Kenaf is sown at a rate of approximately 10-15 kg/ha to achieve a density of 250,000 to 400,000 plants/ha. Plant spacing has little effect on yields and row configuration can be adapted to suit farming and harvesting equipment. Seed should be planted in mid to late spring in irrigated crops or immediately following onset of wet season rains in dryland crops. As kenaf is a high biomass crop, nutrient requirements are high. Fertiliser applications should aim to meet the requirements of the crop, for example 100kg/ha N, 17 kg/ha P and 220 kg/ha K for a 20 t/ha crop.

**Flax:** Fibre flax needs abundant moisture and cool weather during the growing season. It grows best on well drained soils of loamy or clay loam texture. The crop is intolerant of acidic, alkaline or saline soil conditions. Higher nutrient availability leads to higher yield and quality of fibre but as root systems are not extensive, nutrients need to be readily available in the root zone. A fibre
flax crop grows to approximately 90–120 cm in 3–4 months. A fine seedbed with a sowing rate of 80–110 kg/ha is necessary for good crop establishment. Flax is not as competitive as many other fibre crops and early weed control is important. The timing of harvesting of fibre flax is critical to fibre quality. The fibre is harvested once the lower two-thirds of the stem has turned yellow, usually about one month after appearance of flowers.

**Sunn hemp:** Sunn Hemp grows best in the tropics and subtropics on well-drained alluvial soils with a sandy loam or loamy texture. Overseas recommendations for seeding rate and row spacings vary greatly (eg 5 – 60 kg/ha, at 30 cm – 1m rows). For fibre production in Australia, rates are generally higher (10-15 kg/ha) than recommended for seed production or as a green manure crop (3-5 kg/ha). Row configuration and plant density would need to be trialled under local conditions for optimum fibre production. Sunn hemp is currently being trialled as a rotation crop in wheatbelt areas of Western Australia and other areas of southern Australia. Trials as a rotation/cover crop have demonstrated that inoculum is required for successful growth.

**Jute:** Jute is a tropical short day plant that grows in the summer months. It requires at least 1,000 mm over the growing season but is not tolerant of waterlogging in the early growth stages. It is grown traditionally in river valleys and delta areas, requiring fine seedbed preparation with high rainfall or irrigation. Seed is sown at approximately 5–10 kg/ha, aiming for a final plant density of about 35–40 plants/m². Plants are harvested early pod stage, by hand in the current countries of production.

**Ramie:** Ramie is a perennial crop growing over 7 –20 years. It requires a warm humid climate with annual rainfall or irrigation of at least 1,000 mm fairly evenly throughout the year. Ramie tolerates a wide range of soil types, preferably slightly acid (pH 5.5-6.5) but is intolerant of waterlogging. It is usually propagated from rhizomes or stem cuttings that are planted every 30-50 cm in rows 70–80 cm apart. The crop grows multiple stems from underground rhizomes, achieving 1-2.5 m in height. Ramie can be harvested up to 6 times a year in good conditions, current harvesting is done by hand as stems should be harvested at a particular stage of maturity. For high production, high nutrient levels, particularly, N, P and K, should be maintained.

**Sisal and Henequen:** Sisal and Henequen are fleshy perennials with a productive life of 6 to 20 years. The plants consist of a short thick stem bearing a rosette of long fleshy pointed leaves. Propagation is by suckers or bulbils, which are grown in nurseries and then planted out into 1 m spacings in rows about 3–4m apart. Plants are generally grown on well-drained sandy loam soils containing lime but will also grow on well-drained clay soils. Crops have a high requirement for calcium, nitrogen, potassium and magnesium.

**Roselle:** Roselle has similar growing requirements to kenaf although there have not been extensive trials in Australia to date.

### Pest and disease control

Plant fibre crops, where the economic product is cellulose from the stem rather than a fruit or flower product, have very low pest and disease problems. In most cases, where there are pests and diseases present for a species, the

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**About the author**

Tanya Jobling has worked with Ecofibre Industries Limited in Brisbane since 1999, coordinating hemp and other bast fibre crop research trials and commercial production throughout Australia. She has a background in developing agricultural industries since completing postgraduate studies at the University of Queensland. Her current research projects include developing hemp agronomy, new variety trials in hemp and kenaf, germplasm research, fertiliser trials for hemp fibre and seed production, farming systems research using bast fibre crops in rotation and developing regional supply capacity of fibre crops to a potential mill. Ecofibre Industries Limited is a private Queensland based company developing the bast fibre industry through research and marketing, implementing production and processing in Australia.
tolerance threshold is high relative to the economic damage.

In hemp crops in Australia, many pests have been recorded but few have warranted control. In fibre crops, Heliotis (Helicoverpa spp.), Red Shouldered leaf beetles (Monolepta australis), Green Veggie Bug (Nezaria viridula), Jassid (Batracomorphus angustatus) and Lucerne Flea (Sminthurus viridis) have been recorded. Fungal attack has caused minor occurrences of plant death in trials in Queensland and New South Wales and has been identified as species of Sclerotium rolfsii, or White Mould. The infection has been more prevalent in clay soils or where frequent watering occur, creating a wet-dry cycle which encourages the disease. In no cases of fibre crops were these pests or diseases present in large numbers or at economically damaging levels. In hemp grain or seed crops, control of Heliothis and Green Vegie Bug may be required. In cooler moist conditions of southern Australia, Botrytis (Botrytis cinerea) in hemp grain crops may be a problem.

Root knot nematodes (Meloidogyne spp.) have been identified in the root systems of hemp in cropping soils where nematodes are known to be a problem (e.g. sugar cane areas). In some cases, infection with nematodes is thought to be the cause of considerably reduced plant yields.

In kenaf trials in Australia, pests have been noted but few have been problematic. Root knot nematodes have severely infested plants and affected yields in some trials, in areas where root knot nematodes are known to be a problem. In some trials, Red Shouldered leaf beetles (Monolepta australis) have completely defoliated young plants, causing one trial to be terminated.

On the whole however, kenaf and hemp are quite tolerant to the wide range of pests and diseases that have been identified in the crop but caused little economic damage. By their nature of production being the economic product from the plant stalk, plant fibre crops suffer little economic damage from most pest species, particularly insects, unlike fruit, leaf or flower product crops. In this respect, plant fibre crops are considered low risk and low management crops for production systems.

Harvest, handling and processing

Harvesting plant fibre crops in Australia has required mechanisation of processes that are largely manual in other countries of production. Many of the minor plant fibre crops will be unsuitable to broadacre planting in Australia unless viable mechanised harvesting, handling and processing can be developed.

In practice, the bast fibre crops are cut, dried in field and baled after a period to enable retting of the fibre. Retting is the process in which microbes (fungal and bacterial) break down the fibre stem enabling easier separation of fibres in processing.

Machinery for harvesting has been a major developmental project for the bast fibre crops in Australia. For hemp, specialised machinery from Europe has been imported and new equipment is being developed in Australia. Offset sickle mowers have also been used

### Table 1. Suggested yields, costs and returns for commercial bast fibre crops in Australia

<table>
<thead>
<tr>
<th>Crop</th>
<th>Expected yields t/ha</th>
<th>Gross farm gate return per tonne</th>
<th>Variable cost of growing per ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kenaf</td>
<td>10 – 15 irrigated</td>
<td>$75 - $120</td>
<td>$500 – $800 irrigated</td>
</tr>
<tr>
<td>Flax</td>
<td>1 – 3 irrigated</td>
<td>$150 - $200</td>
<td>$300 – $500 irrigated</td>
</tr>
<tr>
<td>Hemp</td>
<td>6 – 12 irrigated</td>
<td>$160 - 220</td>
<td>$600 – $900 irrigated</td>
</tr>
<tr>
<td></td>
<td>4 – 7 dryland</td>
<td></td>
<td>$400 – $600 dryland</td>
</tr>
</tbody>
</table>

Note that flax fibre is available as the stubble of linseed crops and that therefore, gross returns for these crops are not reflected in the stalk price.
but these are only an option where total biomass is relatively low. For kenaf, harvesting using sugar cane harvesters and forage harvesters has been trialled. Where hemp and kenaf are grown as high biomass crops, i.e. over 10 t/ha, specialised harvesters will be required for optimum stalk return.

Bast fibre crops are typically windrowed when mechanically harvested and left to dry in the paddock for one to four weeks, depending on conditions. The stalks should reach a suitable stage of retting and moisture content below about 12% to be baled. Conventional raking and baling equipment can generally be used.

The high biomass, low value nature of the bast fibre crops poses a handling cost issue for the fibre industry in Australia.

Traditionally, the processing facility needs to be located as close as possible to the source of raw material, minimising transport costs of raw stalk bales. Given the larger scales of production in Australia, the bast fibre industry has recognised that raw material needs to be significantly compacted or semi-processed on or close to site of production to reduce transport costs.

Processing for the main bast fibre crops (hemp, flax and kenaf) has been the major impediment to reaching markets for the bast fibre industries in Australia to date. Bast fibre process consists of separating bast (outer bark fraction) from hurd (the inner light woody core).

The proportion of bast to hurd varies between species and varieties within species and there are identified markets in Australia and globally for both bast and hurd fractions.

Capital investment in bast fibre processing facilities in Australia has been the focus of several private companies with several trial or pilot operations currently in place or proposed.

Harvesting and pre-processing of other fibre plant crops such as jute, roselle, sisal and henequen is done by hand in countries where they are currently produced. Australia is unlikely to be able to compete with the low cost production of these crops.

Financial information

Detailed economic analyses of agricultural production costs and returns are not currently available for the two major crops undergoing development, namely hemp and kenaf. This is because the majority of the research and development is being conducted and funded by private companies and individuals and the information developed is therefore commercial and proprietary. In addition, research directions are skewed towards specific commercial outcomes rather than being general in nature.

The key financial components of including bast fibre crops in any farming systems are that they are typically low risk, low input crops, which have associated benefits of rotation cropping in nutrient return to the system through organic matter and break crops for other major crops such as sugar cane, cotton or grains.

Whilst detailed economic analyses for major bast fibres in Australia are not available, research undertaken to date has enabled some generalised figures to be developed. These are presented in Table 1. These figures will vary greatly depending on crop yield, fibre quality, distance to processing, costs of processing, location, farming infrastructure and systems of production. Commercial returns for other plant fibre crops are not established for Australian production systems. Returns from minor plant fibre crops in Australia will depend on there being a bast fibre or plant fibre industry currently established into which to sell these plant fibres, rather than being able to market smaller quantities of plant fibre independently (with the possible exception of local niche markets).

For plant fibre cropping to be viable, the proximity to regional processing is paramount, enabling growers to sell to the processing facility and the processor to market substantial volumes of fibre to both global and local markets. These markets are primarily in the major manufacturing industries requiring large supply capacity rather than entry-level niche production.

There is currently no commercial processing of plant fibre materials in place in Australia but a number of companies are developing regional processing facilities. Once these are in place, growers in these areas will be able to achieve returns for crops grown. Harvesting, baling and transporting costs for high biomass crops such as hemp and kenaf can be considerable.

It should be noted that hemp cropping is subject to state legislation in Australia, with Tasmania, Victoria and Queensland currently enabling licensed commercial production of industrial hemp and New South Wales and Western Australia currently permitting smaller scale trials and research. Licence and compliance obligations and costs vary from state to state and should be factored into production costs.
Key references


See websites listed above under key contacts. Also:

www.dpi.qld.gov.au
www.agric.nsw.gov.au

and other state agricultural departments for relevant notes on new bast fibre crops and State conditions for growing industrial hemp.

Key contacts

Agrifibre Industries Pty Ltd (Hemp and other bast fibres)
54 FE Walker St
Bundaberg QLD 4670
Tel: (07) 4151 0047
Email: jhjhall@hotkey.com.au
Website: www.agrifibre.com.au

Ecofibre Industries Limited (Hemp and other bast fibres)
PO Box 426
Ashgrove QLD 4060
Tel: (07) 3366 0889
Fax: (07) 3366 0890
Email: admin@ecofibre.com.au
Website: www.ecofibre.com.au

Fibrenova Limited (Hemp and other bast fibres)
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Key messages

• Demand for plant fibre is increasing globally, particularly in the manufacturing industries
• Proximity to regional processing is critical for plant fibre cropping to be viable
• Currently no commercial processing of plant fibre materials in Australia
• Commercial production of industrial hemp is subject to state legislation and is currently only permitted in Tasmania, Victoria and Queensland
Specialty mushrooms

Dr Tan Nair
and Dr Andrew Broderick

Introduction

In Australia, the term ‘specialty mushrooms’ is generally used to refer to those varieties of mushroom that are well-known overseas and have increasing popularity with Australian consumers. While certain varieties of specialty mushrooms are grown commercially in Australia, they are not yet considered an industrial scale crop (as for the white button mushroom in Australia, or as the specialty varieties are grown overseas).

Currently in Australia, there are several varieties of specialty mushrooms produced commercially and marketed for fresh consumption. These include Lentinula edodes (shiitake); Pleurotus spp. (oysters); Flammulina velutipes (enoki or enokitake); Auricularia sp. (wood ear) and Hypsizigus marmoreus or tessulatus (shimeji or bunashimeji). Growers have also experimented with Grifola frondosa (maitake).

Recent years has also seen the development of a market for mushrooms collected from the wild and sold through wholesale markets in the larger urban areas, or sold directly to restaurants and hotels. The varieties involved in this market are those for which cultivation methods have yet to be developed or whose cultivation methods are complex and not commercially viable. These include such varieties as Lactarius deliciosus (pine mushrooms); Boletus spp. (ceps, porcini, slippery jacks); and Morchella sp. (morels).

Data on Australian production of speciality mushrooms, and import of these mushrooms into Australia are not available.

As far as we know, there is no formal list of specialty mushroom growers in Australia, and some of these growers belong to the Australian Mushroom Growers Association (AMGA). Members of AMGA grow the common cultivated mushrooms Agaricus bisporus.

Several specialty mushroom species are not currently allowed to be imported into Australia. Work on the Import Risk Analysis (IRA) for edible mushrooms was initiated in 1998, initially looking at 39 mushroom species. Biosecurity Australia is about to re-commence the IRA process.

Markets and marketing issues

Demand for specialty mushrooms is increasing each year as the increasing European and Asian populations seek mushrooms with which they have been familiar in their own countries. Competition is strong from imported fresh, dried and canned mushrooms at competitive prices from China.
and Asia, and on occasions from California and New Zealand. The importers of specialty mushrooms sell their product to supermarkets at a lower price than Australian-grown specialties. However, quality and shelf life are obviously major concerns and food safety standards are now favouring the freshly grown Australian products.

With approximately 80 per cent of Australians buying mushrooms at least once a fortnight, a large percentage have bought specialty mushrooms in the last six months. Market research has shown that consumers would buy more specialty mushrooms if they knew how to use them, or if their stockist carried them more regularly. Retailers and buyers need educating about ways in which to prepare and use specialty mushrooms. When paying a premium price for an apparently gourmet product, consumers like to get best value from the product.

Many small-scale producers deal directly with restaurants, hotels and retail outlets, so by-passing the usual wholesale route. This contributes to the difficulty of obtaining accurate industry production figures or locations. There is no official monitoring body for specialty mushrooms, although the AMGA maintains a watching brief.

Impediments to market development continue to be lack of consistency in quality and supply; lack of R&D into Australian production techniques; poor knowledge of pest and disease problems; competition from cheap imports (especially from China); and food safety issues.

Although there is great demand in Japan, China, Korea, Taiwan, Singapore and other South-east Asian countries, and although Asian foods produced in Australia are highly sought after at present due to the clean fresh image, there appears little chance of development of an export market for specialty mushrooms.

**Varieties and production requirements**

Commercial scale mushrooms production occurs in environmentally-controlled growing facilities inside temperature and humidity controlled rooms. Submicron filtration capability minimises pest and disease entry into the growing rooms, although insect and microbial pest and disease still have to be controlled on all crops. Mushrooms are therefore somewhat independent of location in terms of climate. However, there are two vital aspects to mushroom growing; the first being substrate production, the second being the growing itself.

Specialty mushrooms grow on a range of different substrates under different environmental conditions. This generally means that different crops cannot be grown together in the same facility and separate growing rooms are needed for each type of mushroom. The type of substrate that specialty mushrooms use for growth can be basically divided into two types, reflecting the natural ecological habits of the fungi. Some mushrooms grow on straw-based composted substrates, while others require wood-based substrates. The substrates are mainly agricultural and industrial waste materials such as cottonseed hull, cereal straw, wood chips, tea waste etc. Nutrient supplements such as wheat and rice bran, vegetable oils such as sunflower oil, cottonseed oil etc are added to the substrate.

In contrast to the substrate used for growing the common mushroom Agaricus bisporus, substrate for specialty mushroom does not require a composting process. The substrate is only pasteurised to eliminate pathogenic organisms before the addition of starter culture (spawn) of the desired mushroom. This reduces the cost of producing speciality mushrooms considerably.

The production process of specialty mushrooms requires fewer steps than those of the common mushroom. For instance, there is no need for covering or ‘casing’ the substrate for initiating the production of mushroom fruit bodies. This brings further significant savings in the cost of producing speciality mushrooms.

Unlike the common Agaricus white button mushroom industry where the substrate is produced by specialist manufacturers and distributed to farms, most specialty mushroom growers are required to produce their own substrates. The skill in formulating an ideal
substrate from Australian materials to mimic substrates used overseas is often the key to growing success.

Matching the correct substrate to the right strain is also a major issue in Australian mushroom production. Mushrooms can potentially grow on many different wood-based substrates, but whether they produce viable, quality yields is dependant upon the strain/substrate/environment combination. Small-scale producers may produce their own spawn, or cultures are now available throughout Australia from commercial spawn suppliers.

The primary ingredient used for Pleurotus spp. production is chopped wheat straw or cottonseed hulls or mixtures thereof. For production on wheat straw, the material is milled to a length of about 2 to 6 cm. The pH of the material is adjusted with limestone to about 7.5 or higher to provide selectivity against weed mould, and after completion of pasteurisation at 60°C for one hour, the substrate is cooled to 25°C or less and spawned with the desired strain.

Production of Pleurotus spp. on cottonseed hulls has some advantages over straw-based production systems in that chopping of the hulls is not required. The pasteurised, supplemented hulls are spawned and filled (12 to 15 kg) into clear or black perforated polyethylene bags which are then stacked horizontally in racks and then incubated at 23° to 25°C for 12 to 14 days. Sometimes the bags are removed after the substrates have been fully colonised by the mushroom. Fruit bodies emerge from the top and sides of the substrate and can be repeatedly cropped. In Asia, the ease of growing oyster mushrooms makes them a popular crop for production in low-technology operations.

Eucalypt sawdust is the most popular basal ingredient used in synthetic formulations of substrate used to produce shiitake (Lentinus edodes). Other basal ingredients that may be used include straw and corn cobs or mixtures thereof. Regardless of the main ingredient used, starch-based supplements such as wheat bran, rice bran,

Once the proper ratio of ingredients is selected, they are combined in a mixer and water is added to raise the moisture content of the mix to around 60%. The mix is filled into plastic bags and sterilised in an autoclave for one hour at 120°C, cooled and inoculated at a substrate temperature of 25°C or less with shiitake spawn. After a 20 to 25 day spawn-run, the bags are removed and the substrate blocks are exposed to an environment conducive for browning of the exterior surfaces (15-17°C or higher, depending on the strain being cultivated). As the browning process nears completion (four weeks), primordia (the initial stages of the formation of mushroom fruit bodies) begin to form about 2 mm under the surface of the substrate indicating that it is ready to produce mushrooms.

**Key messages**

- Specialty mushrooms are not an industrial scale crop in Australia
- Many small scale producers deal directly with restaurants and other retail outlets
- Demand for specialty mushrooms is increasing
- Market development is being impeded by lack of consistency in quality and supply
- The key to growing success is formulating the correct substrate
Primordium maturation is stimulated by soaking the substrate in water (12°C) for three to four hours. Soaking allows water rapidly to displace carbon dioxide contained in air spaces, providing enough moisture for one flush of mushrooms. Approximately 9 to 11 days after soaking, mushrooms are ready to harvest.

The cycle for synthetic medium cultivation lasts approximately 4 months from time of inoculation to cleanout. Biological efficiencies for this method may average from 75% to 125%.

Substrates for the cultivation of Enoki (Flammulina velutipes) are primarily sawdust and rice bran; 4:1 ratio. These are mechanically mixed and filled into heat resistant bottles with a capacity of 800 to 1,000 ml. Sawdust consisting primarily of Cryptomeria japonica, Chamaecyparis obtusa or aged (9 to 12 months) Pinus spp. appears to offer the best yields, although eucalypt-based substrates have been developed in Australia. After filling into bottles, the substrate is sterilised (four hours at 95°C and 1 hour at 120°C), cooled to 25°C or less, and mechanically inoculated. The inoculated substrate is incubated at 18 - 20°C for 20 to 25 days. When the substrate is fully colonised, the original inoculum is removed mechanically from the surface of the substrate and the bottles may be placed upside down for a few days. At the time of original inoculum removal, the air temperature is lowered to 10 - 12°C for 10 to 14 days.

To further improve quality during fruiting, temperatures are lowered to 3 - 8°C until harvest. As the mushrooms begin to elongate above the lip of the bottle, a plastic collar is placed around the neck to support the long stalk of the mushrooms. This collar serves to hold the mushrooms in place so that they are long and straight. When the mushrooms are 13 to 14 cm long, the collars are removed and the mushrooms are pulled as a bunch from the substrate.

Auricularia spp. production now represents about 14% of the total cultivated mushroom supply worldwide. Auricularia auricula and A. polytricha are produced commonly on a substrate consisting of sawdust, cotton seed hulls, bran, and other cereal grains or on natural logs of broad-leaf trees. For cultivation on natural logs, members of the oak family (Fagaceae) are preferred, but many other species of both hard and softwoods may be used.

For synthetic medium production of Auricularia, the substrate may be composted for up to 5 days or used directly after mixing. In either case, the mixed substrate (about 2.5 kg wet wt) is filled into heat resistant polypropylene bags and sterilised (substrate temperature 121°C) for 60 min. Composted substrate is prepared by mixing and watering ingredients [sawdust (78%) : bran (20%) : CaCO3 (1%) : sucrose (1%)] in a large pile. The pile then is covered with plastic and turned (remixed) twice at two-day intervals. For direct use of substrate, a mixture of cotton seed hulls (93%), wheat bran (5%), sucrose (1%), and CaCO3 (1%) is moistened to about 60% moisture and then filled into polypropylene bags.

After the substrate has cooled to 25°C or less, it is inoculated with either grain or sawdust spawn. The spawn then is mixed into the substrate either mechanically or by hand, and the mycelium is allowed to colonise the substrate.

Temperatures for spawn run are maintained at about 25°C±2°C for about 28 to 30 days. Light intensity of more than 500 lux during the spawn run may result in premature formation of primordia. Temperature, light intensity and relative humidity all interact to
influence the nature and quality of the fruit bodies grown

Shimeji is usually produced in polypropylene bottles containing a mixed sawdust-based substrate similar to that developed for enoki. After the completion of vegetative mycelial growth (spawn run), bottle lids are removed and the colonised substrate subjected to environmental conditions known to stimulate fruiting.

When the mushrooms are mature, the entire cluster of fruiting bodies is removed from the bottles. Only one flush of mushrooms is harvested prior to mechanical removal of the “spent” substrate from the bottles. The bottles then are refilled with fresh substrate and the process is repeated.

**Pest and disease control**

The pests and diseases that cause problems for specialty mushrooms are similar to those experienced in the Agaricus industry, namely weed moulds, fungal, bacterial and viral infections, flies and nematodes.

While chemical and physical control protocols are in place for the Agaricus industry, pest and disease control for specialty mushrooms is still in its infancy. Methods are being developed by producers and consultants as new problems are encountered.

The Australian Pesticides and Veterinary Medicines Authority (APVMA) will in the future require registration of chemicals to be used in the production of specialty mushrooms and pest and disease control data will be required to support such registration.

**Harvesting, post-harvest treatments & processing**

Specialty mushrooms are hand-picked in situ. This requires skilled workers who can make decisions on maturity, quality and size as they pick. Depending on market demand, pickers will be required to select mushrooms of a specific size and need to be able to distinguish between first and second quality fruit bodies.

Currently supermarket retailers repackage specialty mushrooms in brand packaging – arranging mushrooms in plastic film-sealed trays. There are few fresh specialty mushrooms available for hand selection (as consumers can do for Agaricus). Prolonging shelf-life of mushrooms has been the subject of much research and various packaging regimes have been promoted. Mushrooms remain a highly perishable commodity, consisting primarily of water.

**Medicinal benefits**

The antitumor polysaccharide, β-(1-3)-D-glucan, isolated from H. marmoreus shows very high activity and has been the subject of much research. Dried mushroom powder from this mushroom is believed to stimulate the radical-trapping activity of blood. Excessive free radicals in the blood stream are believed to hasten the aging process.

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Morel species collected in Tasmania: (a) *Morchella deliciosa/Morchella elata*; (b) *Morchella deliciosa*; (c) *Morchella esculenta* var. *angusticeps* (syn. *crassipes*); (d) *Morchella elata* (Source Specialty Mushroom Production Systems: Maitake and Morels, RIRDC Publication No 04/024)
About the authors

Tan Nair’s major area of research is mushroom science with reference to disease management, composting technology, casing technology, and cultivation of speciality mushrooms.

He is a current elected member of the Council of International Society for Mushroom Science, Life Honorary Member of the Australian Mushroom Growers Association, Professional Member of the American Mushroom Institute, and Coordinator of the FAO Network on Conservation and Utilisation of Mushroom genetic Resources for the Asia Pacific Region. Research work also covers the field of viticulture. Publications include 64 referred articles in reputable scientific journals, 8 book chapters, editor of 8 proceedings of international conferences, and 50 extension articles in trade journals.

Andrew Broderick graduated with a PhD in fungal spore production for the pharmaceutical industry, Aston University in Birmingham (UK) 1981. From 1981 to 1991 he was a Research Scientist in New Zealand researching and developing fungal waste recycling fermentation processes. For the past thirteen years he has been undertaking research into Australian wild fungi and commercial Agaricus at the University of Western Sydney. He is currently Senior Lecturer and Head of Academic Programs for Horticulture and Viticulture and Winemaking at UWS.

From 1991-1994 he was the National Training Manager for the Australian Mushroom Growers Association. He is also a founding member and Vice President of the World Society of Mushroom Biology & Mushroom Products.
Stevia

Introduction

Stevia (Stevia rebaudiana Bertoli) is native to South America, originating from the Tropic of Capricorn area of eastern Paraguay, where it has been used to sweeten local teas and medicines for hundreds of years. The extract from stevia - steviosides (steviol glycosides) – has been used extensively in a number of countries, notably Japan, China, Korea and Brazil, for over thirty years in a wide range of food products as a non-sucrose and no-calorie sweetener (it is 250 – 300 sweeter than sugar gram for gram).

With increasing world-wide concern that excess consumption of calories in sucrose is contributing significantly to the rising incidence of obesity, type II diabetes and tooth decay, alternatives to sucrose are being consumed in increasing quantities. Most alternatives used are man-made chemical sweeteners, some of which are not suitable for all uses (being not heat-stable). These chemicals are not regarded as ‘natural’ food products and there is also growing concern about the safety of some of them. Steviosides have been shown to be safe to use and are suitable for a wide range of uses, in cooked foods as well as drinks, confectioneries and the like. They are suited to diabetic and weight loss diets and are beneficial and not detrimental to dental health.

Stevia and its extracts are not yet (March, ’04) approved by Australian authorities (FSANZ) for commercial use as a food ingredient, although they can be used as a “novel food”. It appears that enough research data to obtain registration approval are now available.

Stevia has traditionally been grown in low-labour-cost

Key messages

- Stevia is still an experimental crop in Australia
- Stevia is a good, safe, non-chemical, no-calorie alternative
- The health food market is limited
- Approval as a food ingredient will lead to a significant industry
- There are no processing facilities in Australia yet
- Seedling production is a specialist’s job
- Production levels are not established for Australia
- Reliable mechanisation of harvesting is still undeveloped
- International prices for stevioside are widely variable
countries using labour-intensive techniques for propagation (using cuttings) and harvesting (hand cutting or stripping of leaves). Trials of commercial, mechanised growing of stevia were commenced in Australia in 2002 by Central Queensland University and have shown that seedlings can be grown and transplanted on a commercial scale (using seed imported from China). Appropriate mechanised harvesting and handling procedures have not yet been demonstrated.

There is currently no large scale growing of stevia or stevioside extraction in Australia. Stevia production will require a mix of husbandry skills: crop establishment by planting out seedlings using herb and vegetable crop skills, harvesting and drying similar to lucerne growing (but with much more delicate handling) and processing with parallels to similar technology in the sugar industry.

Markets and marketing

The main stevia producing areas are China, especially north China, and Brazil/Paraguay in South America, the latter near its natural place of origin. The main stevioside consuming countries are Japan, where chemical sweeteners were banned around 1970, and China, South Korea and South American countries. In the USA stevia is currently only approved as a “nutritional supplement” and not as a commercial sweetener and so is mainly sold direct for home consumption through mail/internet order and health food outlets.

The main market in Australia will be for sugar replacement in soft drinks, juices, milk, yoghurt and icecream products, sauces, jams, biscuits and other confectionery. Steviosides can be mixed with sugar to give reduced and low sugar products as well as used alone for non-sugar products. Dried stevia leaves and extracts have very long shelf life and can be easily transported, so any future Australian market will be equally open to imported product and local production. Stevia will initially compete with chemical, non-sucrose sweeteners. The Australian soft drink industry uses approximately $70 million of sugar/sweetener per year, of which more than 20% is non-sucrose. Any future processor of stevia would probably market direct to manufacturers and retailers. Marketing in conjunction with sugar is a possibility.

There is a growing market for certified organic stevia products both within Australia and overseas, particularly in the USA and Canada. Produce from China or South America will have difficulty meeting certification requirements, so the organic market could become an opportunity for specialist producers in Australia. The health food market now mainly imports from South America, often via the USA.

The world price of stevioside powders varies with production and demand volumes. It was very low in 2002/03 (down to approximately $US 20/kg) from very high in the late 90’s (over $US 60/kg). This is from well below to well above the equivalent raw sugar price, to achieve the same degree of sweetness. A premium over world price for high quality Australian stevioside cannot be assured.

Production requirements

Although originating on the Tropic of Capricorn, stevia can be grown over a wide climatic range: from the equator (Indonesia) to the extreme latitudes of St Petersburg (60°N). Once established, it can tolerate frosts but not long periods under snow. It is grown as a perennial (3 to 5 years) in temperate to warm climates but as an annual in colder regions. For high leaf production irrigation is considered essential; under conditions of moisture stress leaf growth stops and flowering can be initiated. Even with good irrigation, temperatures over 35 – 40°C with low humidity can be stressful and induce premature flowering. Coastal and tableland situations would seem to be preferred in northern Australia.

Day length can influence stevioside content and leaf production. Long days increase stevioside production and short days can initiate flowering. Therefore more frequent summer harvesting is required in the tropics (with shorter day lengths) than in Victorian and Tasmanian latitudes.

Acid to neutral soils are preferred. Well-drained soils seem desirable, although once established stevia can thrive with wet feet on a waterlogged subsoil. Production as a row crop or on low beds, of two

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to three rows per bed, is required. This crop is suitable for quite small areas of production (even half a hectare).

Preferred regions for production in Australia have not been established. Latitude effects are part of the investigations by CQU. An accessible outlet for the stevia leaves will be a prime consideration, although once dried the leaves can be stored and transported without loss of quality.

Varieties

Under its natural conditions the wild stevia population is very variable in height, leaf shape and size, overall appearance and stevioside content. Selection has produced many varieties. Off-types occur frequently in most populations, being one reason for the traditional vegetative propagation. Many varieties produce very little or no viable seed.

Some breeding and selection programs overseas, especially in China, have resulted in varieties which also produce good quality seed. This seed is always then sown into nursery areas for later transplanting. Breeding and selection programs have also produced varieties with higher total stevioside content of 14 – 16% of leaf dry-matter compared to the common lines of 8 – 10%. Stevioside quality has also been improved (quality is a measure of taste and is usually defined as the ratio between the glycosides Rebaudioside-A and Stevioside).

Availability of seed limits the choice of varieties for Australia. The 'best' varieties have not yet been identified for possible growing areas here. In future, seed production of selected lines may be possible in Australia, although mechanised production would be required. Because seed size is extremely small (1 – 2 million/kg), freight on seed is not an issue but seed quality (germination) is.

Agronomy

Experience in Australia is limited and overseas growing practices are the best guidelines. Seed can be difficult and very slow to germinate and initial seedling growth is also slow; therefore seedling production is best left to experienced nurseries. A clean seed bed for planting into is essential to reduce weed problems. No chemicals are registered for weed control in stevia; there are suggestions that "Fusilade" and "Treflan" may be suitable. Overseas, hand weeding is generally used. Planting time should avoid the risk, for the first month, of hot weather (over 30°C) or waterlogged soils. In northern Australia a March to May planting out may be best.

Plant densities of 50 – 80,000/ha should be aimed for, with 20 – 25cm between plants in the row. Row spacing will depend on equipment used. Planting under plastic mulch has been successful in controlling weeds but plastic may interfere with mechanical harvesting (picking up) and could also restrict crown development and multiple stem production for second or subsequent ratoons.

Fertiliser requirements are moderate, at 50 units of N, 25 of P and 50 of K per year, with a maximum of twice that sometimes being suggested. Fertiliser is best split into two to four applications and can be applied through the irrigation water.

Irrigation is essential; small quantities frequently may be required after transplanting, with the irrigation interval being increased once seedlings are established. Underground trickle irrigation works well, especially in hotter, northern areas. Sprays can be used, although large travelling irrigators are likely to damage plants with their large droplet size.

Harvesting is required when flowers appear or when the lower leaves start to dry off. Stevioside content in the leaves falls when they dry on the plant as well as when flowering commences. Topping of seedlings early after planting out will induce more branching. Harvesting will also induce branching and multiple stems. In moist, tropical areas (17oS) the first harvest can be as early as 6 weeks after planting out and the next harvest 6 – 8 weeks later, before the longer days reduce the problem of premature flowering. Varietal selection may, in future, overcome early flowering. In cooler regions, with longer days in summer, two to three harvests a year can be expected.

Plants are expected to ratoon for three years before replanting is required. First crop plants may be susceptible to lodging. Multiple stems with subsequent harvests help make the plants less liable to lodging.
**Pests and diseases**

Pests and diseases are not expected to be a major problem. Young seedlings, especially in the first one to three weeks after germination, are susceptible to insect damage and protection is required. Once established, insect damage is not common, although a few caterpillars have been seen to chew the occasional leaf. The leaves are probably too sweet for most insects.

Fungal diseases have been recorded in moist conditions, hence the suggestion to avoid spray irrigation in the tropics. Young seedlings can be susceptible to soil fungi in overwet and warm conditions (possibly Phytophthora, Rhizoctonia or Sclerotinia). Some sudden death of healthy young seedlings has occurred in Australia. Mature plants seem to be much less susceptible to disease.

**Harvest, drying and handling**

Harvest yields of 2 tonnes dry weight of leaves per hectare per harvest are commonly recorded overseas. The leaf to stem ratio varies between 45% and 65% of leaves. At 50%, 2 tonnes of leaves is 4 tonnes of total stem and leaf (‘hay’). This is a relatively light hay crop which could be dried quite readily in the field. Provided humidity is low, drying in under twenty-four hours and sometimes ten or twelve hours is possible. Mowing with a conditioner to crush the stems, which is not done with hand-harvesting, will hasten drying.

The best equipment and method of picking up the dried crop is not yet known, as it has not been trialled in Australia. A conventional round baler may be adequate but leaf loss will need to be watched. If beds are mulched with plastic or weed mat, this may interfere with picking up; suction or airdraft collection may be more appropriate. Because dried leaf is worth about $2,000/t, any leaf loss is expensive and wrapping of bales for transport may be desirable.

As with any hay, drying needs to be carried out quickly to retain stevioside quality. If stored without adequate drying, leaves and stems can quickly (2 – 4 hours) overheat and thus lose quality. Once dried, stevia can be stored in the dry for long periods (years) without loss of quality.

The location of processing facilities could influence the type of handling and transport. There are no stevioside extraction facilities in Australia at present. The use of sugar cane processing technology and equipment is being considered in Queensland, although equipment at most sugar mills will be too big for stevia.

**Table 1: Crop Costs per Hectare**

<table>
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<th>Item</th>
<th>First Year $</th>
<th>Second &amp; Third Year $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land preparation/cultivation</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td>Bedding</td>
<td>250</td>
<td>0</td>
</tr>
<tr>
<td>Herbicides</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Seedlings &amp; planting out</td>
<td>6,500</td>
<td>0</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>500</td>
<td>500</td>
</tr>
<tr>
<td>Irrigation, water &amp; pumping</td>
<td>200</td>
<td>250</td>
</tr>
<tr>
<td>Labour, weed control etc</td>
<td>300</td>
<td>1,000</td>
</tr>
<tr>
<td>Harvesting (per ha contract x 3)</td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>Freight (4 t leaf = 8 t hay @ $37/t)</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td>Sundry</td>
<td>1,300</td>
<td>500</td>
</tr>
<tr>
<td><strong>Total cost for the year</strong></td>
<td><strong>10,100</strong></td>
<td><strong>3,450</strong></td>
</tr>
<tr>
<td><strong>Total 3 year cost</strong></td>
<td><strong>17,000</strong></td>
<td><strong>5,600</strong></td>
</tr>
<tr>
<td><strong>Average cost/year</strong></td>
<td></td>
<td><strong>5,600</strong></td>
</tr>
</tbody>
</table>

Note: Excludes cost of irrigation system, any herbicides and artificial drying.

**Financial information**

There is no experience or hard data in Australia on which to base financial forecasts of income or expenditure.

The largest cost (Table 1) will be associated with the purchase and establishment of seedlings, which are likely to cost about ten cents a plant planted out. As this cost can be spread over more than one year, it would be a significant cost saving if the crop ratooned for three years and not one or two.

Harvesting and drying costs will be reasonable if harvest is fully mechanised and the crop can be sun-dried in the field. If artificial drying is required, for example in the wet tropics, then this cost will be much higher.
About the author
Andrew Rank (B.Ag.Sc., Dip.Agr.Ext.) has been an agricultural consultant for over thirty years. Experience has included farm level dryland crop, livestock & irrigated production in low rainfall, temperate and tropical regions as well as regional & industry level planning, development, research and economic projects in Australia & overseas. He first became aware of stevia in 1984 in SE Asia and, with CQU, has been researching it since 1999. He visited some production areas in China in 2001 and is co-ordinator, for CQU Plant Sciences Group, of a RIRDC funded stevia project, which includes fifteen growing sites from the Atherton Tableland, Qld, to Burnie, Tasmania.

Reference

For health and safety aspects:

Table 2: Crop Income/Year/Hectare – Variable Yields & Prices

<table>
<thead>
<tr>
<th>Yields</th>
<th>Low Price ($20/kg)</th>
<th>Average Price ($30/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 t leaf @ 10%</td>
<td>200 kg St/ha</td>
<td>4,000</td>
</tr>
<tr>
<td>2 t leaf @ 15%</td>
<td>300 kg St/ha</td>
<td>6,000</td>
</tr>
<tr>
<td>4 t leaf @ 10%</td>
<td>400 kg St/ha</td>
<td>8,000</td>
</tr>
<tr>
<td>4 t leaf @ 12.5%</td>
<td>500 kg St/ha</td>
<td>10,000</td>
</tr>
<tr>
<td>6 t leaf @ 10%</td>
<td>600 kg St/ha</td>
<td>12,000</td>
</tr>
<tr>
<td>6 t leaf @ 12.5%</td>
<td>750 kg St/ha</td>
<td>15,000</td>
</tr>
</tbody>
</table>

Note: Yields in second & third year are likely to be higher than first year.
St = total steviosides content of leaves.
Table olives

Stanley Kailis and David Harris

Acknowledgement is given to Susan Sweeney and Gerry Davies, the authors of the chapter on the olive industry in the first edition of this publication.

Introduction

Table olives are popular with Australians. Most table olive products eaten by Australians come from Spain and Greece. Table olives either whole, cracked, stuffed, marinated or incorporated into pastes, are eaten with bread and cheese, with salads and cold collations and cooked foods.

Australia is now emerging as a significant table olive producing country. The development of the table olive industry must be considered in a national and international context because of its potential economic importance. The success of the Australian table olive industry will depend on capturing a significant proportion of the domestic market and the development of international markets. To date, only relatively small amounts of Australian table olive products are available and these for predominantly domestic consumers. Production however, estimated at around 4000 t/year, is increasing. Some processors are targeting international markets. Sustained growth of the table olive industry will depend on advances in efficient production and market development.

Table olive activities can be divided into four categories:
- growing
- primary processing
- secondary processing
- marketing.

Since 1995 there has been intense interest in the commercial potential of an Australian olive
industry. Major olive plantings have already been established in New South Wales, Victoria, South Australia, Queensland and Western Australia, although accurate statistics on plantings or productive olive trees in Australia are unavailable.

One estimate is that around 8.5 million trees have been planted. Current production of raw olives is low because many of the trees have not reached their commercial potential. Based on an average seasonal production of 25 kg of olives/tree, the potential table olive crop is 20,000 t/yr representing only 1% of the world production which in the export market is of greater significance. There can be an overflow in olive production between table olives and oil production. However there are some specialised varieties that are low in oil and can be used predominantly for table olive production. It is envisaged that the two industries will coexist with high quality hand picked olives being used in table olive production and culls and oil specific olives used for olive oil production.

### Markets and marketing issues

Australian table olive products are mostly marketed by processors to the food services industry in bulk, or through specialty food outlets. The olive industry, like the wine industry, has adopted tourism as a major strategy in marketing table olive products with other foods in regional Australia.

Uptake of Australian table olives by national supermarkets has been slow due to high prices, low levels of availability and a lack of products such as pitted and stuffed olives. It is expected that existing imports will persist because of traditional trading patterns of importers, wholesalers, retailers and consumers. Competition from other Southern Hemisphere producers is another threat.

Currently most olives come from South Australia and Victoria. This will change when recently planted orchards in Western Australia, New South Wales and Queensland reach commercial production levels. A number of olive enterprises are making substantial investment in table olive production facilities.

World table olive production reached a record level of 1,748,000 t for the 2002/2003 season representing an increase of more than 18% on the previous season and more than 30% increase compared to the average of the previous four seasons (Table 1). For the same period the European community (EC), Turkey and Syria produced over 60% of the world’s table olives with the USA, Morocco, Algeria and Argentina also being significant producers.

Table olive consumption has also increased markedly with the EC, USA and Turkey accounting for 60%. Exports for the 2003/04 season are expected to be around 481,000 t representing 33% of world production, with the EC, Morocco, Turkey and Argentina

### Table 1. Table Olive Statistics in Tonnes x 1000

<table>
<thead>
<tr>
<th></th>
<th>World</th>
<th>Production</th>
<th>Consumption</th>
<th>Exports</th>
<th>Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990/91-1993/94</td>
<td>953</td>
<td>971</td>
<td>208</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1989/99 - 2001/02</td>
<td>1342</td>
<td>1278</td>
<td>365</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>2002/03</td>
<td>1748</td>
<td>1657</td>
<td>506</td>
<td>426.5</td>
<td></td>
</tr>
<tr>
<td>2003/04</td>
<td>1457</td>
<td>1582</td>
<td>481</td>
<td>441.5</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Australia</th>
<th>Production</th>
<th>Consumption</th>
<th>Exports</th>
<th>Imports</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002/03</td>
<td>4</td>
<td>17</td>
<td>Negligible</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>2003/04</td>
<td>4.5</td>
<td>17.5</td>
<td>Negligible</td>
<td>13</td>
<td></td>
</tr>
</tbody>
</table>

Australian table olives
accounting for nearly 90%. Major importing countries were the USA, EC, Brazil and Canada accounting for 65%.

Imported table olives, black and green, are either sold in bulk by wholesalers to the food services industry or repackaged by third parties into consumer size quantities and sold at retail outlets. The latter includes all types of olives, olive pastes, tapas and hors d’oeuvres.

Australians consume around 0.7 kg of olives/person/yr, making them one of the largest consumers per capita outside those living in and around the Mediterranean. Australian table olive imports have nearly doubled since 1992/93. This marked increase is a significant indicator as to the popularity of olives in Australia and is a clear indicator for Australian growers and processors as to demand. Australia accounts for 3% of world table olive imports, 13,000 t in the 2002/03 season with a value of nearly $40,000,000, mostly from the EC which account for nearly 6% of their exports. For the 2003/04 period, production of Australian table olives is expected to be 4,500 t, a 12.5% increase over the previous season. Export of Australian table olives is negligible.

**Production requirements**

Australia has the physical resources, horticultural infrastructure and food processing expertise to support a modern table olive industry.

The olive, *Olea europaea*, produces fruit when winter temperatures fluctuate between 1.5°C and 18°C and summers are long and warm enough to ripen the fruit. The trees and fruit can suffer severe damage at temperatures of minus 5-10°C. Hot dry winds at pollination may reduce fruit set and productivity, may desiccate young trees and break limbs in mature trees. Most Australian olive groves are irrigated or can be sustained by rainfall (600 and 800 mm/yr). Rain at pollination may reduce fruit set and productivity. Olives can withstand drought, though fruit production is reduced. Hail or frost damaged olives are unsuitable for table olive production.

Olive trees will grow in most soil types as long as these are well draining and not prone to water logging. Soils that are slightly acid to near neutral are advantageous. Planting sites with slight slope facilitate both air movement and water drainage as flat areas with poorly structured soils are susceptible to waterlogging. As steeper slopes are prone to erosion planting should be along contours. Olive trees require direct sunlight for growth, initiation of fruit buds, fruit yield and quality. Radiation levels in Australia are often more than sufficient for olive fruit production and only a problem when trees receive substantial amounts of shade. To maximise radiation, olive trees are best planted on north facing slopes with tree rows in a north - south orientation.

Olive trees bear fruit 2-3 years after planting depending on planting stock age. Pollination and fruit set occur in late spring, fruit grow over summer and ripen during autumn/winter. Seven to ten years after planting, trees can produce 25 to 50 kg olives/tree and possibly up to 100 kg olives/tree, depending on alternate bearing patterns. Poor cropping over three successive seasons indicates a major problem with the grove and, if this cannot be corrected, it signifies poor commercial prospects.
Key messages

- World table olive production is increasing
- World table olive consumption is increasing
- Australians are eating more table olives
- Australian table olive production is increasing
- Australia needs to target national and international table olive markets

Key statistics

- World production of table olives (2002/03) 1,748,000 t
- World consumption of table olives (2002/03) 1,657,000 t
- Australian production of table olives (2002/03) 4,000 t
- Australian consumption of table olives (2002/03) 17,000 t
- Australian exports of table olives (2002/03) negligible
- Australian imports of table olives (2002/03) 13,000 t

Varieties/cultivars

Numerous Australian olive nurseries service the industry. Subject to agricultural and quarantine requirements olive trees are traded interstate. Olives are propagated as self-rooted cuttings and by grafting onto seedlings or clonal root-stock. The latter are used for difficult to root varieties eg Kalamata and Sevillana.

Commonly processed table olive varieties include Kalamata, Verdale, Manzanilla, Sevillana and Hardy’s Mammoth. Common olive varieties from nurseries include:

- large olives - Sevillana, Barouni, Jumbo Kalamata, Hardy’s Mammoth, UC13A6
- medium size olives - Kalamata, Conservolea (Volos), Barnea, Leccino, Manzanilla, Picual, Mission (Californian) and Verdale
- small olives - Frantoio (Paragon, Corregiola, Mediterranean, New Norcia or WA Mission) and Arbequina.

There is scope for the development of new varieties and the introduction of new to industry varieties eg Chalkidiki, Nocellara del Belice and Taggiasca. Most Australian olive orchards have 4 to 6 varieties. With single variety orchards eg Kalamata or Manzanilla, pollinators may improve productivity.

Cultural practices/agronomy

Although the olive is a hardy species it requires a high level of management to yield well. Soils should be assessed for pH, nutrient and organic matter levels and corrections made before planting. The orchard floor is prepared by deep ripping, especially with duplex and heavy soils. Trees are planted in rip lines and supported with stakes at spacings of 8 m x 5 m. Larger olive groves have substantial irrigation installations. Where water is readily available, 2-5 ML of water/ha/yr is distributed at the appropriate times particularly during flowering and fruit set and prolonged dry periods. For mature olive trees, 250 trees/ha, yields should range from around 10 to 20 t/ha depending on water availability. Newly planted olive trees require 10 L/tree/week whereas mature trees require a seasonal average of 500-800 L/tree/week.

Once planted, the olive trees are trained to a maximum height of two metres as a vase shape with a single trunk to facilitate management and hand harvesting. During the establishment period trees must be observed for vigour as well as the presence of any pests or diseases. Once the desired canopy structure is achieved the olive trees should be pruned to maintain canopy shape and to ensure tree health by allowing air circulation and light penetration.

Painting the trunk with latex paint or placing protective paper or foil wrapping around the trunk protects young trees from sunburn or herbicide damage. Competition from weeds, around the trees and in the alleys, a potential problem for young trees, is easily managed by either regular mowing, planting legume cover crops for green mulch, spraying with herbicides or to a lesser extent by tilling.

Because olive trees are often planted as 1 to 1.5 year old trees, most varieties will commence production within 2 to 3 years after planting. The time from planting to first harvest is dependent on variety and management techniques. Most olive varieties will take at least 4-5
years to bear commercially useful crops but longer if not cared for properly.

Olives will respond to fertilisers and it is important to take regular soil and/or leaf samples for nutrient analysis especially around December/January to ensure the correct balance of macro and micronutrients.

During establishment, trees need nitrogen additions but once productive, nitrogen, phosphorus and potassium are required. These can be supplied by broadcasting the fertiliser around the trees half in autumn and half in spring or through the irrigation system.

Deficiency of specific elements in the soil eg boron or potassium can also reduce productivity.

**Pests and disease control**

Australia has been considered relatively free of olive pests and diseases. However since the resurgence of the Australian olive industry, several unexpected problems have emerged.

Pests and diseases include black olive-scale, peacock spot and olive-lace bug, curculio-veevil (beetle), birds and animals and soil pathogens such as phytophthora, nematodes and *Verticillium*. Some growers have also reported olive fruit damage, soft nose, by the fungus anthracnose.

To date, olive fly and olive moth have never been found in Australian olive groves. Some indigenous insects attack young trees and olive fruit. Mediterranean fruit fly is a potential problem for the olive. In drier areas, such as in Western Australia, Rutherglen bug and grasshoppers can attack young trees.

Very few chemicals should be needed for successful olive cultivation. All of these problems can be controlled but they should be positively identified and expert advice on management sought to minimise indiscriminate spraying of broad-spectrum insecticides that will also kill beneficial insects.

Correct pruning to allow adequate airflow through the leaves will help keep many problems under control. Copper sprays applied after harvest and pruning to the tree canopy can be used as a general antifungal treatment. Olive trees are also harmed by some soil-borne pathogens eg. phytophthora and nematodes that damage roots resulting in die-back. If the site has been previously used as an orchard the soil should be tested for these organisms and treated under agricultural agency direction.

Integrated pest management strategies (IPM) using cultural techniques and safe chemical sprays such as *Bacillus thuringiensis* should be adopted. A number of additional pesticides and fungicides have been approved for use with olive trees. Petroleum oil for scale insect pests, Natrasoap for lace bug; copper hydroxide or copper oxychloride for various leaf spots and fruit rots in olives; granular metalaxyl for phytophthora root and crown rot in potted nursery trees; glufosinate-ammonium, fluazipop-p-butyl or pendimethalin for weed control; chloropyriphos for ants (around the tree butt), African black beetle (as a drench around the tree base) and light brown apple moth (foliar spray on non bearing trees); methidathion for scale insects; dimethoate for lace bug, green vegetable bug and Rutherglen bug; fenthion for lace bug, green vegetable bug, Queensland fruit fly and Mediterranean fruit fly; and Alpha-cypermethrin as a but drench for curculio beetle and cutworms.
Harvesting/handling/postharvest treatments/processing requirements

Table olives are mostly picked by hand. Harvesting with hand or mechanised rakes, tree shakers or overhead harvesters bruise olives leading to gas pocket spoilage and soft olives when processed. More serious damage occurs with black olives. Immersing machine harvested green-ripe olives into weak lye solutions within 20 minutes at harvest limits bruising however, this is not widely practised.

With future heavier olive crops serious consideration must be given to selecting varieties with “tough” skin and developing mechanised harvesting technologies that do not damage the olives. Costs for hand harvesting olives are $1.5 - $2/kg depending on the variety, tree shape and height, climate, availability of labour and distance from major community facilities. Machine harvesting estimated at 30 cents/kg would therefore radically reduce table olive production costs.

Olives are processed over three stages of ripeness:
- green-ripe
- semi-ripe or turning colour
- naturally black ripe.

Olive ripening is characterised by increased fruit size and change of skin (green to yellow to reddish - violet to a deep violet) and flesh (green to violet) colour. Harvest time depends on whether green, semi-ripe or ripe olives are required. Small crops of the same variety always ripen quicker than large crops and generally ripen faster in northern areas of Australia than southern areas. Green-ripe olives are ready for harvesting in summer/autumn whereas naturally black-ripe olives are ready in autumn/early winter. Under some growing conditions some olive varieties never fully ripen. When large olives are required the crop is thinned by hand or with chemicals. As yet chemical thinning of olives is not permitted in Australia.

To determine the harvest time for green table olives, the fruit and flesh should be a straw-yellow colour and when squeezed produce a creamy oily juice. Naturally black ripe olives should be picked when the flesh is nearly fully pigmented. Fully pigmented olives when processed produce soft products. Completely black ripe olives are best for dried olives.

Careful post harvest handling of olives is essential for high quality table olive products. Bruised or marked raw olives fetch low prices compared to good quality olives. Harvested olives should be placed into small slotted crates (eg 25 kg) that allow adequate airflow and kept in shade to avoid over-heating and sunburn.

Olives stored in packing sheds or processing facilities should be kept between 5°-10°C under clean and hygienic conditions to minimise the risk of contamination or damage. Transporting olives over long distance should be undertaken at the coolest part of the day or in temperature controlled vehicles. Green-ripe olives generally store better than naturally black ripe olives.

Harvested olives are processed as soon as possible to avoid deterioration by oxidation and fermentation. Olives are washed, graded and placed into tanks where they undergo debittering. Primary processing involves debittering and preserving the olives.

Common primary processing methods include:
- prolonged soaking in water followed by placement in brine (Greek and Kalamata Style)
- brine fermentation - green, turning colour or black ripe
- treating green olives with lye followed by fermentation (Spanish Style) or treating
green olives with lye without fermentation (Picholine Style)
• treating green olives with lye followed by aeration changing their colour to black (Californian Style)
• drying olives on the tree, by salting or heat (Date olives).
Secondary processing adds value to the olives. Here wine vinegar, vegetable oils (olive, canola, sunflower), herbs and spices are added to enhance flavour. Other forms of secondary processing are pitting and stuffing the olives with fillings such as paprika, peppers, almonds, garlic, anchovy or cheese. Ground primary processed olive flesh is used for olive pastes and tapenade.

Apart from dried olives, most olives are packed in salt brine. Here the final product must meet quantitative, qualitative and health standards before being released for sale.

Processing facilities require careful planning with respect to processing methods and capacity. Facilities and processing procedures must meet occupational health, safety and environmental standards. All equipment must be constructed of food grade material that can be easily cleaned and sanitised. Only potable water and food grade chemicals must be used. Processing barrels or tanks vary in size with some exceeding 15 t. Attention needs to be paid to loading and unloading olives. Fermentations are undertaken between 20°C and 30°C so temperature control is essential. Only a single variety and at a specific maturation state is processed in the same tank. Continuous records should be kept and the process controlled especially pH, salt levels, microbiology and spoilage. All operatives need to be trained in food processing methods, handling chemicals and processing olives. Total quality management and HAACP systems should be in place. A small processing plant with a capacity of 20 t of olives can cost from as little as, $50,000 to $100,000 to establish whereas large scale facilities of 500 t or more will cost between one and two million dollars depending on the level of sophistication. Ancillary equipment and facilities such as waste disposal, pumps, sorting tables, graders, de-pitters, bottling lines and testing laboratory can account for at least $300,000.

In Australia, primary processing of olives is undertaken by boutique, small and medium scale operators—see Table 2. Kalamata style olives are very popular with Australian consumers as are stuffed and marinated olives. Tapenade and olive paste production is popular. Current processors are mainly interested in using brine fermentations rather than methods with lye. This view may change as availability of raw olives increases especially for green olive processing. Lye treatments speed up processing but use larger amounts of water and energy than traditional methods involving brine fermentation.

**Financial information**

Financial information relates to both growing olives and olive processing. Australian olive orchards range from boutique to

**Table 2. Indicative scale of future Australian table olive enterprises**

<table>
<thead>
<tr>
<th>Size of Operation</th>
<th>Capacity in Tonnes/Season</th>
<th>Olive Trees Required*</th>
<th>Orchard Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boutique</td>
<td>Less than 5</td>
<td>Less than 200</td>
<td>1Ha or less</td>
</tr>
<tr>
<td>Small-Scale</td>
<td>5 to less than 100</td>
<td>200 to less than 4000</td>
<td>1-16 Ha</td>
</tr>
<tr>
<td>Medium-Scale</td>
<td>100 to less than 500</td>
<td>4000 to less than 20,000</td>
<td>16-80 Ha</td>
</tr>
<tr>
<td>Large-Scale</td>
<td>Greater than 500</td>
<td>Greater than 20,000</td>
<td>Greater than 80 Ha</td>
</tr>
</tbody>
</table>

* based an average seasonal crop of 25kg/tree
large-scale intensive plantings. Boutique and small-scale operations are often associated with vineyards and wineries and have between a few hundred to around 5,000 olive trees. Medium scale orchards range from 16 to 80 ha, whereas large-scale olive operations have more than 20,000 trees. To date most table olive production in Australia ranges from boutique to medium scale. There are no large-scale table olive producers in Australia.

Establishment of new olive groves involves decisions on site selection, planting stock, horticultural management technologies as well as obtaining planning, environmental and water licence approvals from statutory agencies. Establishment costs will vary considerably for each olive orchard depending on the cost of land, irrigation head-works and special soil preparation. Planting stock costs between $5-$10/tree. Irrigation systems vary from $1,000 to $4,000/ha depending on design and installation expenses. With a further $1,000/ha for ripping and soil amendments, establishment costs lie in the order of $3,000 to $7,500/ha for a planting density of 250 trees/ha ie up to $30/tree.

Growers can on-sell their best fruit to table olive processors, undertake primary processing and on-sell the processed olives in bulk quantities, undertake vertical integration - growing, processing and marketing or any combination of these.

Annual gross return for raw olive production is determined by tonnage, variety, size, consumer preference and price. Assuming a planting density of 250 trees/ha and 50 kg of fruit/tree will yield 12.5 t of olives producing around 3,500 jars of table olives.

Using a price of $1.5 to $2/kg for hand picked olives (Kalamata and large olives fetch premium price) would give a gross return of $18,750 to $25,000/ha. Production costs (pesticide, pruning, fertiliser, irrigation, herbicide and picking) are $8,500/ha for hand picked fruit. This gives a gross margin of $10,250 to $16,500/ha/yr.

Little quantitative information is available on the economics of Australian table olive processing such as establishment and processing costs. Currently Australian processed olives wholesale in bulk quantities from around $8 to $10/kg and retail from $6 to $10/jar depending on variety, style, packaging and container size. Imported olives cost around $3/kg. Wholesale mark-up margins for Australian olives are around 40% and retail margins 50%. Value added products such as tapenade and olives in marinade fetch higher prices than plain olives. Excluding the cost of olives processing costs are of the order of 50 cents to $1 depending on the processing method.

The major risks to financial viability being crop losses due to climate variations, international table olive prices and volume of domestic supply. Other threats are competition for resources from other horticultural agencies and the introduction of exotic pests and diseases.

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Professor Kailis is Professorial Fellow at the School of Plant Biology University of Western Australia and a Fellow of Curtin University of Technology WA. He holds qualifications in Science, Pharmacy and teaching and holds a doctorate in science. His antecedents came from the Greek island, Megisti and he was introduced to table olives by his grandmother Kostantinia. His interests focus on quality aspects of olives. Stan has made presentations on olive growing, olive oil and table olives at national and international forums and to industry groups. He has published numerous research papers in national and international journals. He has conducted many schools and workshops in Australia on olive growing, olive oil and table olive production, organoleptic evaluation of olive products and olive propagation.

Dr David Harris is Principal Chemist at the Chemistry Centre (WA) and is section leader of the Food and Agricultural Chemistry Section. He gained a doctorate degree in chemistry specialising in organic chemistry in 1976 in Canada. His main interest is research into the organic compounds present in legumes and pulses as well as pasture legumes, over the last five years he has become very interested in food safety and quality in Western Australia. Working with Professor Kailis over the last few years has aroused a keen interest in table olives and olive oil with regard to the chemistry associated with their production. David has presented papers at a large number of international forums and has published numerous papers in national and international journals.

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**Introduction**

The French black truffle is the fruiting body of the ectomycorrhizal fungus *Tuber melanosporum*. The fungus is an ascomycete of the family Tuberaeae, order Tuberales. It is a native to southern continental Europe, occurring predominantly in the southern regions of France, and northern regions of Italy and Spain.

The truffle is produced when the spores of the fungus attach to the roots of oak and hazel trees to form a symbiotic relationship. The edible portion or fruiting body forms during autumn, and harvesting takes place in the winter once the French black truffle has matured.

The truffles which are formed in the top 20 cm of the soil are harvested manually after using dogs or pigs to detect their presence by the perfume they emit at maturity which occurs in the Northern Hemisphere winter months of December, January and February.

Current estimated annual production ranges from 50 – 80t/annum from three principal sources being France, Italy and Spain. Typically, 60% of production is consumed fresh.
over the four month season with the remaining 40% of production preserved or used in value adding with other foodstuffs. Truffles produced in Europe are distributed to the finest restaurants in the world.

Towards the end of the last century, France produced up to 1000t of French black truffles from more than 20 departments located in southern France. Since this period, output has fallen continuously, with some slight variations to a level of combined production from France, Spain and Italy of 50–80% annually. The causes of this decline in production are many including; abandonment of land cultivation; wartime destruction of trees; planned deforestation; and acid rain.

As one of the great mysteries of the gourmet food industry, truffles are much sought after by the world’s leading chefs and gourmets. When available fresh in the Northern Hemisphere winter prices can exceed $AUD3,000/kg in a season of poor harvest.

Established in 1992, Perigord Truffles of Tasmania (PTT) is a private company owned by directors Duncan Garvey and Peter Cooper. PTT has been established to capitalise on the opportunity to supply French black truffles fresh into the traditional truffle markets of the world, six months out of season.

Focusing on the on the colder agricultural areas in South eastern Australia truffières now have been established in Tasmania, and the colder areas of NSW and Victoria.

**Marketing**

The truffle markets in France have remained unchanged for centuries and are very much part of French culture. The first point of sale for the truffles is the traditional truffle market, which spread across the main production areas in the Perigord and the Provence. The key markets in the areas are held weekly in the small villages. In the Perigord region the markets are in Lalbenque and St Alvere, in the Provence region where up to 70% of production occurs the market towns are Richerenches, Vaucluse, Carpentras and Vars.

The truffles are presented in plastic bags or small baskets and generally are unwashed and not graded. The quality of the truffles sold at these markets varies considerably from the perfect shaped fresh truffles to broken, badly frosted types.

The traditional market is the first stage in the distribution chain for truffles. The truffles purchased from these markets by the wholesalers and processors are then transported back to premises where they are cleaned and graded.

In France the restaurants either purchase their fresh truffles directly from the markets or through the wholesalers. Due to the limited shelf life of the product the wholesalers distribute the truffles very quickly.

The fresh truffles, which are exported, are distributed through importing agents in the respective countries. The importing agents handle all the importing protocols and distribute to the individual restaurants.

The value added or processed truffles are distributed through fine food outlets in both France and other countries. Similarly to the fresh truffles, the importers handle the distribution in their countries.

![Jellied Perigord truffles of Tasmania, Claudes Restaurant, Sydney 2003. (Photo: Claude’s library)](image)
PTT’s objective is to be the principal supplier of French truffles in the Southern Hemisphere.

As the industry expands the company will be strategically placed in the Australian domestic market and will capitalise on its market research already undertaken and will have markets firmly established in Europe Asia and the United States of America. Market research and product evaluation has already commenced on developing a range of value added truffle products in association with Chef Tim Pak Poy, Claudes Restaurant, Sydney.

Therefore growers purchasing trees from Perigord Truffles of Tasmania will have the opportunity of having their truffles marketed under the company’s brand name. We firmly believe that a coordinated approach to the harvesting and marketing of the truffles will ensure maximum returns on production.

**Production requirements**

The major production area in Europe is the Provence region of south east France and the Perigord region the south west of France.

The areas of production in France have warm springs, which is important for the truffle initiation and cold winters with regular below 0°C frosts. The areas regularly have summer droughts and high summer temperatures.

Suitable climatic conditions are important for the production of French truffles. The cold winters are important for the maturation of the truffle. The French truffle matures as the soil temperature decreases through the autumn and winter. So regular frosts and cold periods are very important to produce French truffles of high quality with good perfume.

In France the truffles are produced in the calcareous soils rich in calcium and high soil pH's.

Soils need to be free draining and well structured and ideally with low phosphorus levels.

The key issues with respect to the soils physical characteristics are drainage, structure texture and porosity. Soils with high clay content in the sub soil, which restricts drainage through the soil profile, are deemed not suitable for French truffle production.

Access to a good source of irrigation water is very important, as soil moisture is very important at different stages of the truffle lifecycle.

**Host tree varieties**

In France the tree species used as host trees in the French truffle industry are a range of oak trees *Quercus* and hazelnuts *Corylus*.

PTT produce hazelnut *Corylus avellana* and two oak species deciduous oaks (*Quercus robur*) and evergreen oaks (*Quercus ilex*).
Based on scientific and anecdotal evidence the hazels will commence truffle production earlier than the oak trees. Typically PTT recommends the truffières be established with all three species.

**Pest and disease control**

There are two issues with respect to truffle production; firstly pests and disease of the host trees and the potential contamination of the truffle fungus.

The oaks and hazels are very much disease and pest free in the truffières established thus far.

PTT try and avoid any use of insecticides and fungicides on the trees unless absolutely necessary.

There is a potential that any applied pesticide could have a detrimental effect on the truffle fungus.

Ectomycorrhizal fungi associated with many Australian trees such as eucalyptus, wattles, blackwoods etc and many introduced trees such as willows, poplars and pines can potentially contaminate the inoculated truffle trees. The result is the invading fungi will occupy root space on the inoculated truffle trees and replace the slow growing *Tuber melanosporum* from the root system.

It is very important that the truffières are established well away from other trees, which can host other ectomycorrhizal fungi.

All the truffières are fenced to stop the transfer of competing fungi being introduced by native grazing animals.

**Harvesting**

The traditional method of harvesting in France is to use a trained dog to indicate the presence of a truffle to its handler. The animal is directed along the rows of trees and upon detecting the scent of a mature truffle is taught to indicate its presence by scratching on the soil surface above the truffle, which is then carefully excavated by the handler.

It is usually the case that dogs used by truffle harvesters in France are household pets, but due to the scale of operations and the contractual arrangements of the joint venture, PTT has adopted a strategy of owning, training and housing all dogs used for its harvesting operations.

PTT has contracted Mr. Steve Austin, one of Australia’s leading dog trainers to advise and assist in the selection and training of both dogs and their handlers. His having held the contract to train all AQIS detector dogs and their handlers in recent years evidences Mr. Austin’s expertise.

Handlers are introduced to the principles of handling and are then allocated a dog 2 to 3 months prior to the start of the season in which they reinforce the training procedures required. They are assessed on their ability and relationship with their dog regularly. They then accompany an experienced handler and dogs through the season.

The new team is given first opportunity to search a truffière, followed by the proven team who provides a check on the progress and ability of the new team until the new team is detecting truffles with the same efficiency and reliability as the proven team.

PTT currently has ten trained and proven dogs and will expand the number as required to service truffières, as they become mature enough to begin production. It is anticipated that PTT will require 60 dogs and 30 handlers over a 4-month season from May to September to harvest truffles. All the truffières are inspected weekly over this period.

PTT have developed a mapping extension using a geographical information system (GIS) Arcview 3.2.
During the truffle harvest details include tree type, date of harvest, truffle weight and quality, distance from tree, depth in the soil and angle from tree.

The development of the program has allowed for the information to be displayed spatially for easy accessibility. The information can now be analysed readily to investigate relationships between truffle yield and other parameters such as tree species, lime treatments, soil types, irrigation regimes etc.

Once harvested, truffles are weighed and transported daily to a central location where they are cleaned and graded ready for dispatch.

The strategy is to have the truffles delivered to the restaurants in Australia within 24 hours of harvest, to ensure maximum freshness.

Financial information
The company has conservatively estimated yield in a well managed truffière to be 60 kg/ha once the trees reach maturity in year 8-10.

Yield estimates are conservatively based on what is achieved in well managed and irrigated truffières in France and from a limited experience in New Zealand. PTT have budgeted on truffle production commencing in years 5-6 and yield increasing as the trees reach maturity. In France truffles have been harvested form oak trees over one hundred years and from hazels established in truffières after 25 years.

As with any agricultural pursuit many factors can effect the level production and success of the enterprise. The production of French truffles is no different and there is definitely a risk associated with this venture and the ability to accurately forecast yields and returns.

PTT offer two options for landholders to participate in the production of French truffles.

1. Firstly in a joint venture agreement with PTT supplying an ongoing agronomic advisory service. PTT will be responsible for the harvesting and marketing costs of the truffles, the gross income derived from the sale of truffles will be equally divided between the company and the growers.

2. Non contracted growers, where landholders purchase the trees out right and can utilise the advisory and harvesting services provided by PTT on a fee for service arrangement.

Initial establishment costs approximately are $21,000/ha. Of this the tree component will range between $8,000 and $12,000 depending on tree density and the ratio of hazels to oaks.

Establishment costs will vary considerably between different sites depending on what infrastructure is already in place with respect to fencing, irrigation and the initial pH of the soil.

Annual maintenance costs are $1,000 - $1,500/ha per annum, which comprises mowing, limited pruning in later years and irrigation.

There is a well established market for truffles in the Northern Hemisphere. The risk in the French truffle industry is one of production rather than of marketing. During the harvests in 2002 and 2003 the truffles produced by PTT have been marketed for $3,000 per kilogram which represents a substantially higher price than the budgeted figure of $1,500.

Key references
Garvey, D.C., Cooper, P.B.2001 Establishment and production of the French Black Truffle (Tuber melanosporum) in Tasmania. Rural Industries Research and Development Corporation, Kingston, ACT

Garvey, D.C., Cooper, P.B.2003 Increasing the productivity of truffières in Tasmania. Rural Industries Research and Development Corporation, Kingston, ACT

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Duncan Garvey (B Ag Eco, UNE;), Joint Managing Director, Perigord Truffles of Tasmania

Duncan has been working on developing the truffle industry over the past eight years. In this time, he has critically reviewed the literature on truffles, made a number of trips to France to research truffles and conducted market research in Europe, Japan and the United Kingdom.

Duncan Garvey has had extensive experience in Agri-business. After completing studies Duncan was employed as an agronomist. During his time as an agronomist, he developed new cropping opportunities for Tasmanian farmers and was instrumental in extending a number of innovative farm management practices.

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Native foods Overview

Juleigh Robins

Acknowledgement is given to Caroline Graham and Denise Hart, the authors of the chapter on Bushfoods in the first edition of this publication.

Introduction

The native food industry has grown slowly since its inception in the mid 1980’s. Native foods have proven to be difficult to commercialise. They have been difficult to commercialise agronomically, as they are new crops without the benefit of existing established production systems, skills, knowledge and reliable plant material. They have also been difficult to commercialise in the marketplace, as they are innovative products without an established market or general consumer knowledge.

Currently it is estimated that the industry has a gross production value (farm gate and ex-nursery) of between $5 million for native foods (Fletcher, 2003) and $10 million for native food and essential oils from native plants combined (Lester, 2003). It is impossible at this time to extrapolate this to a total “industry” value.

The industry although very small, has four major levels. It is not unusual for individuals or companies to be active in more than one level and may be active in all four:

1. Nursery operators
2. Cultivators and wild harvesters
3. Commodity traders and Value Add-ers (retail and foodservice)
4. Marketers – foodservice, retail – domestic and export

The industry operates within a variety of commercial structures including single-purpose enterprises, networks, cooperatives and vertically integrated supply chains.

Commercial horticultural cultivation of native food species is expanding, however managed wild harvest remains an important and integral part of the commercial supply of native foods.

Table 1 lists, at this stage of the industry’s development, the most commercially utilised native foods. It should be noted that this table represents current industry knowledge but does not take into account plantings that are not yet yielding fruit, leaf or seed product.

The majority of the produce is dried, frozen and/or further processed into value-added products. Native foods are essentially used in the broader food industry as a defining flavour to an existing food product or process; e.g. condiments, sauces, biscuits, ice cream etc.
The main markets for native foods are in the hospitality and tourism foodservice, industrial food manufacturing and retail industries. Within the past two years some native food brands have successfully entered and remained in the mainstream retail market. There has also been significant development in the industrial food manufacturing market both domestically and internationally over the same time frame.

The industry requires an ongoing and targeted focus on the further development of these markets in order to achieve critical mass and anticipated returns.

The native food industry will only succeed commercially in the long term if native food and native food products meet mainstream market needs.

The native food industry continues to face great challenges and must find timely solutions if it is to grow further. These challenges include:

- supply issues – over and under supply – not matched to market demand
- inconsistent and unreliable plant material (yield variability, attrition rates etc)
- establishing efficient and sustainable ways to grow and harvest the crops
- under-capitalisation of the industry in general
- low economic returns to growers through high costs of production and limited markets
- low economic returns to wild harvesters due to climatic and geographic constraints
- low economic returns to processors due to high cost of ingredients and marketing costs in limited markets
- establishing food safety and quality standards
- low levels of co-operation, communication and information sharing within the industry
- identifying appropriate ways to incorporate Aboriginal interests in the native food industry
- increasing homogenisation of food industry which has potential to marginalise niche foods/products
- ongoing product development
- market development and education – native foods are still largely unknown in the domestic and global market place
- establishing a market focus across all levels of the industry.

Some necessary steps towards a sustainable and prosperous growth in the industry are:

- market driven – not production driven
- ongoing research and development in plant selection, sustainable production and post harvest systems (for cultivated and wild harvest)
- uptake across industry of food safety and quality standards
- increasing co-operation, communication and knowledge sharing between all levels of the industry
- product development to meet market needs
- clear and consistent industry marketing messages
- generic marketing initiatives to benefit entire industry.

<table>
<thead>
<tr>
<th>Species</th>
<th>Mainly cultivated</th>
<th>Cultivated/wild harvest</th>
<th>Mainly wild harvest</th>
<th>Supply</th>
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</thead>
<tbody>
<tr>
<td>Aniseed myrtle *</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>under</td>
</tr>
<tr>
<td>Bush tomato</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>under</td>
</tr>
<tr>
<td>Davidson’s plum</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>over</td>
</tr>
<tr>
<td>Kakadu plum</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>over</td>
</tr>
<tr>
<td>Lemon aspen</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>over</td>
</tr>
<tr>
<td>Lemon myrtle</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>over</td>
</tr>
<tr>
<td>Native citrus</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>over</td>
</tr>
<tr>
<td>Native pepper</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>under</td>
</tr>
<tr>
<td>Pepperberries*</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>under</td>
</tr>
<tr>
<td>Native mint *</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>under</td>
</tr>
<tr>
<td>Ribberries</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>under</td>
</tr>
<tr>
<td>Quandong</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>over</td>
</tr>
<tr>
<td>Wattleseed</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>over</td>
</tr>
</tbody>
</table>

* Recent (since last edition) additions to commercial supply

Table 1. Commercially utilised native foods - supply status
The native food industry offers opportunities at the agricultural level in farm diversification and the development of sustainable and environmentally appropriate agriculture. At the marketing level, native foods offer a unique point of difference to the food industry globally, adding value by product differentiation to potentially every area of food manufacture. There are potential nutritional and functional food benefits and intangible benefits to indigenous and non-indigenous stakeholders.

Dr. Rob Fletcher refers to many of these in his introductory chapter – desire for change, desire for improvement, creating real benefit and an expectation of intrinsic worth in the activity. Aboriginal people who are actively involved in the industry identify social, cultural, economic and health benefits arising from that involvement (Mr John Collyer, Chairperson, Indigenous Australian Foods Ltd). The meaningful involvement of Aboriginal people brings authenticity and integrity to the native foods industry.

**Marketing overview**

**Identifying markets**

All commercially utilised native foods are marketed to the Australian domestic and export markets in four major forms:

- Farm gate commodity product (limited value adding may include drying, freezing, cleaning, grinding etc.)
- Value added into a wide range of industrial food manufacturing flavourings and seasonings
- Value added into a wide range of hospitality foodservice products
- Value added into a wide range of consumer products in mainstream, specialty and tourism markets

There is little or no interest at present in the mainstream market for native foods as fresh fruit or herbs, although this may change as production and post harvest systems are improved.

Table 2 provides some current (2004) indicative farm gate prices for large volume sales. These prices are indicative only and frequently volume users will negotiate a tailored price with suppliers. The pricing may be expressed as a range and may change at any time due to seasonality, shortage of supply, glut of supply etc. The most common forms for each of the native foods are also described in Table 2.

Table 2 illustrates generally high prices for native foods. While these prices may appear attractive to new entrants into the industry, they are based on the high cost of cultivation or wild harvest.

Most food processors and larger scale commodity buyers within the native food industry will usually require tonnage (usually

### Table 2. Some indicative farm gate prices (2004)

<table>
<thead>
<tr>
<th>Product</th>
<th>Form</th>
<th>Current indicative farm gate price/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aniseed myrtle</td>
<td>Dry and milled leaf</td>
<td>$38.00</td>
</tr>
<tr>
<td>Bush tomatoes</td>
<td>Dry whole or ground</td>
<td>$20-24.00</td>
</tr>
<tr>
<td>Davidson’s plum</td>
<td>Frozen whole</td>
<td>$2-6.00</td>
</tr>
<tr>
<td></td>
<td>Frozen de-seeded halves</td>
<td>$5-13.00</td>
</tr>
<tr>
<td></td>
<td>Frozen puree</td>
<td>$9-10.00</td>
</tr>
<tr>
<td>Kakadu plum</td>
<td>Frozen whole</td>
<td>$15-20.00</td>
</tr>
<tr>
<td>Lemon aspen</td>
<td>Frozen whole</td>
<td>$8-12.00</td>
</tr>
<tr>
<td>Lemon myrtle</td>
<td>Whole fresh leaf on stem</td>
<td>$2.00-10.00</td>
</tr>
<tr>
<td></td>
<td>Dried and milled</td>
<td>$22-25.00</td>
</tr>
<tr>
<td>Native citrus</td>
<td>Desert lime frozen whole</td>
<td>$5-15.00</td>
</tr>
<tr>
<td></td>
<td>Finger lime whole</td>
<td>$25-80.00</td>
</tr>
<tr>
<td>Native pepper</td>
<td>Dry and milled leaf</td>
<td>$38.00</td>
</tr>
<tr>
<td>Pepperberries</td>
<td>Fresh</td>
<td>$6-20.00</td>
</tr>
<tr>
<td></td>
<td>Dried</td>
<td>$30-70.00</td>
</tr>
<tr>
<td>Native mint</td>
<td>Dried and milled leaf</td>
<td>$35.00-38.00</td>
</tr>
<tr>
<td>Ribberries</td>
<td>Frozen whole, seedless</td>
<td>$13.50</td>
</tr>
<tr>
<td>Quandong</td>
<td>1st grade premium dried</td>
<td>$40-60.00</td>
</tr>
<tr>
<td></td>
<td>Frozen deseeded halves</td>
<td>$25-28.00</td>
</tr>
<tr>
<td>Wattleseed</td>
<td>Raw whole seed</td>
<td>$15.00</td>
</tr>
<tr>
<td></td>
<td>Roasted and milled</td>
<td>$20-24.00</td>
</tr>
</tbody>
</table>
provided over an agreed time frame) and will expect fruit to conform to minimum food safety requirements. With increasing demands within the food industry to provide ever-safer food products, growers (and commodity traders) of native foods will increasingly be expected to provide microbiological data on their products, nutritional information and the provision of specifications and conformation to those specifications. Specifications will describe the product – colour, flavour, typical size etc (including micron for milled product), describe the packaging the product is provided in (which must be food safe) and provide storage instructions for food safety and optimum shelf life. Any known allergens must be identified on the specification sheet.

Smaller quantities can be successfully marketed within local markets and in some sectors of the native food industry this has become the prime market (see quandong chapter).

**Market demand**

Reliable information on market demand is very difficult to obtain, as the industry remains fragmented and unwilling to share information. As Hugh MacIntosh points out in the native citrus chapter there are still “significant amounts of semi or sub-commercial activity ...Further the industry is too small to be considered in the normal horticultural production statistics”. A recent analysis has stated, “claims for sales volumes and market leadership are difficult to substantiate and appear to be exaggerated in a number of cases. However, the native food industry, while small and still fragmented, is nevertheless thriving on a diverse number of fronts and the substantial industry growth predicted in the 1990s is likely to occur in the next several years.

The industry continues to be driven by highly motivated individual “visionaries”, whose ideas for the industry generally vary widely” (Lester, 2003).

One unifying “vision” throughout the industry (see following chapters) is the recognition that without mainstream processors and markets adopting the products, critical mass for the industry will not be achieved.

To encourage uptake by mainstream processors and markets, native foods must become affordable and sustainable to the broader food industry that operates in a highly competitive market place. Consistency of supply must be guaranteed regardless of variations caused by climate, harvest, handling and transport.

Key marketing issues for native food producers include:

- a lack of market awareness about native foods in general and how to use native foods in particular
- developing a clear, industry marketing message that can be heard amongst the cacophony of mainstream food marketing
- how to match the economic viability of native food agriculture with the market’s need for affordable product.

**Species**

There has still been little genotype selection of improved plants, but the following species are at present the most commonly used and in demand. The species are listed alphabetically and are not ranked.

**Aniseed myrtle** (*Backhousia anisata*) A relative “newcomer” the aniseed myrtle is typically an eastcoast rainforest tree with dense foliage that has a strong anise flavour. Used primarily as a herb or flavouring.

**Bush tomato** (*Solanum centrale*) A small shrub with grey/green leaves; fruits turn from green through to yellow when ripe and dry on the bush until they reach a reddish ochre colour and resemble a raisin. It is an arid zone plant native to Central and Western Australia and...
it grows in lighter soils in areas of extremely variable rainfall. Fruit can be harvested mechanically and it has enormous potential for dry zone cropping (but needs water).

The fruit is intensely flavoured with a piquant, spicy taste balanced by fruit sugars. Used primarily as a spice or flavouring.

Kakadu plum (*Terminalia ferdinandiana*) Top end coastal tree from the Kimberley to Darwin. Pale olive green, ovoid fruits with central wooden stone (similar to an immature olive). Fruit is fibrous and difficult to process but has an ongoing market as a value added product.

Lemon aspen (*Acronychia acidula* and *Acronychia oblongifolia*) Eastcoast rainforest tree bearing pale lemon fruits. Can fruit within two years of planting and will grow in a variety of locations. Lemon aspen has a wonderful lemon flavour with secondary flavour of eucalyptus. Used as a processing or culinary fruit.

Lemon myrtle (*Backhousia citriodora*) Probably the most intensely cultivated of all native foods, with 150,000 trees in NSW and a further 1 million trees in Queensland. Lemon myrtle prefers nutrient-rich soils of a medium to heavy texture in a well-drained, wind-protected, sunny position. Prefers acidic soils and areas recording more than 800 mm of rainfall per annum. Lemon myrtle has a distinctive lemon/lemon grass flavour due to the extraordinary level of citral in the leaf. Used as a herb or flavouring ingredient.

Native citrus (*Citrus glauca, Citrus australasica and other spp.*) Australia has seven native plant species that are true citrus. The wild lime (*C. glauca*) is endemic to the semi-arid regions of south-west Queensland, western New South Wales and South Australia. Finger lime (*C. australasica*) is endemic to rainforest habitats on the east coast. Like all citrus, native citrus prefer a well-drained soil. They will tolerate poor soils, dry conditions and cold (particularly the wild lime). Plantation grown trees have been shown to respond well to both irrigation and fertiliser. The fruits have distinct lime flavour but with that unique difference found in native foods – but so difficult to describe. Extremely versatile and excellent processing and culinary fruits.

Native pepper and Pepperberries (*Tasmannia lanceolata and other spp.*) Native or mountain pepper is found naturally in the wet forests and shrublands of southeast Australia and extending, at higher latitudes as far as the Hastings River catchment in mid-north New South Wales. It grows best in cool, sheltered environments free from water stress, on neutral, acidic soil, preferably well drained and fertile. Mountain pepper
leaf and berries have a hot, spicy and aromatic flavour derived largely from a terpene compound—polygodial. The leaf is used dried and milled as an herb and flavouring. The berries are a processing fruit or are used dried and milled as a spice or flavouring.

Native pepper berries

Native mint (Prostanthera rotundifolia and other spp) A recent addition to commercialised and cultivated native foods. Native mint predominantly is grown in southern Victoria. The plant is a large bush with dense foliage, which may be harvested three times a year, once established. The leaves have an intriguing minty flavour with a peppery finish. Native mint is used as an herb and flavouring.

Riberry (Syzygium leuhmanii)
With a similar range as Davidson’s plum, the riberry is mainly grown in northern New South Wales, but has potential in many areas. Plants are established easily and there are some selections/hybrids available. The fruit is small and has a striking purple colour that fades to pink when cooked. Riberrys are strongly clove and spice flavoured. Excellent processing and culinary fruit.

Quandong (Santalum acuminatum) Quandongs require a climate with high light intensity, low relative humidity and will grow in a range of soil types including pH variations and high salinity. Soils must be well drained and quandongs will not tolerate waterlogged soils. The fruit is a visually appealing red, tart tasting and dry textured. It is either dried or frozen and is a processing and culinary fruit.

Ripening Powell No. 1 fruit (prov. PBR)

Wattleseed (Acacia victoriae and other spp) Acacia grows throughout the country and many species are suitable for culinary use. The most popular wattleseed in the food industry is Acacia victoriae, which is found extensively throughout the Central Desert region and into South Australia, Western Australia and New South Wales. The seeds can be harvested mechanically. The flavour of wattleseed is nutty with coffee/chocolate overtones. The seed with aril intact is used and it must be roasted and milled before using as a herb/spice or flavouring.

In addition to the above, RIRDC is supporting two projects researching tuberous plants, one based on Adansonia (Boab) tubers, the other based on Platysace tubers which may lead to field crops for fresh produce from native plants. The first project is in conjunction with AgWA and the second with the University of Western Australia. For further information, readers should consult Research In Progress published by RIRDC.

Agronomy

In general, to make a good profit, the producer needs a good knowledge of what management practices will yield good quantities of high quality produce. In the native foods industry producers need more – they need to know they are planting reliable plants with proven yields. Harvest and post-harvest issues need to be identified and addressed with a focus of continual improvement. To gain this knowledge will take time and those entering the industry will need to take a long-term view.

Although commercial production of many native plant foods is still in development stage, sufficient demand for some species is encouraging commercial production (refer Table 1). While basic establishment costs per hectare for most species is unavailable, Table 3 (from Ryder, 2004) encapsulates some of the current limiting constraints and requirements for long-term success for each crop. Dr Ryder has been conducting research of a number of trial plantings of various native foods in South Australian and Victorian locations.

Specific agronomic information for selected species will be found in the following chapters. Species discussed in depth are:
- Bush tomato
- Lemon myrtle
- Quandongs
- Native citrus
- Native pepper
- The Davidson plum.
### Table 3. Native food crops: limiting factors and requirements for success.

<table>
<thead>
<tr>
<th>Species</th>
<th>Current constraints</th>
<th>Needed for long-term success</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quandong</td>
<td>Not easy to cultivate, market development</td>
<td>Cultivation methods, market and product development</td>
</tr>
<tr>
<td>Acacia</td>
<td>Improved planting material, harvest methods, market development, product awareness</td>
<td>Improved planting material, market development, product awareness and education</td>
</tr>
<tr>
<td>Citrus</td>
<td>Product development, market development, education and awareness</td>
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<td>Mountain pepper</td>
<td>Improved planting material and cultivation methods, market development, education and awareness</td>
<td>Improved planting material, mechanical harvesting, market development, education and awareness</td>
</tr>
<tr>
<td>Lemon myrtle</td>
<td>Education and awareness, market development</td>
<td>Education and awareness, market development</td>
</tr>
<tr>
<td>Lemon aspen</td>
<td>Improved planting material, cultivation methods, market development</td>
<td>Improved planting material, cultivation methods, market development</td>
</tr>
<tr>
<td>Riberry</td>
<td>Improved planting material, cultivation methods, long lead-time to fruit (some locations), market development</td>
<td>Cultivation methods for fruit set and development, market development</td>
</tr>
<tr>
<td>Bush tomato</td>
<td>Improved planting material, cultivation methods, harvest methods, education and awareness</td>
<td>Improved planting material, cultivation and harvest methods, education and awareness, market development</td>
</tr>
</tbody>
</table>

### Key messages
- There are native food species enjoying commercial utilisation and some success
- Focus on those species that have an established demand
- Grow what the market wants
- Be aware of all issues that contribute to or inhibit success
- Be prepared for a long term investment and involvement—native food production is not an overnight success story

### References


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**About the author**

Juleigh Robins is co-owner and Director of Robins Foods Pty Ltd, manufacturers and brand marketers of Outback Spirit products. Juleigh has worked extensively on the native food supply chain, strategically at the inbound supply end and the outbound market end.

Juleigh has also authored two native food cookbooks - ‘Wild Lime’ and ‘Wild Classics’ published by Allen & Unwin. Robins Foods was the 2003 Rabobank Agribusiness Award for Excellence Rural Industries Research & Development Corporation Agribusiness Value Adding Award winner’. Juleigh was also a Victorian finalist in the 2003 Telstra Business Women’s Awards Westpac Group Business Owner Award’.

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Bush tomato

Introduction

Bush Tomato is a common name for the arid land species Solanum centrale that is found naturally throughout the Central Desert region of Australia. Bush tomatoes are the fruit of the plant and are usually sun dried on the bush before harvesting. Post harvest the dried bush tomato is usually ground into a fine powder or coarse granule depending on application. There are many Solanum species in Australia, not all edible. S. centrale is by far the most common edible species used in the food industry but further research and product development work is being focused on Solanum chippendalei amongst others.

Bush tomatoes are essentially a herb/spice product and a major strength of the bush tomato is its unique and intense flavour that retains its integrity in many applications, and in relatively small ratios to total ingredient mass (refer “Wild Lime- cooking from the bushfood garden” Juleigh Robins (1996) Publisher Allan & Unwin). This characteristic is a double edged sword for the bush tomato “sector” – on the one hand it is an attractive and marketable flavouring ingredient providing a distinctive flavour difference at a relatively economical usage and cost to the manufacturing or hospitality consumer, and on the other a difficult crop for the agricultural sector to commercialise due to the high costs of production combined with the relatively small quantities currently required by the food industry.

The current demand for bush tomato is being met mostly by the wild harvest sector. The wild harvest sector while operating under particular climatic, cultural, geographic and economic constraints is however an important supply chain partner to existing users of bush tomato and provides a valuable income source to its largely Aboriginal members. It is unlikely that wild harvest

Juleigh Robins and Maarten Ryder

Natural distribution
Cultivation recorded outside of natural distribution

Fruit of bush tomato
can continue to meet the growing demand except in the very short term.

The current uptake of bush tomato into the food manufacturing and food service industry is encouraging and further demand is expected over the short and long term. It is clear however that the professional agricultural sector, while identifying bush tomatoes as a potential alternative crop suited to low rainfall and arid regions, will limit investment in bush tomato production until the demand pull is sufficient to make broad acre production viable. It is also clear that the agricultural sector is seeking reliable plant material with consistent and demonstrable yields. Managed wild harvest activities and small-scale cultivation in particular regions/circumstances will need to fill ongoing and growing demand in the short term.

Marketing

Bush tomatoes, particularly *Solanum centrale*, are proving to be one of the most marketable products emerging from the burgeoning Australian native foods industry.

Bush tomato flavoured and seasoned products are now successfully ranged in mainstream categories in supermarkets nationally in Australia.

Chris Mara, Chairperson of the Coles Indigenous Food Fund (a Coles Supermarkets initiative) says bush tomato products are the most popular native foods purchased by consumers and are commercially successful in Coles’ supermarket range of native food products.

Bush tomato based seasonings and flavourings are now available extensively throughout Europe, the UK and Asia and are experiencing growing acceptance in the industrial food sector. Mr. Geoff Gordon, Managing Director of Hela Schwarz Australia, exports high volumes of native food based flavour bases, premixes and seasonings for distribution throughout Europe and Asia and identifies bush tomato as one of the most versatile of all native ingredients currently available. According to Mr Gordon, bush tomatoes have been successfully incorporated into flavour bases because they “impart a fascinating flavour twist to so many standard herbs and spices”.

The broad supply chain for bush tomatoes is described in the following flow chart.

At present the supply is largely sold direct to the food industry for further on sale or value adding. Bush tomatoes are currently marketed to both the Australian domestic and export markets in three major forms:

- prime ingredient/commodity as a whole dried fruit or ground/powdered dry ingredient;
- value added into a wide variety of industrial food flavourings and seasonings; and
- value added into a wide variety of value added consumer products (sauces, chutneys, herbs and herb blends, breads, biscuits etc)

In some cases companies utilising bush tomatoes in their own value adding production are also acting as commodity warehouses and suppliers to other parts of the food industry. A clear sourcing and warehousing capability has yet to be developed in the bush tomato supply chain. Given the small size of leading companies in the native food industry the overlapping roles may be a major constraint to marketing effectiveness as precious financial and time resources are spent largely on inbound supply chain activities and storage rather than at the outbound marketing activities. Suppliers of bush tomatoes could gain a competitive advantage by developing a warehousing capability. This would fit supply more closely to customer demand by supplying bush tomatoes as required, rather than in bulk seasonally.

Outback Spirit products including bush tomato chutney
As a broad generalisation, the demand for bush tomatoes in the short term is greater than available current supply and future demand is expected to grow significantly. However, it is impossible to provide an exact figure for the total value of bush tomato production (wild harvest and/or cultivation) in Australia today. Recent analysis suggests that annual volumes of bush tomatoes traded are between 8-10 t, of which up to 2 t may be from cultivated sources. The total value of the bush tomato crop per annum is currently fairly modest but expected increases in demand may see the value of the bush tomato crop increase significantly – but of course only if the crop is available to fill demand!

The recent supply of bush tomatoes has been severely affected by drought in the Central Australian region. Prices have moved upward from the range of $15 to $20/kg three years ago. It is now common for wild harvest fruit to fetch around $20.00 to $24.00/kg (depending on fruit supplied as whole or partially value added by grinding etc). Good conditions (rain when the plants need it) in Central Australia may see wild harvest prices ease marginally. Cultivated fruit is similarly priced at approximately $22 to $24/kg and this price is significantly higher than some in the sector had anticipated.

While these prices may sound attractive they clearly reflect the high costs currently involved in either wild harvesting or commercially cultivating these plants. For the bush tomato “sector” to continue to grow it is important that we find ways to make this product economically sustainable in both the cultivated and wild harvest sectors. Barriers to increased cultivation, and therefore large-scale supply, are high initial set up costs, low and inconsistent yields and perceived small market demand. Prices for broad acre cultivated crops are unlikely to reduce until these barriers are removed and bush tomato production must provide commercially acceptable returns to bush tomato suppliers.

It is critical for the future viability of the bush tomato sector that the industry focuses on demand to pull production. However in order to stimulate demand, bush tomatoes need to be more affordable and viable to the food industry that operates in a highly competitive market place. Bush tomato products are expected to compete successfully against mainstream food products using ingredients from supremely well-developed supply chains – perfected over years if not centuries.

Matching and meshing these needs will be essential for long-term bush tomato sector growth.

**Production requirements**

**Climatic**
The bush tomato is an arid zone plant native to central and Western Australia and grows in lighter soils in areas of extremely variable rainfall. The plant will normally grow, flower and fruit after a sufficient rainfall event. Re-growth from below ground is favoured by soil disturbance. Although frosts are common in the natural range of bush tomato, the plant itself and the ripening fruit are susceptible to frost damage. The plant is best grown as a perennial in warm, dry, frost-free or low frost-risk locations, but can be grown successfully in a wider range of conditions.

Bush tomato can also be grown as an annual crop, but must be planted early (in spring) because of the extended ripening period in autumn. Bush tomato fail to thrive or even to establish in colder, wetter areas (eg south east coast of SA).

Most of the current crop of bush tomato comes from wild harvest in central Australia. Note that within the same geographic range there are closely related species that are similar in appearance to *S. centrale* but which produce POISONOUS fruits. Similarly, it is important to note that the fruit of *S. centrale* in the green (immature) state contains the toxins solanine / solasidine (similar to the toxin in green potatoes). Green fruit should not be harvested for human consumption. Yellow / mature dried fruits have very low, acceptable levels of the toxin (Hegarty et al., 2001).

**Soil**
Lighter, well-drained soils are preferred. Mounding (e.g. 0.3 to 0.5 m high) to assist drainage is very likely to be beneficial. In heavier soils, mounding will

Bush tomato grown on mounds, Junee New South Wales
probably be essential. Deep ripping e.g. to 0.5 m, is also likely to aid bush tomato production. There is a view that for large-scale (broad-acre) production in well-drained soil, mounding is unnecessary.

**Water**
A water supply is required, either from natural rainfall or from irrigation. The plant does appear to have a reasonable tolerance of saline water supply.

**Topographic requirements / constraints**
Bush tomatoes have been cultivated with some success at several locations in central Australia and in South Australia (e.g. Reedy Creek Nurseries and associated growers in Indigenous communities, Simarloo Pty Ltd, farmers in the mid-north of SA and Tangentyere Council, Alice Springs). They have also been grown successfully on a small plot trial basis in locations from Ceduna in western SA through to Junee on the western slopes of New South Wales (CSIRO).

**Varieties / cultivars**
When grown from seed, bush tomato plants vary a great deal in morphology (e.g. leaf colour, presence or absence of spines etc). This indicates that there is a great potential for plant improvement, which has barely begun. Plants are usually supplied in seedling trays and, depending upon the supplier, will consist of highly variable unimproved material or more uniform, improved (selected) planting material. Reedy Creek Nurseries have begun selecting bush tomatoes for increased fruit size and other desirable characteristics.

There are very specific requirements for the good germination of bush tomato. This has been investigated scientifically (Ahmed, 2001) and also by various plant propagators in nurseries. Scarification of the seed, soaking and smoke treatment all promoted germination, but there were also differences in response between seed lots (Ahmed, 2001).

Plant material is available from:
- Australian Native Produce Industries (Paringa, South Australia; Tel 08 8595 8129)
- Steve Ross, AZEC (Broken Hill, Tel 08 8087 8023).

Reedy Creek Nurseries (Kingston SE, South Australia) sells to Indigenous communities (Tel 08 8768 7220). Plants are available from August onwards.

Tangentyere Council Nursery in Alice Springs supplies a variety of native food seedlings including selected bush tomato (10 Brown St, Alice Springs, NT, Tel 08 8952 6644).

**Cultural practices**

**Site preparation**
It is recommended that the soil is ripped and mounded (e.g. to 0.5 m) where possible, to aid drainage, especially on heavier soils and in cooler environments in southern Australia. Where mechanical harvesting is used, the planting layout should be designed to suit the type of harvesting equipment. Some growers practice weed control by use of weed matting.

**Equipment / facility needs**
Equipment is required for ripping the soil along the planting line and for soil mounding where practised.

**Good cultural practices**
Some growers advocate planting rows of other *Solanum* species every third or fourth row, to attract pollinating insects, since bush tomato is bee-pollinated. Native bees appear to be the preferred pollinators.

Row spacings are commonly in the range 1 to 2 m, with 0.5 - 1 m between plants within the row. At Tangentyere, approx 1/3 ha was
The bush tomato can be grown as a perennial, with the second and later year crops coming either from persistent above-ground growth, or from suckers that re-grow in spring after the plant has died off in winter. The plant grows best as a perennial in warm, dry locations that have a low incidence of frost. In less favourable locations, the crop can re-grow from suckers but will be harvested later because complete regeneration of the shoot is necessary. It is possible to grow the crop as an annual, planting as early as possible in spring and harvesting in autumn.

Mulching can be beneficial but must be combined with good drainage.

**Fertiliser**

Slow release fertiliser has been used on plantings of bush tomato. Not a great deal is known of the specific nutrient requirements of bush tomato, although high potassium fertiliser after flowering, during fruit development is likely to be beneficial. Phosphorus and Nitrogen fertilisers as well as organic manures have been used successfully. However, experience shows that a fertiliser treatment that works at one location will not necessarily be beneficial at other locations.

**Time lines to first harvest**

If planted in early spring at a suitable location, harvest should occur the next autumn. In places where the plant is a perennial, the yield can be expected to rise in the second and third years. Quality can decrease after that time, so Reedy Creek Nursery and associated growers plant the crop on a three-year cycle. Expected yield figures vary from 25 to 100 g of fruit per plant in year one.

Depending on the conditions (and especially where the plant is perennial), this can increase to twice the initial figure in years 2 and 3 (50 to 200 g fruit per plant). However, note that there are examples where yields were similar in years one and two (around 0.7 t/ha) and then decreased dramatically in years three and four. Where unimproved plant material is used, the variation in yield between plants is likely to be very high.

**Pest and disease control**

**Common pests / diseases and controls**

Establishment rates of bush tomato in cultivation can be very variable. It can be excellent, but complete failures have also occurred. The failures were possibly due to soil-borne pests and/or diseases, however no research has been done into the cause and control of these problems. Small trial plantings are therefore recommended for new areas.

Sooty mould on the foliage and fruit has caused problems when grown in moister (especially moist coastal) locations.

**Harvest, post-harvest storage and treatment**

Harvest is by hand or mechanical. The crop should be harvested when the fruit is either dried or at least yellow in colour and ideally when it reaches a rich ochre brown. Green fruit in the harvest should be avoided because these contain higher levels of the toxin solanine. In summer, individual plants very often carry all stages of fruit development from flowering through to ripe fruit. It is therefore more efficient to harvest late in the season when the fruit is more uniformly ripe. When hand-harvesting, protection from the spines of the plant is necessary (gloves). Mechanical harvesting has been achieved by adaptation and modification of grain crop headers.

Fruit that has not dried out to a very dry state or is still yellowish in colour will need to be further dried after harvesting. Fruit must be protected at all times from moth and insect infestation.

**Financial information**

Cultivation of bush tomatoes has only been practiced on a small scale to date. Tangentyere Council in Alice Springs, Northern Territory, pioneered the successful trial of cultivated bush tomatoes on three plots at Tangentyere Town Camps around Alice Springs between 2001-2003. Tangentyere Council generously provided a table of typical set up
costs for a plot of 3,500 m² (Table 1, pp 2). The plot comprised 35 rows of 60 m each, with a 1.5 m spacing between rows.

**References**


**Acknowledgements**

The authors acknowledge very helpful discussions with Noel Sims of Simarloo Pty Ltd, Peter Hoffmann (Eudunda SA), Peter Cowham (Tangentyere Council, NT) and Mike Quarmby of Reedy Creek Nurseries. We also acknowledge very helpful discussions regarding the markets for bush tomato with Chris Mara, Chairperson, Coles Indigenous Food Fund, Coles Supermarkets and Geoff Gordon, Managing Director, Hela Schwarz Australia.

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Juleigh Robins is co-owner and Director of Robins Foods Pty Ltd, manufacturers and brand marketers of Outback Spirit products. Juleigh has worked extensively on the native food supply chain, strategically at the inbound supply end and the outbound market end. Indigenous Australian Foods Ltd (an Aboriginal owned and controlled supply company), is a unique and tangible outcome of this focus and has enabled Hela International, Kez’s Kitchen, Cooka’s Country Cookies to become valued Robins’ supply chain partners. Coles Supermarkets also support Robins via the distribution of the Outback Spirit range in Coles 600 supermarkets nationally and through partnering Robins Foods in Coles Indigenous Food Fund.

Maarten Ryder graduated from the University of Adelaide with Honours in Botany in 1975. He gained a PhD in Agricultural Biochemistry and Plant Pathology from the same university in 1985. He has worked in soil biology research at CSIRO since 1986. More recently (1999) he began working on the cultivation of native food plants and joined the Desert Knowledge Cooperative Research Centre in 2003, where he is working on “bush produce”.

About the authors
Introduction

Lemon myrtle (*Backhousia citriodora*) F. Muell. is a medium-sized native tree (3-20m), first discovered by Baron Ferdinand von Müller in 1853. It originates from coastal rainforest areas from 50-800 m above sea level in Queensland Australia, between the latitudes 17˚30’S and 27˚S.

Joseph H. Maiden reported the potential use of lemon myrtle for commercial production in 1889 and a German company, Schimmel & Co., was the first to identify the ingredient, citral. This ingredient, comprising up to 90% in lemon myrtle essential oil, gives it a distinctive lemon fragrance and taste; other lemon flavoured oils have less citral, such as citrus (3-10%), lemon grass (75%) and tropical verbena (74%).

Although lemon myrtle essential oil has been used from early last century for lemon flavouring, it could not compete with the much cheaper essential oils distilled from lemon grass and tropical verbena.

In the early 1990’s, lemon myrtle was rediscovered as a promising culinary herb in the emerging Australian cuisine, fusing native flavours into a variety of dishes. This led growers to view the crop as a potential new enterprise for the Northern Rivers region of the North Coast of New South Wales.

By 1996-7, farmers in New South Wales had planted over 150,000 trees hoping to satisfy a market demand anticipated during the Sydney 2000 Olympics. More than 1 million trees have also been planted in Queensland.
Lemon myrtle prefers nutrient-rich soils of medium to heavy texture in a well-drained, wind-protected sunny position. Young trees are particularly frost and drought tender and require irrigation during dry spells.

The tree prefers neutral instead of acid soil and is prone to yellowing in alkaline soils. Once established, the trees are relatively hardy and recover quickly from dry spells.

Although trees have been grown in Victoria and South Australia, most of the crop is located in northern New South Wales and southeast Queensland, in areas recording more than 800 mm rainfall. A well-managed mature orchard in northern New South Wales with rich soil and ample water can achieve a yield of 5.5 t/ha dry leaf per annum.

Flat, free-draining ground is essential for mechanical harvesting. River flats are not suited, as the trees succumb to waterlogging. The tree is prone to snap off in wind-prone areas.

**Market and marketing issues**

Since 1997, the Lemon myrtle industry has been production driven with growers not realising their anticipated returns. Lemon myrtle essential oil is not commercially produced anywhere in the world and the product is largely unknown in the global market place.

Lack of research in growing, processing, storage and product use has severely challenged the industry which faces a glut of raw material and no market. In the past ten years, many more uses of lemon myrtle have been discovered, though lemon myrtle is still only a niche market product, currently oversupplied.

Lemon myrtle product is mainly traded as a specialist culinary ingredient to be added to food for its unique flavour. Some food manufacturers use small amounts of either dried milled leaves or essential oil to flavour pasta, oils, sauces, ice creams or tea. Without mainstream food processors adopting the product, critical mass for the industry will not be achieved.

Lemon myrtle essential oil in vitro has been shown to be superior in antimicrobial and antifungal action to the now popular tea tree essential oil (Ryan, Cavanagh and Wilkinson, 2000). It may have a future as an antiseptic, surface disinfectant or perhaps for inclusion in foods as a natural antimicrobial agent. Although the Therapeutic Goods Administration of Australia (TGA) has listed lemon myrtle essential oil as an active ingredient for external application, no health benefit claims can be made without the appropriate TGA approval.

Key Australian production statistics are unavailable due to the reluctance of key producers to share production information.

Prices for lemon myrtle (as fresh leaf on stem) at the farm gate have recently fallen sharply from $10 to $2/kg, perhaps as a result of the advent of mechanised harvesting.

**Varieties/cultivars**

There are two main commercial clones being planted. The line commonly referred to as “Limpinwood” is hard to strike, but shows superior ornamental presentation, high biomass and high oil yield and citral content. The other variety, commonly referred to as Line B or Eudlo clone is relatively easy to strike, vigorous but slightly lower in biomass, oil and citral yield. Most plants have been supplied from contracted specialist nurseries.

**Cultural practices/agronomy**

The decision to cultivate Lemon myrtle as a commercial crop should only be made in
Lemon myrtle is a perennial tree crop typically planted in rows. Site planning requires that there is easy mechanical access year round. The land preparation required for lemon myrtle is deep ripping, followed by rotary hoeing. It is essential to clear the rows of weeds before planting. Lemon myrtle is most commonly planted in late spring or early autumn. Young trees are transplanted at 30-40 cm tall, placed 1.5 m apart with a 3.5-4 m spacing between the rows. Ample moisture, mulching and weed control are essential for successful crop establishment.

The nutritional requirements for lemon myrtle are not well understood, though the trees grow best in rich fertile soils and need increasing amounts of organic fertilisers as they are maturing. The trees can be cut up to three times each year and as each harvest removes a large amount of biomass it is essential to return nutrients for long term productivity.

In New South Wales, trees are tip-pruned for the first 18 months to encourage leaf production. After 24 months, the trees start to form hedges, which can be mechanically harvested.

Specialised harvesting and post harvest machinery is not available off the shelf and the prospective grower needs to consider investing substantial resources into mechanising harvesting.

Good cultural practises and good manufacturing practises are paramount as the product is a food ingredient. Traceability, HACCP and product specification including microbial or residual counts are now becoming an essential part of virtually any food business. Farmers need to be very diligent about the integrity of their products if they want to sell them.

**Pest and disease control**

Lemon myrtle has not so far been significantly challenged by pests or diseases in northern New South Wales. There is no chemical pesticide approved for the crop.

**Harvest and post-harvest**

Growers of lemon myrtle need to consider economy of scale or critical mass to be cost effective, to be able to assure consistently high quality supply in quantity. This can only be achieved by mechanised production and processing. The capital intensive nature of the production/processing chain, coupled with the high cost of establishing markets poses risks for the grower.

Lemon myrtle mechanical harvest for dried leaf product is done by specially designed and custom-built harvesting machinery cutting the tips of the tree in an angled position. The cut material falls onto a conveyor belt transporting it into a stainless steel bin. Some people in the industry still hand cut and hand strip the leaf from the stem, but this will not be a viable situation for the future.

The leaf-on-stem material is dried as is and is de-stemmed after drying or is mechanically stripped wet, to then be dried in herb drying rooms or custom designed specialised driers.
Due to the high volatility of the citral component, it is imperative to dry lemon myrtle at low temperatures (>35°C) as quickly as possible. Ideally, the product is placed into the drier within one hour of harvesting to prevent the product heating up, deteriorating and becoming contaminated with a significant microbial load.

After drying, the leaves are ground to customer/product specification and stored in a cool dark environment until dispatch.

For essential oil, specialised machines cut the stems and leaves into smaller particle sizes. This cut material is then fed into a stainless steel bin and placed in a steam distillation unit. The essential oil is very corrosive to plastics and stainless steel containers or glass are commonly used for cool room storage until dispatch.

**Financial information**

The estimated start up cost per hectare, not including land, machinery, clearing, labour or structures is about $14,000–$16,000 including operating costs for one year. Plants can be obtained from specialised nurseries for $150 - $450 per hundred, depending on size. Weed control, mulching, irrigation and fertilising are the main costs in the two-year establishment phase. While the need for weed control diminishes as the plants mature, harvested trees require application of more fertiliser with age.

Capital outlay for lemon myrtle cultivation needs to include tractors, trailers and mowers. However, the capital outlay for specialised equipment such as custom-built harvesters, stainless steel bins, conveyors, specially designed units to remove leaves from stems, drying units or distillation equipment such as boilers, condensers, separators are very high. Furthermore, suitable structures for processing need to meet the requirements to comply with HACCP.

The size of accessible markets is limited and the marketing cost for a new crop not previously grown commercially anywhere in the world is very expensive. Economic analyses for lemon myrtle, as for all new crops need to be treated with extreme caution. The lemon myrtle industry in Australia is still in the early stage of development and reliable statistical information is unavailable.

Lemon myrtle is one of the most cultivated species of the native food industry, excluding macadamias. It shows wonderful potential as a specialist food ingredient, functional food and cosmetic ingredient. However, its financial viability will depend on mainstream food industries using the product.

**Key references**


[http://www.hort.purdue.edu/newcrop/ncnu02/v5-040.html](http://www.hort.purdue.edu/newcrop/ncnu02/v5-040.html)


Key messages

- Versatile native herb
- Multiple uses in different categories
- Promising bio-actives present
- Currently in oversupply

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Native citrus

Hugh Macintosh

Introduction

Most Australians would be surprised to learn that there are seven native plant species that are a true citrus. Despite this abundance, the cultivation and use of native citrus was largely ignored until the 1960’s when the CSIRO began investigating the use of some species in their citrus breeding programs.

The application of these native species was primarily in developing new rootstocks, suited to Australian conditions, to support the growth of traditional Citrus species (Sykes, 2000). The native species’ unique characteristics, particularly relating to salt and drought tolerance and disease resistance were of particular interest.

Wild limes have often been cited as one of the native foods with the most potential for commercial development. However, it is only in the last 10 years that researchers have been developing new crop plants based on the native species.

Commercial producers such as Australian Native Produce Industries (ANPI), have seen the potential in these new varieties and secured the right to commercialise them. At the same time, other commercial producers have been developing plantations based on selections taken from better performing wild plants. In some instances these selections are being grafted onto specially selected citrus rootstock.

High quality native limes are now being harvested from orchards, reducing the need to collect limes from the wild, improving the reliability of supply and minimising any detrimental impact on wild populations.

While production issues continue to demand research attention, it is the market that ultimately determines the success of otherwise of a product. Producers, processors and marketers need to continually ask themselves whether the product satisfies a demand in a particular target market.

As with many young industries, the native lime sector suffers from a general lack of understanding of...
existing and potential markets and the forces that drive these markets. This can lead to participants not focussing their energies and scarce resources on the potentially most rewarding sectors of the market.

**Marketing and marketing issues**

Reliable market demand information and statistics are difficult to obtain as the wild lime industry remains fragmented, with a significant amount of semi or sub-commercial activity – e.g. small-scale operations that collect fruit and sell it to local restaurants. Further, the industry is too small to be considered in the normal horticultural production statistics.

The domestic market for native citrus based products is relatively small at present, but there seems to be a significant export market potential for both processed and part-processed product. Until recently, most of the native citrus supplies have come from wild harvest, which has constrained industry expansion as annual yields are highly variable. The emergence of significant plantation grown quantities of limes means that the industry is beginning to establish a base from which to develop a reasonable market presence.

Market development will require a significant capital base from which to develop a range of products and to establish an efficient marketing and distribution chain.

The industry structure includes:
- Wild harvesters
- Commercial growers
- Wholesalers
- Processors
- Marketers
- Retailers
- Nursery operators
- Food service operators.

Native citrus and, indeed, native foods usually comprise only a small part of the business of many of these operations.

Depending on the variety, native citrus are usually sold as either fresh or frozen whole fruit. There are a number of specialist processors currently marketing processed native citrus products. The major companies include:
- ANPI/Red Ochre
- Australian Desert Limes Pty Ltd
- Australian Harvest Fine Foods Pty Ltd
- Byron Bay Native Produce Pty Ltd
- Cherikoff Food Services Pty Ltd
- Kurrajong Australian Native Foods Pty Ltd
- Rainforest Foods Pty Ltd
- Rainforest Liqueurs Pty Ltd
- Robins Australian Foods Pty Ltd
- Taylors Food Pty Ltd
- Tuckombil Native Foods Pty Ltd.

Most of these companies operate at more than one level in the supply chain. The major processor, ANPI, is a grower, wholesaler, processor, retailer and marketer of a range of products. ANPI source most, if not all, of their limes from plantations, predominantly from plantations that they own or control.

Taylors Food is a ‘mainstream’ food processor that also produces a range of native food products under the ‘Wild Taste’ brand.

There is still some product being sold directly from growers/harvesters, in unprocessed form, to restaurants.

The industry is constrained by a lack of critical mass, largely due to a lack of commercial quantities of raw material, and the lack of any real supply chains.

In common with the native food industry generally, the main
marketing issues (McKinna et al, 2002) affecting native citrus are:

- the large number of brands relative to the size of the industry
- an unclear market position relative to the mainstream food categories
- the relatively small volume of assured supply from plantations
- a general lack of market awareness about how to use the raw product.

Despite the industry’s infancy, there are some significant success stories in achieving export sales of processed products. ANPI and Robins have been successful in penetrating foreign supermarkets/department stores, particularly in the United Kingdom (UK). Export sales have also been established in the United States, Germany and Canada.

Similarly, some of the more established native foods processors have been able to penetrate the domestic supermarket trade with their products. These include Robins Australian Foods and ANPI.

The continued establishment of plantation based production systems is essential to the development of the native citrus industry. As demand increases a reliable supply of high quality produce will be required (Phelps, 1997). In the past, manufacturers have needed to cease production, or reduce promotion of some products due to the unavailability of raw produce. The ‘failure’ of the desert lime wild harvest in 1998 forced food processors to shift to alternative raw materials or to abandon desert lime based products altogether (Cherikoff personal comm., 1999).

Industry sources suggest that the annual use (production) of native limes is around 25 t/yr, with at least 50% of this being from plantation production. This excludes the harvest of hybrid varieties such as those used by ANPI.

Prices can be highly variable due to fluctuations in supply. Indicative price ranges are shown below:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Product</th>
<th>Wholesale price ($/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desert Lime</td>
<td>Frozen whole</td>
<td>$5 - $15</td>
</tr>
<tr>
<td>Finger Lime</td>
<td>Whole</td>
<td>$25 - $80</td>
</tr>
</tbody>
</table>

The continued development of commercial plantations will see these prices fall to more reasonable levels, and will assist the market development.

Native limes are an extremely versatile fruit. They may be used in any product or process where ‘normal’ limes are used, the main difference being their size and intense flavour. The typical uses of citrus are shown below.

Production requirements

The five rainforest species of native citrus are all endemic to rainforest habitats on the east coast. Their distribution originally extended from Cape York Peninsula to the Clarence River on the north coast of New South Wales. Due to the impact of land clearing and urban encroachment, each species now has a limited distribution, with two of the species endemic to Queensland currently listed as rare in the wild (Birmingham, 1998).

The desert lime is endemic to the semi-arid regions of south-west Queensland, western New South Wales and South Australia.

Like all citrus, native limes prefer a well-drained soil. They will tolerate poor soils, dry conditions (particularly the desert lime) and cold. Plantation grown trees have been shown to respond well to both irrigation and fertiliser.

Research into plantation production is still relatively limited, and commercial growers closely
guard many of the techniques they have learned by trial and error. The CSIRO Division of Land and Water have established trial plantations at a number of sites around Australia to research optimal production strategies.

In the absence of specific detailed research, intending growers should treat native citrus as they would a traditional citrus orchard.

**Varieties and cultivars**

Birmingham (1998) reports that there is a lack of standardisation of common names within the native citrus industries, with the seven different varieties and their hybrids listed as ‘native citrus’ or ‘wild limes’. Botanical names are the only positive method for identifying the true native species.

The Finger Lime and Desert Lime, in particular, hybridise easily with traditional commercial citrus varieties. Cultivated hybrids are generally referred to by their cultivated variety name or origin, e.g. the ‘Australian Blood’ PBR lime is a hybrid between Citrus and Microcitrus.

There are two distinct genera of true native citrus in Australia. These were initially identified as either *Microcitrus* (the five rainforest varieties) or *Eremocitrus* (desert lime). More recently there has been a move to re-name all seven varieties as *Citrus* species, bringing them into line with mainstream citrus varieties.

### Citrus australasica - Finger lime

The Finger Lime is found wild as an under-storey shrub in the rainforests of southern Queensland and northern New South Wales. It grows naturally in heavy shade in high rainfall areas, but also appears at the edge of cleared forest where there is more sunlight. In their natural environment trees can reach 6 metres in height.

The fruit is cylindrical, up to 10cms long and can be green, yellow, red, purple or black when ripe. The pulp is usually greenish yellow although there is a variety - Sanguinea - that is red fleshed.

Unlike other citrus the Fingerlime flesh consists of tiny, slightly sticky globules. Flowering generally occurs from February to May, with fruiting from May to September. Production is usually bi-annual.

The finger limes can be used as a fresh fruit for garnish and for processing into a wide range of value-added products. There are a number of commercial plantations in northern New South Wales, producing small quantities of fruit. Wholesale prices can range between $25 - $80/kg, though $8 - $12 is probably a more realistic price.

### Citrus australis - Round lime

Also called the Gympie lime, this is the most vigorous of the Australian native citrus, growing to a height of up to 18 metres. It is endemic to south-eastern Queensland, in lowland sub-tropical rainforest.

The fruits are about 2 - 5cms in diameter and have a thick, green to yellow coloured skin and pale green pulp. This species flowers from August to November.

The round lime is suitable for processing into a range of value-
added products. The skin is very thick (up to 7mm) and has potential for culinary use, such as grating into spice pastes, or for candied peel. The species may also have potential for essential oil extraction (Birmingham, 1998). Recent farm gate prices range from $8 - $9/kg (Hele, 2001).

**Citrus inodora - Russell River lime**
A fairly rare species from near coastal areas in far-north Queensland. Plants require shady conditions, plenty of water and organically rich, loamy soil although they will grow in poorer soils. This variety is very slow growing, and only reaches a height of 2 – 4 metres.

Of all the native citrus, *C. inodora* looks the most similar to a traditional citrus. It is somewhat unusual in that there is a distinct lack of fragrance in the flowers.

The fruit are green on maturity, oval (somewhat lemon-shaped) and up to 6.5 x 3.2cm in size. This species is also classified as rare and is protected (Birmingham, 1998). Fruit is not commercially traded.

**Citrus maideniana - Maiden's Australian wild lime**
Commonly known as Maiden's Australian lime, this species was originally described as a variety or subspecies of *M. inodora*. The two species have a similar distribution, limited to a small area in far-north Queensland. Fruit is not commercially traded.

**Citrus garrawayae - Mt White lime**
This species is endemic to the foothills and upland rainforest of the Cook District on Cape York Peninsula. It grows in deciduous vine thickets as an under-storey shrub and has been recorded at a height of 15m. Due to its limited distribution, this species is now classified as rare and is protected under the Queensland Nature Conservation (Birmingham, 1998).

*M. garrawayae* is similar to *M. australasica*, but has broader leaves (Birmingham, 1998). Fruit forms from April to November. The fruits are also ‘finger-shaped’, with a green skin and greenish-white pulp on maturity. The fruit may be used for processing into a range of value-added products, as for the round lime (Birmingham, 1998).

**Citrus glauca - Desert lime**
Also known as the wild lime or native cumquat, the natural distribution of this species is the semi-arid regions of eastern Australia, from Longreach in western Queensland, south to Dubbo in central New South Wales and west to Quorn, in the Flinders Ranges of South Australia (Alexander, 1983).

The desert lime has blue-grey leaves and prickles along the branches, though above a height of about two metres, there are no more prickles on the branches. Plants are usually found growing on clay or heavy clay soils, often in clumps. They are occasionally found as single large trees to 5-6 metres in height.

The desert lime is extremely drought tolerant and able to withstand extremes of hot (45°C) and cold (-2 – -4°C) temperatures (Swingle and Reece, 1967).

The flower to fruiting time is the shortest of any citrus species, being from 10-12 weeks (Sykes, 1997). The species flowers mainly in spring and fruits ripen in summer.

Fruit can be picked when still green, and has a pleasantly refreshing and tangy taste. Desert lime fruit is extremely popular and becoming very well known within the native food industry. The fruit has a very thin rind, is often seedless and can be used whole in cooking. Fruit must be frozen within 24 hours after harvest.

Wholesale prices can range from $5 - $15/kg.

**Citrus gracilis**
*C. gracilis* has recently been described and grows wild as a straggling tree in Eucalypt woodland in the Northern Territory. It has a similar growth habit to the desert lime and produces round fruit up to 8cm in diameter (Hele, 2001). Fruit has not been traded commercially. It is also known as the Humpty Doo or Kakadu lime.

There is one known native citrus hybrid – the Sydney hybrid (*C. australis* x *C. australasica*), which was developed by the US Department of Agriculture. This species is not known to be grown commercially.

In addition, there are four known cultivars (cultivated hybrid) of native citrus currently available.
Rainforest Pearl PBR is a selection of *C. australasica* var. *sanguinea* made by Erika Birmingham from Byron Bay Native Produce in northern NSW. The Outback Lime PBR is a selection of *C. glauca* made by Dr Steve Sykes of the CSIRO. Two cultivars of partly native citrus parentage have also been developed by Dr Sykes, the Blood Lime PBR and the Sunrise Lime PBR.

ANPI have secured the rights to commercialise the three cultivars developed by Dr Sykes.

Plant stock is available from a number of nurseries around Australia (refer to listing at the end of this chapter). The Rainforest Pearl is available from Byron Bay Native Produce, while the three CSIRO bred cultivars are available from ANPI.

**Agronomy**

Commercial cultivation of bush foods is a very young industry and the cultivation techniques being used are, to a certain extent, experimental.

Plantations range from those mimicking the standard commercial orchard design to permaculture food forests. These forests have a mixture of species planted in a design that imitates the structure of a natural forest ecosystem. At the other end of the spectrum some growers are planting out using rows in the traditional orchard set up though, until recently, very few were planting mono-cultures.

Generally, orchards have up to 10 species which are either planted in different rows or grouped in a certain part of the orchard to create a mosaic of species. The rows are often inter-planted with a shelter belt of native species which also provides a refuge for insects (Seabrook, 1999).

The food forest structure is often used by growers who are using bush tucker species for revegetation programs. However, this type of orchard poses particular management problems.

Plants may be grown from seed (though the resulting plants may not be true to type), by cuttings which are slow, or by budding onto citrus rootstock. Grafting buds (budding) on to citrus rootstock is the preferred method for most commercial plantation growers.

Budding allows growers to avoid the long juvenile period and enables trees to bear fruit in their second or third year. The selection of the best rootstock will need to be determined, based on soil type and climatic conditions.

Many growers tend to use natural fertilisers and, if herbicides are used, generally this is restricted to Glyphosate (Seabrook, 1999). Weed and grass control around the base of trees or shrubs is important, particularly during the early years of establishment.

Before selecting a species to grow, it is worth examining its natural range and determining whether your area has similar climatic conditions.

While there are a number of research projects under way (e.g. CSIRO) to determine the optimum production systems.

Three year old grafted *C. glauca* in south-west Queensland (Photo: Australian Desert Limes, 2003)
Native Citrus

for native citrus in a range of conditions, in the first instance, new growers should treat their native citrus as any other commercial citrus crop. In these early days of commercial production, the application of irrigation, fertiliser and management processes (pruning, etc) will need to be refined and improved based on personal experience.

Pest and disease control

Being natives, many of the pests and diseases that afflict traditional commercial citrus orchards may not affect native citrus. That said, there are pests and diseases that will afflict native citrus orchards, particularly those that are planted as a mono-culture.

One notable disease, ‘Sunrise Lime Dieback’, emerged in some orchards during 2000. The disease is similar to diebacks that occasionally occur in other citrus varieties, though it appears that at present the disease is confined to the Sunrise Lime cultivar (Hele, 2001). The disease has been shown to be caused by a *Phoma* sp fungus.

Control is best achieved through good management practises that minimise the incidence of twig death, physical injury or plant stress (e.g. water stress, fertiliser burn, wind abrasion)

Dead wood that may have been killed by the fungus or could be harbouring the causal organism should be removed and burnt. All pruning cuts should be painted (Hele, 2001).

Copper sprays, which are often applied to control fungal diseases in citrus are also likely to be a successful in native citrus.

As far as is known, no significant pests or diseases have been reported in plantations of the true native varieties.

Harvest, handling and storage

Native citrus is harvested by hand, though some of the CSIRO bred varieties, reportedly, may lend themselves to mechanical harvesting. Mechanical harvesting will significantly reduce the labour cost involved in harvesting, and may be suitable for processing fruit but is unlikely to be useful for fruit destined for the retail or food service market where appearance is important.

As with any fruit, it is important to minimise handling so as reduce labour costs and to minimise the damage done to the product.

Harvesting should take place during the cooler parts of the day so as to reduce the effects of heat on fruit quality. In any event, fruit should be refrigerated as soon as possible after harvest, and/or frozen within 12 - 24 hours of harvest (*C. glauca*).

Whether fruit is being supplied to food service outlets or being used in manufacturing, it will need to be graded and cleaned of dirt, sticks and other foreign matter. In small orchards this task is done by hand, but this method becomes impractical as volumes increase.

Though there is no commercial grading equipment available, some of the more innovative growers have developed their own unique grading/cleaning machines.

Fruit is generally packed into 500 g or 1 kg food grade bags or punnets. Occasionally, larger packages may be used for supply to manufacturers. Different manufacturers may have particular packaging requirements depending on the end use of the product.

The majority of the native citrus crop is used for processing into a range of value added products, with a small amount being sold direct to restaurants.

Financial information

The economics of production will depend on the production system being used. However, the following indicative costs are provided as a guide. These costs assume:

- plantings are in a mono-
culture orchard
- spacings follow ‘normal’ horticultural practice giving a stocking rate of 625 trees/ha; grafted plantstock is used
- the cost of land, water storage, packing shed and plant and equipment is excluded
- owner-operator labour is used.

Based on these assumptions, the indicative establishment cost for a one hectare (ha) Desert lime orchard will be in the order of:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site preparation</td>
<td>500</td>
</tr>
<tr>
<td>Plant stock @ $15 per tree</td>
<td>9,375</td>
</tr>
<tr>
<td>Planting</td>
<td>2,000</td>
</tr>
<tr>
<td>Fencing</td>
<td>500</td>
</tr>
<tr>
<td>Irrigation</td>
<td>5,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17,375</strong></td>
</tr>
</tbody>
</table>

Ongoing operating costs will include chemicals, fertiliser, irrigation, harvesting, row maintenance and marketing. Again, on the one hectare example orchard outlined above, the indicative operating costs (excluding labour except in harvesting) will be in the order of:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost ($/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicide</td>
<td>50</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>550</td>
</tr>
<tr>
<td>Irrigation (excludes water cost)</td>
<td>200</td>
</tr>
<tr>
<td>Orchard maintenance</td>
<td>2000</td>
</tr>
<tr>
<td>Harvest, grading and packing</td>
<td>3500</td>
</tr>
<tr>
<td>Marketing</td>
<td>3700</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>10,000</strong></td>
</tr>
</tbody>
</table>

Assuming an average yield from mature trees of 15 kg per tree, and a delivered price of $5/ kg, the gross margin on this crop will be in the order of $36,000.

As with most businesses, production is the easy part - marketing is the hard part. The big question is whether the 9.4 tonnes of limes produced from the theoretical orchard can be marketed at an average price of $5/kg. The marketing effort needs to be well planned and should start well before the first fruit is picked.

While native citrus based products are a novelty product, in relatively short supply, they can be expected to attract a premium price. However, in the medium to longer term this premium will be eroded as supply increases and/or competing products emerge. The novelty value will disappear and native citrus based products will have to compete on more or less equal terms with other more conventional product lines.

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**Key statistics**

- Australia has 7 varieties of true native citrus
- The annual use (production) of native limes is around 25 t/yr, with at least 50% of this being from plantation production
About the author

Hugh Macintosh is the Managing Director of IQ Agribusiness, a management advisory firm based in Brisbane. He is a founding partner and Director of Industry Data Online Pty Ltd, a business providing online business benchmarking services to SME’s and industry groups (www.industrydataonline.com).

Hugh holds qualifications in Agricultural Economics and Business Administration.

Key messages

- Plant breeders have developed a number of new hybrids based on the native varieties
- A number of companies have developed export markets for native citrus based products
- An increase in the area of commercial plantations is reducing the reliance on wild harvest
- CSIRO has established trial plantations at a number of sites around Australia to research optimal production strategies
- Native citrus is usually harvested by hand
- The majority of the native citrus crop is used for processing into a range of value added products, with a small amount being sold direct to restaurants
- Price premiums will be eroded as more plantation grown fruit becomes available

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Native Citrus

Red finger lime

C. australasica - finger lime flower (Photo: Red finger lime)
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Native, or mountain pepper products are obtained from the species *Tasmannia lanceolata*, found naturally in the wet forests and shrublands of southeast Australia, and extending, at higher altitudes as far as the Hastings River catchment in mid north NSW.

The commercial appeal of the species derives largely from the presence in both leaf and fruit, of a hot tasting terpene compound, polygodial, for which a wide range of biological activity has been demonstrated, including antibacterial, antifungal and insect antifeedant properties. It is the hot taste to humans which has resulted in the ‘native pepper’ description, thus the potential of both leaf and berries as culinary ingredients.

Most production presently derives from wild harvested stands, mostly on previously disturbed sites where it flourishes as an early coloniser after removal of wet forest or rainforest canopies. Several substantial stands on previously cleared land in Victoria and Tasmania presently supply most of the traded product.

Figures on gross consumption within Australia are difficult to determine since both production operations and the present market...
are small and dispersed. However it would appear likely that total domestic consumption at present would be no more than 3 tonnes of dry leaf, 1 tonne of dry berries and a small amount of fresh or frozen fruit, certainly less than 1 tonne.

Markets and marketing issues

Both leaf and berry are traded in the culinary market principally as dried products and leaf is sold mostly in milled or ground form. There is a small market for fresh or frozen berries and fresh leaf, the latter mainly as a garnish.

Food service manufacturers use milled leaf in a range of prepared foods including relishes, sauces, mustards, cheese, meat seasonings and flour mixes.

Most pepper berries are used as an alternative to ‘normal’ pepper, either whole, as a condiment (in grinders) or milled and blended with other spices to produce novel spice mixes and specialty blends. There is a substantial trade in retail gourmet and gift lines and packaged products for the tourist industry.

A proportion of the leaf produced is solvent extracted for the food flavouring market, and some is sold as a raw material in the preparation of health products and nutraceuticals.

All of these markets are small and there is considerable ‘churn’ among the smaller users.

There have been major changes to quality and safety requirements in recent years, and most larger buyers of native pepper products now require some supporting analytical and microbiological data, guarantees of safe and consistent product and avoidance of pesticides in the production systems. While these changes have increased the costs of production and marketing in recent years, they have also helped rid the trade of some unscrupulous operators and led to major increases in efficiency among the more serious producers.

Prices obtained for pepper products vary widely, reflecting the range of producer types – from hobbyists with few overheads and no investment in production systems to a small number of more serious producers. Prices ‘at the farm gate’ can range between $6 and $20/kg for fresh berries, from $30 - $70/kg for dry berries and milled leaf prices range from the low $30's to over $60/kg, dependent on quantity, quality and the specific requirements of the customer.

From 1994 to the present the average price for 25 kg of milled pepper leaf has fallen from $48/kg to around $38/kg– in real terms
a very large reduction reflecting increased competition for a slowly growing market, and improved efficiency of production.

A major issue for production and marketing is the unreliability of wild fruit production between seasons.

Between 1994 and 2003 almost no fruit survived to harvest in two seasons, while bumper crops occurred twice. The reasons for this are not clear, but from an ecological perspective, the pattern is not unusual, with large crops of fruit or seed often occurring only infrequently, interspersed with small or negligible fruit set in other years. Environmental factors such as late frosts, temperature extremes and drought stress will obviously be important.

Production requirements

The species is typically found in higher rainfall regions of southeast Australia (see map), and grows best in cool sheltered environments free from water stress, on neutral to slightly acid soil, preferably well drained and fertile.

Of particular importance is protection from warm winds which can kill plants even if water is being supplied at the time—the plant’s transport system and transpiration regulation appear unable to cope with extreme demand on hot days.

The species is quite frost hardy in the natural situation, although unseasonal late frost has been observed to burn newly emerging shoots in November – December, although the effect is slight and temporary.

Varieties/cultivars

In the natural population, the species displays considerable diversity of form, vigour and chemotype, offering plenty of scope for selection of favourable types. Several producers have identified individuals with characteristics suited to their production location or practices, and it is likely that this will continue into the future.

Producers in Victoria, for example, have chosen a ‘Toora form’, and several Tasmanian growers have chosen forms either from nearby local stands, or on the basis of analysis of leaf extract composition for yield of polygodial or presence of undesirable constituents.

Plants are available from most native plant specialist nurseries in southeast Australia, since there is a small market for the plant as an ornamental shrub. Propagation for commercial production may be easily arranged with any competent propagator.
**Cultural practices/agronomy**

Most plantations have been established using rooted cuttings, both for speed and convenience and to enable introduction of uniform material from selected plants. Seed germination is extremely slow (more than 12 months in some reports), and seedlings, once germinated are very small, slow to establish and extremely variable in habit.

Sites should be well prepared, preferably on soils in the neutral to slightly acid range, having good drainage, protection from hot winds and adequate provision for irrigation. In most situations, some protection from browsing animals or rabbits which will dig up newly planted material, is advisable.

In some existing mixed plantations, *Tasmannia lanceolata* is grown as a semi-understorey plant, providing good protection from exposure. This practice reflects the common natural occurrence of the plant as an understorey plant in rainforests.

Weed control during establishment is essential, and mulch mats, hand weeding or careful use of glyphosate products are all effective methods.

Native pepper responds well to the application of side dressings or foliar application of nitrogenous fertiliser, but little is known of the long-term requirement for fertiliser in the situation where substantial quantities of leaf and berry are harvested annually.

Irrigation is required where natural summer rainfall cannot be relied upon, and as mentioned, warm windy weather can cause serious damage to the plant, destroying all the new foliage and shoots or in extreme cases killing the plant.

Symptoms of water stress are not easy to detect until too late – wilting can indicate a complete collapse of the transport system, and shoots may not recover at all, so it is important to monitor soil moisture and to anticipate hot weather with extra watering, shade or shelter.

In ideal situations, vigorous selections will yield fruit and limited quantities of leaf within 2 – 3 years.

**Pest and disease control**

While the hot compound present in the leaves of the plant has been shown to have antifungal and insect antifeeding properties, in the natural situation a variety of insects appear to browse on the species. Leaf miners and leaf rollers consume the leaf, while a tiny grub can be found within the fruit and seed. None of these have been observed in damaging numbers, however, and the plant is typically quite free from severe infestations of any kind in the wild.

No work has been conducted on the ecology of these insects from the point of view of management of commercial pepper production.

**Harvest and post harvest handling**

At present all harvesting of fruit is by hand, while simple mechanical aids are usually used for removing leaves and other foreign matter from berries. Establishment of plantations will enable use of simple mechanical harvest aids, as the fruit is quite robust when ripe, and may be shaken from the bush.

Leaf material is presently either plucked from the plant or gathered using simple trimming equipment after which leaves are dried then separated from the twigs and other woody material. Most producers employ home-made equipment for this purpose, but again, the development of plantation production will enable mechanisation of this process. Most leaf is traded as milled product.

Warm air drying is typically used to achieve better than 93% dry matter, and as with any herb, must be achieved with good air circulation, to prevent ‘stewing’ of the leaf. In more humid environments it may be necessary to use dehumidification equipment but this has not been the case in Tasmania and Victoria where most leaf and berry is produced at present. The importance of adequate drying must be emphasised, as high residual moisture will allow the development of spoilage bacteria and fungi and may compromise the quality of the product.

When properly dry, a handful of berries should not yield to a firm squeeze.

Product must be stored in a cool, clean, dry, dark and insect-proof environment to maintain the quality, particularly of the leaf, which discolours quickly in sunlight.

**Financial information**

Intending growers should assess the key issues below, and attempt to balance production and marketing issues in their approach to the enterprise.

Key issues for any new producer should be

- to establish a sound marketing strategy
- to address the post harvest and food safety technology
issues for their enterprise

- to devise a plantation system suited to their site and location.

The current market is quite small and marketing could include product development, networking with existing producers or approaching end users for potential partnership arrangements.

At present most producers are employing very simple, low cost harvest and processing equipment in their operations, and any new producer would be well advised to delay major investment in this area until a firm market has been established. A cooperative approach to harvest and drying equipment is to be recommended, especially if the equipment can be used for other herb crops during the year.

The cost of establishing and maintaining a plantation will depend on the approach and resources of the intending producer. A stand-alone plantation on purpose bought land might cost $50,000/ha to bring into production (4 years), while a low key pepper enterprise as part of a broader horticultural operation will be much less capital intensive. The decision on the size of area for production should be made in the context of the identified market and the estimated amount of product demanded.

Indications are that a single tree at five years old should produce (sustainably) at least 3 kg fresh pepper leaf (about 750 g dry leaf) or 1.5 kg fresh berries per year depending on the season. The mature yield will depend greatly on the extent to which the tree is allowed to develop a canopy before harvest of leaf material commences (ie time to first harvest and annual yield).

### Key references


### Key messages

- Market currently restrains growth
- Pepper prefers sheltered moist site
- Production and marketing networks do work

### Key statistics

- Leaf production (dry) <3 t/year
- Berry production
  - fresh <1 t/year
  - dried 1 t/year

### About the author

Dr Chris Read owns and operates Diemen Pepper, a small pepper production and marketing business from his mixed horticultural operation in southern Tasmania. He has worked in commercial horticulture as a field officer, consultant, researcher and commercial operator for more than 20 years, specialising in essential oils and cut flower production.

He is presently developing a small farm tourism operation based around a café and essential oil distillery on his property south of Hobart.

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Quandongs

Ben Lethbridge

Introduction

The quandong (Santalum acuminatum) is an Australian native shrub or tree that produces a visually appealing yellow to red, tart tasting, dry textured fruit which is a significant component of the native food industry. The flesh is amenable to most culinary purposes including pie filling, liqueurs and preserves. The kernel (nut) is also edible but as yet has attained little commercial significance.

Quandong is closely related to the arid zone Sandalwood and although the good quality timber of the quandong tree is prized as a craft wood, it lacks the fragrant essential oils derived from the heartwood of most Santalum species.

The quandong is highly tolerant of saline water and drought but orchard production has been limited by having only a rudimentary understanding of the root semiparasitic nature of the plant (ie requires a host plant for best production). This has restricted successful orchard production to those with some horticultural training.

The Australian Quandong Industry Association was formed in 1992 to help guide the development of the industry by organising an annual conference, a regular newsletter and collating relevant industry information.

Markets and marketing issues

The limiting factor to quandong fruit marketing has been a lack of quantity and quality of supply. The dominant market for the quandong is as processed product, usually dried or frozen immediately after being picked. Dried halved fruit can be stored indefinitely in an airtight container. Although the fresh fruit is visually appealing there is virtually no market for the product to be consumed as fresh fruit. Most producers have been able to dispose of all fruit product to local tourist outlets and speciality stores.

Quandong production is currently an entirely Australian industry.

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The quandong industry has been rated conservatively at a $0.7-1.3 million industry (farm gate gross estimates, 2001) with commercial planting of around 26,000 trees which equates to 50 to 100 hectares assuming average planting densities. This constitutes approximately one third of the total production of 25 tonnes (2001) with the remainder wild harvested.

It is unlikely that the high prices obtained for wild harvested fruit in the past will continue, and as orchard production rises, the price is likely to fall to values more consistent with manufacturing grade (mainstream processing) fruit. Quality product will always command higher prices (estimates of $40-60/kg dried fruit).

**Production requirements**

Quandongs require a climate with high light intensity, low relative humidity and will grow in a range of soil types including pH variation and high salinity, but should be well drained and will not tolerate waterlogged soils where susceptibility to root diseases will be more prevalent. Mature quandongs have shallow root systems. The type of host plant chosen will dictate the irrigation requirements of the orchard. Prior to attachment to host plants, young quandongs are very prone to desiccation and will require a regular watering regime, shading and wind protection. Post-attachment, the irrigation should be matched to the host plant with due consideration to the distribution and depth of the root system and water holding capacity of the host and the quandong tree. The map shows the natural distribution range of the quandong and offers a very rough guide to the types of environments suitable for production.

**Varieties**

Two named varieties, Powells No.1 (provisional PBR) and Frahns Paringa Gem (provisional PBR) are available as grafted scions onto seedling quandong rootstocks. There is limited supply both in quantity and quality. Many new varieties from wild or seedling orchard selections are expected in the coming years, so check with AQIA for latest selections and propagators.

**Agronomy**

The agronomy of quandong production is enhanced by the horticulturally unique semiparasitic nature of the quandong. This parasitism is non-specific and the exact nature of what determines a good host is not completely understood, although drought and salt tolerance are implicated. Because of their semi-parasitic nature, quandongs are able to indirectly adopt many useful adaptive features of the host plant. For example, the nutrient efficiency and atmospheric nitrogen fixing ability of legumes such as Acacias make them good hosts in nutrient starved soils, which are common to many Australian landscapes. *Acacia victoriae* (bramble wattle) is proving to be highly adaptable to many climates and soil types in orchard situations and is a relatively good host for quandong.

Other useful species include other *Acacias*, and species from the genus *Atriplex, Melaleuca, Myoporum, Allocasuarina* etc.,

Many quandong growers have chosen to introduce quandongs into the orchard as potted plants whose root structure has been modified significantly and may retard the attachment to host plants. Young pre-attached quandongs require significant care to prevent desiccation including shade and wind protection. Prior to attachment to a significant host (ie greater than one year old), quandongs require regular supplies of a general purpose, water-soluble fertiliser for good growth. Some small orchards of quandongs have been developed on this host free, simplified plan. Under this system quandong plants usually only attain shrub-like proportions.

The pre-attachment phase can be minimised by direct seeding of quandong onto one year old, dripper fed host plants (usually acacia) when soil temperatures permit significant root growth of the quandong.

After attachment of quandongs to significant host plants the management of the orchard should be based on the requirements of the host plant.
Most propagation of selected quandong varieties has been achieved using nursery techniques. Field grafting onto established seedling root-stocks is possible but the technique needs improvement to obtain a commercially satisfactory success rate. This technique offers much potential, for example sandalwood root-stocks (other Santalum species) are compatible with quandong scions, allowing conversion of seedling orchards of Santalum to specified varieties of quandongs, thus combining high value sandalwood and quandong fruit production.

Weeds should be removed manually and frequently from around the plant, with cautious use of herbicides because of the potential for transfer of toxic compounds through the roots of the host plant to the semiparasitic quandong. Check that annual weed roots have not been parasitised, by examining a selection of hand pulled roots, before application of herbicides.

Training and pruning of quandong trees should be early and light to improve tree structure and where shading by the host plant could be significant this should also be addressed early in the life of the orchard.

Quandong trees are predominantly cross-pollinated, so planting of at least two varieties of trees in close proximity to each other is recommended.

**Pest control and disease**

The major pest affecting quandong fruit is the quandong moth, (Paraparmenia santicella), a native species common in the natural range of the quandong. Quandong moth may be controlled by spraying with a dimethoate based insecticide when eggs are detected in the fruit calyx or if there is obvious fruit damage. Although there can be highly conspicuous damage from leaf feeding insects, this will not greatly affect fruit yield. Scale insects may be damaging to trees and are usually controlled by natural enemies or for heavy infestation, oil based sprays have been found to be useful. Gall forming insects and bud mites (Family Eriophyidae) have been reported to cause damage to some trees.

Root rot diseases such as Phytophthora have been implicated in poor establishment rates from nursery-derived plants and inhibiting growth on poorly drained sites.

**Harvest / handling / post harvest treatments**

All quandongs are currently harvested by hand. The current scale of production does not yet warrant ‘cool chain’ procedures to be developed. Residual pest infestations may be eliminated by heating the harvested quandong fruit at 60°C for 30 minutes. Most quandong varieties are free stone and fruit are de-stoned and halved on manual or automatic cutting machines based on technology developed from the apricot industry. The fruit is either fresh vacuumed packed and frozen or more commonly sun dried. Quandong fruit has a low moisture content relative to other fruits, so drying is a relatively simple process.

**Financial information**

An economic analysis for new crops should be treated with caution due to uncertainties in production and prices of quandong and host plant products. It is recommended that the host plant be established at least one year prior to planting of quandong trees and therefore establishment costs should be based on that of the host plant, plus the additional cost of quandong plants and protection from desiccation.

Most quandong orchards are currently based on seedlings for which yield data is highly variable. For improved grafted varieties estimates of production is predicted to begin in year 4 with increasing yields of 0.5 kg dried fruit per annum to year 15 (dried equivalents, equals approximately 25% of fresh whole weight). Assuming 300 quandong trees/ha, a farm gate price of $40/kg (first quality) of 1.5kg dried fruit per annum, the potential for transfer of toxic compounds through the roots of the host plant to the semiparasitic quandong. Check that annual weed roots have not been parasitised, by examining a selection of hand pulled roots, before application of herbicides.

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fruit per tree gives an estimate of $24,800/ha (gross), at year six. This is comparable to returns from other new horticultural pursuits. There exists opportunities to include quandongs in farm revegetation programs. The indirect economic benefits of improved environmental status and seasonally dependant, manufacturing grade quandongs and host plant products (eg. wattle seed) are difficult to calculate.

Key messages

- The economics of this new industry are uncertain but an industry infrastructure is developing according to well-formulated plans
- Research into a better understanding of the semi-parasitic nature and production of quandong is occurring. _Acacia victoriae_ is showing much promise as a host in orchard situations

Key statistics (estimates)

- 25 tonnes (2001), 33% cultivated, remainder wild harvest
- $0.7 - $1.3 million, farm gate gross estimate (2001)
- 26,000 orchard trees, in various stages of production (predominantly SA)

About the author

Dr Ben Lethbridge B.Ag.Sc.(Hons.) Ph.D. is a private consultant and has been a member of The Australian Quandong Industry Association since its inception and committee member since 1994. He has contributed to RIRDC funded research projects on the quandong. For contact details see key contacts.

Key contacts

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It is recommended that all prospective quandong growers contact the association for up-to-date status of the industry.

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The Davidson Plum (Davidsonia spp) is an ‘un-domesticated’ Australian native rainforest fruit well suited to commercial production. It offers new ingredient value to the global food industry and its versatility of use gives it opportunities in many food market niches. The fruit, whilst versatile, is constrained by market unfamiliarity and thus greater market risk. Present production outweighs demand. There is a need for improved production efficiencies and technologies, as well as improved post harvest processing techniques. Overall, the greatest challenge is better marketing and greater adoption of the fruit in the food-manufacturing sector. Being very sharply acid, the Davidsonia does not have access to a fresh food market. The fruit is a processing fruit and must compete on price with processing-grade fruits of other species. These other fruits may be cross-subsidised by fresh produce sales to an extent and hence come onto the processing market at or below cost of production.

Australian production of the Davidsonia is very limited but, as long as the market identity of the fruit continues to be ‘Australian Native’, Australian production will be advantaged. At present overseas production seems entirely limited to enthusiasts and researchers. Market demand is perhaps the most significant limitation at present, with many growers over the past 4 years having difficulty selling their crops.

The Davidson Plum is a sour and plum-like fruit used in jams, sauces and preserves, cordials, dairy products, confectionery,
wines and liqueurs. Its tart flavour and intense burgundy colour lend the plum to many uses in food manufacturing industries, particularly those seeking to portray images of Australiana, indigenous Australia, wilderness, nature or rainforest. Current market demand is around 5,000 kg per annum, and buyers estimate growth at 5-20% per annum, though most are relatively young businesses and trends are difficult to assess.

Current production is predominantly in the sub-tropical coastal regions of NSW and tropical NE Queensland.

As with any new crop, a broad range of skills is required to be a successful *Davidsonia* grower. In many cases, due to poor market demand, value adding and marketing skill and commitment are necessary. A strong entrepreneurial ability is advisable. Sound horticultural knowledge and practical abilities are needed. There is a need for technological innovation in the industry and keen improvisational and observational skills. Growers may also need to be in a position to weather financial loss due to market volatility.

**Table 1: Marketing chains**

<table>
<thead>
<tr>
<th>Sold at farm gate</th>
<th>Value-added and marketed by grower</th>
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<tbody>
<tr>
<td>Producers</td>
<td>Producers</td>
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<tr>
<td>Brokers</td>
<td>Transporters</td>
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<td>Transporters</td>
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<td>Processors</td>
<td>Contract manufacturers</td>
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<td>Manufacturers</td>
<td>Consumers</td>
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<td>Distributors</td>
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<td>Consolidators/providers</td>
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<td>Retailers</td>
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<td>Consumers</td>
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**Markets and marketing issues**

Current principal markets are specialty jam and sauce manufacturers, dairy foods, the hospitality and food service industry and wine and liqueur makers. Only a very limited amount of the crop has been exported raw, though value-added products made with *Davidsonia* are exported. The fruit is sold either fresh or frozen as whole fruit, frozen as de-seeded pulp or de-seeded puree. Many growers deseed their crop by hand and freeze to sell as fruit pulp, though the majority prefer to sell whole fruit.

There is a clear and present need for market brokerage and/or grower organisation to ensure quantity and quality of supply in order to access higher volume markets.

Accurate industry estimates are difficult in a dispersed and unorganised industry. Production has been estimated at between 6,000 and 10,000 kg/annum, with many producers not harvesting their crop due to lack of market demand. Some growers have pulled out their orchards in recent years either due to marketing or management problems. Many small orchards (100–1,000 trees, with some to 6,000) were planted in the mid to late 1990s, with very few operating profitably at present. Total plantings may have reached 30,000 trees.

Prices range from $2 to $6 per kg for whole fruit, $5 to $13/kg for hand de-seeded pulp, and around $9 to $10/kg for puree. Organically certified produce attracts a premium in certain markets.

**Production requirements**

The commercial range of the *Davidsonia* is as yet untested. The tree’s natural range for New South Wales species is from Tintenbar near Ballina to the Tweed Valley in far northern New South Wales, and around 30 km inland from the coast. This suggests the optimum growing area. Young trees do not tolerate frost, but trees more than around three years old can tolerate mild frost to -2°C or -3°C. The natural range of the Queensland species is in rainforest of coastal NE Queensland, however the species is grown commercially in mid-north coastal areas of New South Wales.

No data have been ascertained for *Davidsonia* requirements for optimal photoperiod, chilling hours or diurnal variation to date, and more research in this area would be useful. Good rainfall distribution and volume of around 1,200 to 2,500 mm/annum seems appropriate.

*Davidsonia* do best in deeper, high organic matter, friable soils but naturally occur across a range...
or soil types. Soil moisture and therefore water holding capacity is important during flowering and fruit set, though the tree itself can tolerate seasonal dry periods once established. Irrigation is generally thought to be essential for good productivity, particularly at flowering and fruit set during dry springs. During dry periods, competition for water from other tree crops or nurse crops in polycultural orchard plantings has resulted in poor fruit set and size.

Davidsonia are able to produce in semi-shaded conditions, and can be appropriate to south-facing slopes. However the most productive orchards appear to be those grown in full sun or east-facing slopes with adequate soil fertility and irrigation. There are problems with losses occurring due to sunburned fruit, which has led to suggestions that south-facing slopes and/or shade tree interplantings are appropriate. Some observations suggest that fruit will burn even in relatively shaded situations, and that fruit burn seems more dependent upon how abruptly high temperatures and sunny conditions follow on from cooler, overcast periods. Orchards should be protected from wind to reduce tree stress.

Varieties and cultivars

No recognised cultivars or varieties are available to date. Though some selections have been made by various nurseries for improved performance and manageability, no formal breeding has been carried out on the fruit. Seed-bearing Davidsonia spp. are reasonably true to type when grown from seed and are relatively easy to propagate. There are presently three species of Davidsonia: D. pruriens – the Queensland Davidson Plum, D. jerseyana – the New South Wales Davidson Plum, and D. johnsonii – the Smooth Leaved Davidson Plum. A reported hybrid cross of D. jerseyana and D. pruriens has fruited for the first time in the last year.

The predominant species grown is Davidsonia jerseyana, the New South Wales Davidson Plum. This species is the smallest growing, with trunk-bearing (cauliflorous) characteristics, which lend themselves well to hand harvesting from ground level. The fruit are born in early to mid summer. Selections have been made for larger fruit, a leaf-free trunk and longer flower panicles.

Davidsonia pruriens is the predominant crop in Queensland, with much of production in the past coming from the harvesting of naturally occurring trees. This species bears fruit in winter in its natural range, however fruiting period seems less clear in NSW. Crop that is produced in winter has minimal Fruit Fly pressure. Fruit is borne on long flower panicles, generally from upper branches, but often from the tree trunk. Fruit is larger and paler than D. jerseyana.

Davidsonia johnsonii is very rarely cultivated and is extremely rare in the wild but has been reported to have very high yields. Grafted specimens have been known to bear fruit at year 4 in optimum conditions. This species has significant pest problems from fruit fly (Dacus spp) and caterpillars (Lepidoptera spp). D. johnsonii fruit, though known as ‘seedless’ (seeds are infertile), still
The Davidson plum have a persistent pericarp or seed coat which needs to be removed for most processed products and the flesh of the fruit is paler when compared to *D. jerseyana*.

In the wild, *Davidsonia* are classified by New South Wales NPWS as ‘Endangered’ under the NSW Threatened Species and Conservation Act 1995 and as such a permit is legally required to pick and/or sell material from these plants. Genetic pollution of wild tree populations may be an issue in selecting appropriate planting sites. There are specialist native food nurseries in northern New South Wales selling selected provenance material for fruit production and many rainforest nurseries in both New South Wales and Queensland stock the species or grow to order. One specialist nursery in northern New South Wales offers grafted selections.

**Cultural practices**

Site selection should enable adequate safe machinery operation and the ability to irrigate (around 100 l/tree per week during dry periods throughout the flowering and fruiting season may be used as a rough guide). Orchard sward should be established prior to planting if possible, and care should be exercised to avoid any chance of erosion occurring when ripping or exposing soil. Deep ripping will improve the permeability of soil to tree roots, liming materials, fertilisers and water. Liming materials should be applied as early before planting as possible. Soil pH of around 5.2 – 5.5 (CaCl₂) is appropriate for *Davidsonia*. Planting of young trees (less than 300 mm high) will need great attention to weed control, irrigation, sun and frost protection to avoid tree losses and setbacks. Planting of older stock (at least 600 mm high) will improve successful establishment rates, though adequate care will still be needed. Trees from selected seed source or clonally produced will maximise orchard productivity and manageability. Pelleted poultry manure or compost applied at or prior to planting will improve soil organic matter and microbiological health.

Planting models are numerous, ranging from highly diverse plantings to monocultures. Monocultures will provide management efficiencies, though may entail greater pest and disease management inputs. Planting in rows 2.5 – 3.5 m apart will allow for machinery access and plants can be spaced at 1.0 – 1.5 m centres within rows.

Basic equipment relevant to *Davidsonia* production:

- irrigation plant – water storage, licence, pump, controller, mains, laterals and emitters
- tractor with ripper/auger
- mower/offset slasher
- trailer
- brush-cutter or other weed control equipment
- chainsaw/loppers/machine pruner
- picking bags/boxes
- wash and brush system, sorting table/machine
- ripening trays
- ripening room, cool storage, packing room, cold storage (optional)
- commercial grade certified food handling kitchen if value adding
- dispatch, office and warehousing if value adding.

During establishment of young orchards, adequate weed control is essential. As orchards mature, a permanent groundcover should be encouraged. Inter-row sward should be mown or slashed when long and directed under trees as a mulch.

As trees grow taller, canopy must be managed to keep to a harvestable height. Trees beyond this will not be harvested regularly and will become a pest haven. Trees respond to topping at harvestable height by chainsaw every 2-3 years. Alternatively, training the trees to a multiple trunk structure and then periodically trunk stumping
on a rotational basis will achieve a similar result.

Harvesting during bearing must be done every 1-3 days, depending on temperature and cloud-cover. Fruit picked just as it is beginning to develop its purple blush will ripen off the tree readily, and this will minimise pest build-up. Other pest control practices should be maintained from flowering to final harvest.

Fertiliser requirements for *Davidsonia* spp. are not well understood or well researched. Current practices are based on individual site observations. Broadly: from year one to three, nutrition aimed at vegetative growth should ensure good tree establishment and bearing structure. Pelleted poultry manure at rates of around 300 g for each site twice a year or 4 litres of composted broiler litter can be applied after harvest, along with 10 g per site of K$_2$SO$_4$.

For bearing orchards, at year four onwards, pelleted poultry manure broadcast or banded at rates of around 2,000 kg/ha after harvest or composted broiler litter at 6 m$^3$/ha and 150 kg/ha of K$_2$SO$_4$,

*D. jerseyana* will bear in year three, with commercial production by year four or five. *D. pruriens* will bear in year five or six.

### Pest and disease controls

Common pests potentially causing large losses:

Native Budworm – *Heliothis sp.* – high populations can occur rapidly and are particularly destructive of flowers and fruit at all stages to maturity.

Light Brown Apple Moth – *Epiphyas postvittana* – larvae grazes on fruit skins and bores into fruit, often grazing on seed. Can cause significant and extensive damage.

Orange Fruit Borer Moth - *Isotenes mierana* - Larvae will eat into fruit and graze on fruit skins.

Fruit Fly – *Dacus* spp. - in heavy Fruit Fly seasons, with poor orchard hygiene, the larvae of this common pest can cause heavy crop losses. Adults may lay eggs in green fruit, not only in ripe fruit, particularly if there are high populations of the pest.

### Occasional pests causing minor losses:

Variegated Hairy Caterpillar – *Anthela varia* – can cause damage to flowers and fruit.

Brown Loopers – *Lophodes sinistraria* – can cause damage to leaves.

Leaf Hoppers and Grasshoppers (unknown spp) can cause damage to leaves and fruit, heavy, deep grazing is often found at all stages of fruit development.

Red Shouldered Leaf Beetle – *Monolepta australis* – often heavily defoliates young leaves of the tree, particularly *Davidsonia pruriens*.

Fruit Spotting Bug – *Amblypelta nitida* – piercing and sucking mouthparts of this common insect superficially damage fruit but do not cause observable losses.

Larvae of Longicorn Beetle – a stem borer, have been known to ringbark and kill off branches and trunks of trees.

Rodents - *Rattus* spp. and *Mus* spp. - Rodents relish the seed of *Davidsonia* spp. but will generally only use fallen or over-ripe fruit, however it has been noted that rodents will forage on fruits in the tree, with the potential to cause substantial damage. Isolated orchards have also lost significant numbers of trees due to rodents chewing the tree bark and root system. Seedbeds in nursery production must be protected from rodents with wire mesh.

King Parrot – *Alisterus scapularis* - will forage on the seed of the fruit and will damage much of the fruit in the process.

Flying Fox – *Pteropus* spp. - have been reported to damage some crops recently. Generally these
native animals have posed a minor problem to *Davidsonia* crops to date.

**Control practices**
There are currently no registered preparations for pest control in *Davidsonia*. Good orchard practice such as maintaining high organic matter, fertile, healthy soils, appropriate canopy management, regular harvest and orchard hygiene are the best measures to minimise the impacts of pest problems.

Integrated Pest and Disease Management practices such as designing orchards to include refuges and corridors for beneficial insects and insectivorous birds will assist in buffering orchards against severe pest problems.

Bait spray or paint yeast autolysate and insecticides (organic or otherwise) subject to compliance with the Pesticides Act and label indications may be a means of controlling fruit fly.

Observations show that where ants are present, generally associated with Mealy Bug (*Planococcus citri*) on fruit stems or calxes, incidence of caterpillar is minimal. Mealy Bug does not observably affect the development or quality of the fruit.

**Harvest and handling, storage, post-**

Harvested fruit should be picked into picking bags or boxes and field heat removed as soon as possible. Food grade approved ripening space at high humidity and low temperature (6-8°C) will be needed for ripening the fruit to full colour. High humidity cool room (2-4°C) storage space for up to a week of harvest during peak bearing period should be planned (around 6m³/ha). Fruit are held cool storage in shallow trays before processing or cold storage. Cold (-18°C) storage facilities may be necessary if fruit is not being sold or processed immediately, or whilst adequate fruit volume is accumulated for processing runs. Around 1m³ will be needed for every 300 kg of whole fruit to be stored. This is often very costly if only seasonally used. Rental of such facilities close to the farm may be practical. Fruit pulp or puree will take less space to store than whole fruit per $ value, and sugar-stabilised puree is able to be stored at more economic temperatures than fresh frozen puree.

Post harvest processing will vary depending on the degree to which a grower value-adds and buyer requirements. Small jam and sauce processors manufacturing boutique or cottage style products generally prefer a hand-de-seeded fruit pulp, which has a high ratio of larger fruit and skin pieces in it. There is reasonable demand for hand de-seeded fruit pulp, however the process is very labour-intensive, and growers are often overstretched for labour. Often the hand processing is done in a domestic situation or by junior labour. At award rates and under commercial conditions the costs are such that buyers are often not
Longer panicles occur on some specimens of D. jerseyana

prepared to pay realistic amounts for the resulting pulp. Machine pulping to remove the fruit seeds and calyx has been in development by some growers and processors for some years. Getting a balance between removal of the fruit calyx and keeping larger fruit and skin pieces has been difficult, however the resulting puree is well suited to sauces, jams, syrups and beverages and offers commercial scale volume and a more acceptable market price.

**Financial information**

Davidsonia are a high risk crop. It may provide an alternative crop to diversify an existing enterprise, but at this time does not offer a predictable or commercially profitable business opportunity. Enterprises with existing value-adding or tourism operations may be better placed to make a viable income from a Davidsonia growing enterprise through integration with these other businesses.

Broad figures here are based on a monocultural planting on relatively flat and clean, rock-free ground, with water supply, planted at 2000 trees/ha.

**Getting started – establishment costs**

General equipment and infrastructure costs, excluding land, will run to over $100,000. Establishment costs including irrigation, set out, preparation planting and planting stock will run to around $15,000/ha.

**Ongoing costs**

Maintenance costs run to around $3,500/ha/yr including slashing, weed-control, fertiliser, fuel and canopy management. Harvest, grading and packing costs may run to over $8,000/ha.

**Yield**

Given 2,000 trees/ha, a yield of between 1 and 3 kg of fruit/tree is likely – a total of 2,000 to 6,000 kg/ha.

**Value**

Calculating a predicted value in an oversupplied market is fairly academic. Broadly: market prices of between $2 and $6/kg whole fruit give a value range of $4,000 - $36,000/ha. After operating expenses of $11,500 this leaves a profit margin of between $(-7,500) loss) and $24,500/ha.

Other costs such as cool or cold storage, finance costs etc. need to be considered. The major risks to the grower lie in the small scale and vulnerability of the buyers’ sector. Only a limited market is established for the fruit, and the market is currently oversupplied. Any further plantings would need significant market development in order to be viable.

**Key references**


About the author

Anthony Hotson operates a wholesale nursery at Tuckombil, near Alstonville in Northern NSW, which specialises in sub-tropical native food plants, rainforest reafforestation and macadamia trees. He has been growing and researching Davidsonia since 1995 and runs a 1,500 tree commercial orchard.

Key messages

- Native rainforest species
- Versatile processing fruit
- Clear need for market development
- Need for improved technologies

Key statistics

- Estimated production 6,000 - 10,000 t/yr
- Estimated plantings - perhaps 30,000 trees
- Estimated current market 5,000 t/yr

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Introduction

Cashew (Anacardium occidentale L.; Anacardiaceae) is a tropical evergreen tree from north-east Brazil. Distribution of the species around the world is mainly attributed to the Portuguese who brought the cashew to their colonies in East Africa and India during the 14th and 15th centuries. World production of cashew in 2002 was about 2,100,000 t of nut-in-shell (NIS), produced mainly in India, Brazil, Vietnam, and Africa. Local consumption and demand by importing countries continues to increase, providing opportunities for expansion of the crop worldwide.

Commercial cashew growing has potential in the Australian tropics. Large areas of suitable land with adequate water supply and suitable climate exist in the Northern Territory and far north Queensland. Cultivation in remote locations does not have the risks associated with highly perishable fruits as the nut can be stored for long periods and can tolerate long-distance transport. Australia imported an estimated A$50M (wholesale value) of cashew kernels in 2002. A local industry would provide import replacement and create export
opportunities for sale of NIS, raw kernel and value-added products.

There are currently two major plantations in Australia, one in north Queensland and the other in the Northern Territory. To be profitable, the Australian industry needs suitable varieties and field management practices to achieve and sustain economic yields. Plantations of at least 500 ha in single or cooperative plantations may be required to establish a brand name in the local/international market and to minimise the unit costs associated with production and the overseas processing. Sound financial, personnel, agronomic and marketing skills are required to manage and operate plantations of this size successfully.

**Markets and marketing issues**

Of the total world production of cashew kernel (estimated at 522,000 t), 241,000 t was traded on international markets in 2002. India (51%), Vietnam (26%) and Brazil (13%) are the major exporters. The major consumers are the USA (46%), the Netherlands (10%), the United Kingdom (5%), and Australia, China and Canada (4%). Australia imported about 8695 t of kernel in 2002. (Data supplied by FAO).

As the major importer of cashew, the USA has a strong influence on the world price which is fixed in US$/pound (1 pound = 0.45 kg) of kernels. The price of W320 grade (320 kernels/pound) over the last 10 years has been quite volatile ranging from US$2.30 in March 1994 to US$3.15 in September 1999 to US$1.75 in July 2003.

Overseas, the nuts are collected from the growers by local traders who in turn sell to large processing companies. After processing, the kernels for export are sold by trading companies to overseas markets through agents or dealers. Several Australian dealers who import from India, Vietnam and Brazil supply the major retailers in Australia with kernel. The major Australian dealers are GB-Commtrade Pty Ltd, Michael Waring Trading and Scalzo Food Industries.

The raw nut produced in Australia is shelled overseas and the kernel returned to the grower and sold raw or as value-added products. Australian production of raw nut in 2002 was 130 t. As the Australian industry expands, it is likely that growers will benefit from pooling their production, producing value-added products, and marketing with an Australian brand name.

**Production requirements**

Commercial cashew production requires a seasonally wet/dry tropical climate, the dry season coinciding with flowering and nut development. The area selected for cashew production should be frost-free. Mean daily temperatures of less than 25°C will limit growth and production. These conditions can also delay flowering resulting in nut maturity during the wet season with potential crop loss. With exceptions, areas south of 16oS latitude are generally considered marginal for cashew in Australia (see map).

Soils should be free draining, as cashew does not tolerate waterlogging. Rocky or stony soils disrupt harvesting and increase post-harvest cleaning costs and should be avoided. Slopes should not exceed 12% to minimise erosion risk and facilitate the operation of heavy machinery. Cashew is known for its drought tolerance, however it is unlikely that economic yields (above 3t/ha NIS advisable) can be achieved without irrigation. Sufficient water should be available to apply irrigation during flowering and nut development (July to December, depending on location) at weekly intervals at the rate of 500 L/tree/week.
Varieties/cultivars

Australian plantings have been established mainly with locally selected or recently imported varieties and generally this material has not been proven under commercial culture in local climatic conditions.

A number of hybrids were selected under a joint government/grower plant improvement program in 2002. Royalties apply to the use of this material and enquiries regarding availability should be directed to CSIRO. Limited genetic material of some local selections is available from DPI&F in Queensland and DBIRD in the Northern Territory. Cashew growth and yield is influenced by environment (climate, soil, culture). Material should therefore be tested on a range of rootstocks in the intended plantation location if the environment of this location is different from the environment from which the material was sourced.

Cultural practices

Before developing the property, a farm plan defining the placement of infrastructure (buildings, roads, dams, underground irrigation mains, etc) and a schedule of development tasks should be formulated. Careful site preparation (land clearing, windbreaks, erosion and drainage structures, soil tilth and amelioration, irrigation installation, root and rock removal) will promote healthy tree growth and harvest efficiencies. In areas where giant termite (*Mastotermes darwiniensis*) exists, root removal is also important to reduce the risk of infestation.

Cashews are commonly planted in rows 8 m apart and 6 m apart within the row. Commercial trees are propagated by grafting because trees raised from seed do not grow true-to-type. With good culture, grafted trees will produce sufficient yield by the third year after planting to warrant mechanical harvesting. Nuts with ‘apples’ attached are harvested from the ground, then cleaned, dried, applies removed and the nuts stored. A well managed plantation will require propagation/nursery facilities, an under-tree sprinkler irrigation system with fertigation capability, tractors, slasher/weedicide boom, mist-blower, hedger, sweeper/harvester, nut cleaning, drying and apple removal equipment and storage facilities.

Cultural practices are designed to promote healthy trees while at the same time managing canopy growth, nut yield and quality, and timing of nut drop. In the period from planting to first harvest, a canopy framework is developed which is structurally sound, shaped to facilitate spray coverage and mechanical harvesting, and maximises nut yield in the shortest time from planting.

The main season of vegetative growth (December–April) coincides with the wet season and is followed by flowering (July–September) and nut drop (October–December). The critical aspects of managing growth and nut production are: insect control during vegetative
growth, flowering and early nut development; irrigation during floral and nut development; and adequate nutrition during vegetative growth. Additional operations include pruning immediately after harvest (before vegetative growth season), pre-harvest field preparation, and weed control.

Cashews require all the major nutrients (N, P, K, Ca, Mg and S). They are particularly sensitive to zinc deficiency, and iron deficiency has been observed in trees growing in high pH soil (>8.0). Nitrogen nutrition is very important because it has a major influence on vegetative growth that determines nut yield and timing of nut drop.

Pest and disease control

Various insect and animal pests are prevalent in the cashew growing areas in Australia. Only two diseases are of significance, cercospora blotch (*Pseudocercospora anacardii*) in north Queensland and anthracnose (*Colletotrichum gloeosporioides*) in areas where rainfall occurs throughout the year.

Some insects are confined to the wet season, e.g. mango shoot caterpillar (*Penicillaria jocosatrix*), leaf miner (*Acrocercops spp.*) and leaf roller (*Anigraea ochrobasis*).

Others can attack trees at any time during the year, e.g. giant termite (*Mastotermes darwiensis*), tea mosquito bug (*Helopeltis spp.*), fruit spotting bug (*Amblypelta lutescens*), red-banded thrips (*Selenothrips rubrocinctus*) and pink wax scale (*Ceroplastes rubens*). Insects (*Ephestia spp.*) can also infest nuts in storage.

Most of the insect pests attack tender growth causing defoliation, death of flowers and premature nut drop. Control during mid to late vegetative growth, panicle emergence and early nut development is essential as damage during these periods can result in the greatest reduction of nut yield.

An integrated pest management approach involving regular monitoring, biological control, and strategic sprays during critical times should be taken. Green ants (*Oecophylla smaragdina*) attack a number of insect pests of cashew and the wasp, *Anicetus beneficus*, is a parasite of pink wax scale.

Giant termite, only a problem in the Northern Territory and Western Australia, burrows within the tree, gaining entry through the roots from subterranean canals. Infestations can exist unnoticed until death of the tree. Control requires constant surveillance and baiting. Fruit bats and rats can also cause economic loss. Fruit bats feed on the apple and can remove significant quantities of nut from the plantation boundaries.

Windbreaks planted within the plantation have been effective in encouraging bats to feed on the cashew apples and drop the nuts within the plantation. Rats can destroy polyethylene irrigation pipes and fittings. Damage can be minimised by baiting and plantation hygiene (grass control).

Currently there is only one insecticide registered with the Australian Pesticides and Veterinary Medicines Authority for use in cashew. This chemical does not control the full range of insect pests and will burn some cashew varieties. Effective management of insects in cashew will require the registration of additional chemicals.

Harvesting, post-harvest handling and processing

Cashew fruit (nut with apple attached) fall to the ground when mature. The fruit is swept to the centre of the inter-row and then picked up by a harvester. Tree canopy obstruction and ground surface condition influence the speed of harvest, the quantity of nuts harvested and the amount of extraneous material mixed with harvested nuts.

A pre-harvest cleanup is necessary to remove low branches, level the...
ground surface and remove trash and old nut.

While the harvester aspirates light extraneous material, further cleaning may be required before the nuts are dried and the apples removed.

Nuts must be stored at less than 9% moisture content to prevent rancidity.

There are no shelling facilities in Australia. The process of kernel extraction is complicated and laborious and involves removal of the shell's caustic oil, shell cracking and testa removal.

Australian nuts are currently sent overseas (e.g. China) for kernel extraction. Overseas processors are reluctant to accept small quantities of raw nut (less than 100 t).

Growers with less than 100 t can sell to a local large producer or combine their raw nut crop with other small producers to meet processors requirements.

Nuts may be sold as NIS, raw kernel or as processed value-added products (roasted, chocolate coated). The price paid for NIS is influenced by the nut's size and kernel recovery that together determine the yield of kernel to the processor. Kernel price is influenced by kernel quality (e.g. kernel size, whether whole or broken), and quality specifications are defined by the International Organization for Standardisation (ISO).

Australian nuts to date have been sold mainly as processed value-added products. Such sales reap higher returns compared with NIS and raw kernel sale.

In addition, broken kernel, which would otherwise be downgraded under ISO standards, and so draw a lower price, can be marketed at the same price as premium grade kernel.

Financial information

Since 1987, a number of economic analyses of the profitability of commercial cashew growing in Australia have been undertaken that conclude various yields up to 5 t/ha NIS are needed to attract investment. The most recent analysis, completed in 1998, investigated the profitability of growing cashew in the Mareeba–Dimbulah Irrigation Area (MDIA) of far north Queensland.

Growing cashews in the MDIA was profitable based on an analysis of a 200 ha farm. The analysis used a farm-gate price of A$1.63/kg NIS and a most likely yield of 14 kg NIS/tree from Year 6 onwards. All nuts were processed in China and the raw kernels were sold in Brisbane. The estimated equivalent annual return (net of all operating, labour and capital outflows) was $144,000 or $0.34/kg NIS. The internal rate of return and discounted payback period were 14% and 11 years, respectively.

To establish the farm it was estimated that an investor would outlay $1,607,000. This included cash outlays for land, capital equipment, water allocation and establishing the plantation.
Key references


About the authors

Pat O'Farrell is a Senior Experimentalist with the Department of Primary Industries and Fisheries based in Mareeba in north Queensland. Mr O'Farrell has worked in horticulture research for over 30 years, mainly in banana, cashew and macadamia agronomy.

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Key statistics

Quality and value of cashew kernel imported into Australia and estimated Australian production of kernel in 2002.

- Kernel imports (t) – 8695
- Import value (A$m) – 50
- Australian production (t) – 35

Key messages

- Domestic and export market opportunities
- Tropical Australia suited to cashew
- High NIS yields (>3 t/ha) advisable
- Efficient in-field production systems necessary
- Limited chemical registration
- Overseas processing required
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Hazelnuts

Introduction

Although hazelnuts (*Corylus avellana* L.) were introduced into Australia over 100 years ago, to date they have only been grown on a relatively small scale. Current annual production is estimated to be approximately 50 tonnes of in-shell nuts. However, there appears to be an opportunity for considerable expansion of the local industry, as more than 1600 tonnes of nuts and kernels, valued at over $12 million, are imported into Australia annually.

It is considered that the establishment of a local industry could complement overseas production through the provision of fresh, locally grown nuts that could be stored, in-shell, at a relatively low cost and cracked as required to supply fresh kernels for local processors and consumers. Major users of hazelnuts in Europe are also interested in obtaining product from Australia, provided the nuts or kernels are of appropriate quality and are available in sufficient quantities.

In addition to the freshness of the Australian product for local users, it has the potential to capitalise on a ‘clean and green’ image, as few of the major pests and diseases of hazelnuts have been introduced.
into Australia. In order to capitalise on these market opportunities, there is a need for research to evaluate appropriate varieties and develop efficient production systems. To be competitive and gain labour efficiencies, growers need to mechanise harvesting, storage, and processing of nuts. Although opportunities exist for growers to market their own produce, as production expands and smaller market niches are satisfied there will be a need for growers to develop strategic alliances with major buyers.

### Markets and marketing issues

Hazelnuts are marketed as two products, nuts in-shell and kernels. Nuts in-shell, marketed mainly for home or table consumption, account for less than 10% of the total market. Most hazelnuts are cracked and sold as kernels, which can be eaten fresh, but the vast majority are either blanched or roasted and then used in confectionery products, cakes and biscuits. Hazelnuts are highly nutritious and can be used for a wide range of purposes, such as in muesli, salads and as a complement to many food dishes. Other products include hazelnut spreads, nougat, hazelnut oil and liqueurs.

The major centre of hazelnut production in the world is in northern Turkey, on the Black Sea coast. There are other important production areas in Italy, Spain and Oregon, USA. The nuts produced by the Turkish growers are commonly stored on farm and then sold during the year to operators of cracking plants. The cracked kernels are size-graded and placed in plastic vacuum packs, which are kept in cool storage to prevent rancidity. The volume and value of nuts and kernels imported into Australia in recent years are given in Table 1. The quantity of imported kernels has generally risen over the last decade, as has the average price. The unit value is the landed price in Australia.

There are many variations of the market chain from production to processing and consumption (Figure 1).

### Table 1: Quantities and values of hazelnut imports into Australia

<table>
<thead>
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<tr>
<td><strong>Hazelnut kernels (Shelled nuts)</strong></td>
<td></td>
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<tr>
<td>Total tonnes</td>
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<td>1811</td>
<td>1764</td>
<td>1648</td>
<td>1990</td>
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<td>Total customs value (A$’000’s)</td>
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<td>12317</td>
<td>10936</td>
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<tr>
<td>Unit value (A$/kg)</td>
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<td>6.20</td>
<td>5.23</td>
<td>6.32</td>
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<tr>
<td><strong>Hazelnuts in-shell</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tonnes</td>
<td>28</td>
<td>125</td>
<td>111</td>
<td>42</td>
<td>43</td>
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<tr>
<td>Total customs value (A$’000’s)</td>
<td>66</td>
<td>590</td>
<td>476</td>
<td>221</td>
<td>149</td>
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<tr>
<td>Unit value (A$/kg)</td>
<td>2.33</td>
<td>4.71</td>
<td>4.28</td>
<td>5.27</td>
<td>3.45</td>
</tr>
</tbody>
</table>

Source: Australian Bureau of Statistics

![Figure 1. Principal components of the market chain from overseas nut production to processing organisations and retail outlets](image-url)
To date, one of the major constraints to the development of the local industry has been the lack of knowledge on the performance and appropriate management of introduced varieties which might be grown to complement imported nuts.

**Production requirements**

Hazelnut production is favoured by a climate with a cool winter and mild summer (Allen A. 1986) such as is found in the coastal and upland areas of southern Australia.

Hazelnut trees have a poor tolerance to heat, wind and moisture stress. The trees are deciduous and, when dormant, can tolerate temperatures as low as -15°C. At the time of pollination, June - August, the pollen and stigmas can be harmed by temperatures below -8°C and above 20°C. In Australia, spring frosts at the time of leafing in September and October do not seem to be a problem.

The main production areas in the Northern Hemisphere have a Mediterranean-type climate and are in the latitude range 37° to 47°. The climate of locations in Australia where hazelnut groves have been successfully established compares favourably with major Northern Hemisphere production areas (Table 2).

The growth of hazelnut trees is favoured by well-drained, fertile loam soils with a pH range of 6.5 to 7.5. Overseas, where annual rainfall exceeds 900mm, the crop is generally grown without irrigation, particularly where soils are deep. In Australia, it is considered highly desirable to irrigate orchards in the establishment phase. Where annual rainfall is less than 850-900mm and soils are not deep, irrigation is recommended for mature orchards, particularly during the phase of nut development and kernel fill, which is from late November to early February. Water requirements are estimated to be about 1-1.5 megalitres for every 150mm of rainfall less than 900mm. Dry weather during the harvest period is advantageous. This is generally during March in Australia.

Hazelnut trees do not tolerate strong winds and therefore the selection of sheltered sites, or the planting of wind breaks before establishing the grove, is very important. Flat or gently sloping sites are preferred to facilitate operations within the grove, particularly mechanical harvesting.

**Varieties**

Selecting the most appropriate hazelnut varieties for planting

| Table 2: The climate of hazelnut production areas overseas compared with Australian localities where hazelnut groves have been successfully established |
|---|---|---|---|---|---|---|---|
| Climatic Data | Ordu Northern Turkey | Nola Campania Italy | Corvallis Oregon USA | Bega, NSW | Myrtleford Vic | Orange NSW | Kettering Tas |
| Latitude | 410N | 410N | 450N | 370S | 370S | 340S | 420S |
| Mean annual rainfall (mm) | 990 | 1010 | 1050 | 870 | 910 | 940 | 700 |
| Hottest month | Mean max (oC) | 25 | 30 | 27 | 27 | 28 | 25 | 22 |
| Mean min (oC) | 18 | 18 | 11 | 14 | 12 | 12 | 10 |
| Mean rain (mm) | 68 | 29 | 14 | 89 | 45 | 109 | 46 |
| Rain days | 5 | 4 | 3 | 7 | 5 | 9 | 9 |
| Coldest month | Mean max oC | 10 | 12 | 7 | 16 | 14 | 9 | 12 |
| Mean min (oC) | 3 | 5 | 1 | 1 | 1 | 0 | 2 |
| Mean rain (mm) | 95 | 111 | 173 | 53 | 106 | 87 | 56 |
| Rain days | 10 | 11 | 19 | 6 | 14 | 14 | 12 |
| Harvest month | Mean rain (mm) | 72 | 79 | 38 | 98 | 60 | 50 | 52 |
| Rain days | 6 | 5 | 6 | 8 | 6 | 7 | 9 |

Source: Climatic Averages, Australia, Bureau of Meteorology, www.bom.gov.au
is a very important decision. The University of Sydney is undertaking research on this matter with funding provided by RIRDC. A report of research to-date is available at http://www.rirdc.gov.au/reports/NPP/03-141sum.html

There are two main aspects that have to be considered when selecting varieties; these are the productivity of the variety for the particular conditions of the site and the marketability of the nuts. Ideally the varieties planted should be both productive and of a type for which there is a market demand.

Although a wide range of varieties can be sold in-shell, there is a customer preference for nuts that are large with a clean, shiny appearance and even size. Varieties that meet these requirements include Ennis from the USA and Wanliss Pride, an old Australian selection (Table 3). A large proportion of the imported in-shell nuts are of the variety Oregon Barcelona, which has relatively large attractive nuts. However, imports of this variety are being superseded by the larger sized Ennis.

Those growers who plan to sell into the kernel market need to talk to buyers or potential buyers to ascertain whether any particular variety or varietal characteristics are sought such as kernel size, shape, texture, taste, oil content and blanching or roasting characteristics. Some processors have very specific requirements for their products. Small round kernels (13-15mm diameter) are generally preferred in confectionery products, such as from the variety Tonda di Giffoni. A few buyers have specific varietal preferences, such as Bristowe Farm Hazels who prefer the variety Tokolyi/Brownfield Cosford (TBC), see http://www.hazelnuts.net.au/

Wanliss Pride is a variety that was widely grown in the past. It has a large nut and produces a sweet tasting kernel. However, it is prone to rancidity when insufficient care has been taken to thoroughly dry the nuts at harvest time.

Hazelnut kernels are covered with a skin or pellicle, which varies in thickness and appearance between varieties. The pellicle can be readily removed from most varieties by a process known as blanching, which involves heating kernels for 10-15 minutes at 140°C, followed by brushing off the loose pellicle to leave a clean white kernel. Examples of varieties that blanch well are Tonda di Giffoni, and the Australian selections Tokolyi/Brownfield Cosford (TBC) and Wanliss Pride. Roasting, which involves heating for a longer period of time increases the flavour and crunchiness of kernels. General descriptions of nut and kernel characteristics are given in Table 3.

Many of the early hazelnut introductions into Australia were in the form of nuts. As the species is cross-pollinated, the seedlings grown from these nuts were not true to varietal type. Local selections have been made from these seedling types, some of these have been found to be useful, such as Wanliss Pride, Tokolyi or Brownfield Cosford (TBC) and Tonollo. Unfortunately, the word Cosford as applied to Tokolyi Cosford is a misnomer as the selection is a round nut, rather than the typical, elongated Cosford shape.
Table 3: Key characteristics of some important overseas and Australian hazelnut varieties

<table>
<thead>
<tr>
<th>Variety</th>
<th>Country of Origin</th>
<th>Av. nut wt (g)</th>
<th>Yield attributes</th>
<th>Characteristics of nuts &amp; their uses</th>
<th>Principal pollinisers (Early (e), mid (m) and late (l) female bloom)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduced cultivars</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barcelona</td>
<td>USA</td>
<td>3.3</td>
<td>Good, wide adaptation</td>
<td>Moderate blanching, kernel and in-shell</td>
<td>Butler (e), Casina/Lewis/TBC (m) and Hall’s Giant (l)</td>
</tr>
<tr>
<td>Butler</td>
<td>USA</td>
<td>3.3</td>
<td>Good, wide adaptation</td>
<td>Mainly a polliniser, but suited to the in-shell</td>
<td>Barcelona (e), Ennis (m) and Hall’s Giant (l)</td>
</tr>
<tr>
<td>Casina</td>
<td>Spain</td>
<td>1.6</td>
<td>Moderate yield, mainly used as a</td>
<td>Little pellicle, poor blanching</td>
<td>Hall’s Giant (m)</td>
</tr>
<tr>
<td>Ennis</td>
<td>USA</td>
<td>4.0</td>
<td>Moderate to good yield</td>
<td>Large nut for in-shell market</td>
<td>Butler /Casina (e), Hall’s Giant (m) and Jemtaegaard#5 (l)</td>
</tr>
<tr>
<td>Hall’s Giant or Merville de</td>
<td>Germany</td>
<td>3.4</td>
<td>Very low yield.</td>
<td>Large nut, principally a late pollinator for many</td>
<td>Ennis and Casina (e)</td>
</tr>
<tr>
<td>Bollwiller</td>
<td></td>
<td></td>
<td></td>
<td>varieties</td>
<td></td>
</tr>
<tr>
<td>Tonda di Giffoni</td>
<td>Central Italy</td>
<td>2.7</td>
<td>Early variety, high yield</td>
<td>Excellent blanching, used in confectionery</td>
<td>Barcelona (e), Lewis (m) and Hall’s Giant (l)</td>
</tr>
<tr>
<td>Lewis</td>
<td>USA</td>
<td>2.8</td>
<td>Promising new cultivar</td>
<td>Blanches well</td>
<td>Tonda di Giffoni / Barcelona (e), and Hall’s Giant (l)</td>
</tr>
<tr>
<td>Willamette</td>
<td>USA</td>
<td>2.8</td>
<td>Promising new cultivar</td>
<td>Blanches well</td>
<td>Tonda di Giffoni (e) and Hall’s Giant (l)</td>
</tr>
<tr>
<td><strong>Australian selections</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TBC (Tokolyi/Brownfield</td>
<td>Aus</td>
<td>3.0</td>
<td>Appears to be productive over a wide</td>
<td>Kernel blanches well, very crunchy</td>
<td>Barcelona/Ennis (e), Casina/Willamette/Turkish Cosford (m)</td>
</tr>
<tr>
<td>Cosford)</td>
<td></td>
<td></td>
<td>range of environments</td>
<td></td>
<td>and Daviana/Woodnut (l)</td>
</tr>
<tr>
<td>Tonollo</td>
<td>Aus</td>
<td>3.2</td>
<td>High yields on basaltic soils</td>
<td>Sweet kernel, blanches well</td>
<td>Butler (e), Casina/Lewis (m) and Hall’s Giant (l)</td>
</tr>
<tr>
<td>Wanliss Pride</td>
<td>Aus</td>
<td>3.3</td>
<td>Poor growth on red basaltic soils</td>
<td>Large nut, sweet kernel for in-shell and kernel</td>
<td>Suggest TBC (e), Woodnut (m) and Kentish Cob (l)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Spreading habit of growth</td>
<td>markets</td>
<td></td>
</tr>
</tbody>
</table>

During the last ten years, many individual growers and propagators have imported varieties from the USA and Europe. These are currently being evaluated at sites in New South Wales, Victoria and Tasmania. The yield attributes, under Australian conditions, of the local selections and promising overseas varieties are given in Table 3.
Cultural practices

It is important to select a sheltered planting site, as hazelnut trees are very sensitive to wind damage, particularly in the establishment years. It is advisable to plant shelter belts around a proposed site, two or three years ahead of planting the grove.

It is generally advisable to apply lime to sites that are acid, one year before planting, to bring the soil pH up to a reading of about 6.5. Ripping the planting rows in the autumn of the planting year may be beneficial on soils that are prone to compaction. Cultivating the planting row in autumn will loosen soil in preparation for planting in winter and provide an environment that favours root growth.

Groves are commonly planted at a density of 400 - 500 trees/ha, with a spacing of 5-6m between the rows and 3-4m between trees within the rows. The more vigorous varieties are planted at the wider spacing. It is essential to keep new plantings free of weeds and highly advisable to mulch around the base of young trees to favour moisture retention and lower the soil temperatures in summer. It is very important that young trees receive adequate water. Supplementary irrigation will be required if rainfall is insufficient.

Hazelnut varieties produce suckers to varying degrees. These suckers grow vigorously and must be removed several times each year, in order to restrict growth to the main productive part of the tree. Suckers are either removed by hand or by chemical spraying. The removal of sucker buds before planting can reduce subsequent sucker production.

Hazelnut trees are cross-pollinated. The male catkins, formed during late summer and autumn, elongate in winter and shed pollen, which is carried on the wind to the small female flowers. When receptive, these female flowers appear as small buds with reddish filaments (stigmas) at their tips. Although catkins and female flowers are borne on the same plant hazelnuts are not self-fertile. Pollination occurs in the winter, but fertilisation does not take place until early summer when the seed (kernel) develops within the shell. The mature nuts ripen in late summer with most varieties falling free from their husks to the ground during March.

For pollination to be effective, the two varieties involved need to be genetically compatible and their period of pollen shed and stigma receptivity must be synchronous. The genetic compatibility of overseas varieties is known and can be used by growers to select appropriate varieties for effective pollination. The variety Barcelona, for example, which is grown for its high nut yield, is pollinated by the varieties TBC and Halls Giant. TBC sheds its pollen earlier than Halls Giant. These two varieties cover the main period when the female flowers of Barcelona are receptive. Both TBC and Halls Giant produce many catkins and copious quantities of pollen.

The selection of appropriate pollinisers is a critical aspect of hazelnut production. A ratio of one polliniser tree to nine main crop trees is generally recommended to ensure sufficient pollen is spread through the grove. Some main crop varieties such as Barcelona and TBC are cross compatible, with TBC giving good pollination of Barcelona. Unfortunately Barcelona only pollinates the early flowers of TBC; thus additional pollinisers are required for TBC.

Pollen that is shed from the elongated catkins is blown through hazelnut groves to cross-pollinate the receptive female flowers.
Hazelnut producers overseas have to contend with many pests and diseases but, as a result of strict quarantine regulations, most of these have so far been excluded from Australia. Hazelnut blight (Xanthomonas corylina), an important bacterial disease of hazelnuts world-wide, does occur in Australia. It was first detected in Victoria in 1980. Blight mainly affects young trees, causing dieback of new shoots and reddish brown lesions (1 - 3mm diam.) on the leaves. The husks of infected nuts also have reddish-brown lesions on them and some staining or discolouration of the actual nuts can occur. The disease is favoured by wet weather in spring and seems to be more prevalent at sites where trees are exposed to strong winds. The rubbing of leaves under windy conditions causes damage to the leaf surface, which allows bacteria to enter and blight to develop.

The principal method of blight control is through the application of protective copper-based sprays. Cupric hydroxide is the most commonly used chemical.

Aphids are often found on the underside of hazelnut leaves. These small, greenish insects suck out the sap of the plant and can affect development when aphid populations are high. Sooty mould develops on the honeydew excreted by the aphids, causing an unsightly black discoloration of the leaves, nuts and wood.

Flocks of sulphur-crested cockatoos have caused losses of mature nuts in some Australian groves. This pest is a major threat in some areas. Foxes can also be a pest at harvest time, as they eat the fallen, ripe nuts.

Harvesting and postharvest handling

In most commercial varieties, nuts fall freely to the ground, falling free from their husks. In small groves, nuts are often picked up by hand but as this is a relatively slow process mechanised or partly mechanised systems are usually employed. There are three types of mechanical harvesters - sweep and pick-up, vacuum and finger wheel harvesters. The sweep and pick-up method is fast and best suited to larger orchards. Flory Industries in the USA manufacture a range of sweeping and pick up machines for hazelnuts, see under Products on their web site http://www.floryindustries.com/.

Vacuum harvesters are of intermediate price. They have hand held hoses which operators use to suck up the fallen nuts. Most of these harvesters use wind to separate the nuts from the leaves and have dehuskers and rotary screens for cleaning nuts. A tractor driver and two operators on the suction hoses can pick up 5kg of nuts per minute in productive orchards. Leading Australian growers Brian and Glenice Horner of Glenbri Farm near Eden, use a small suction harvester for their crop. This can be seen on the RIRDC Thirty Australian Champions web site http://www.rirdc.gov.au/champions/GlenbriFarmHazelnuts.html

Well-grown hazelnut trees at Myrtleford at a spacing of 3m x 5m. The highest yielding varieties achieved the equivalent of 3t/ha in their sixth year from planting.
countries are subject to stringent quality specifications. There is a zero tolerance of foreign material and uncracked nuts as well as kernels that are rancid and mouldy. Those planning to crack nuts and sell kernels must develop quality control systems to similar standards.

**Financial information**

The economics of production is strongly influenced by crop yield, the price obtained for the kernels or nuts and the scale of operations. The cost of land will have a major influence on the establishment costs. Assuming that an intending grower already has the land and a water supply, the main costs incurred in establishing a hazelnut grove are land preparation, purchase of young plants (whips) and the installation of an irrigation system. Typical establishment costs are:

<table>
<thead>
<tr>
<th>Costs</th>
<th>$/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime application 5t/ha @ $60/t</td>
<td>300</td>
</tr>
<tr>
<td>Land preparation, fertilisers and weed control</td>
<td>250</td>
</tr>
<tr>
<td>400 trees @ $11/tree</td>
<td>4400</td>
</tr>
<tr>
<td>Irrigation system (1)</td>
<td>2000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>6950</td>
</tr>
</tbody>
</table>

Note (1) - Assumes water supply to the site

Little production occurs before the fifth year, with nut yields rising steadily over the next five years. Assuming a yield of 2t of nuts/ha per annum by the tenth year from planting, the following annual gross margin could then be achieved:

<table>
<thead>
<tr>
<th>Income</th>
<th>$/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazelnuts (in-shell) 2t/ha</td>
<td>6000</td>
</tr>
</tbody>
</table>

**Variable production costs**

<table>
<thead>
<tr>
<th></th>
<th>$/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fertilisers</td>
<td>150</td>
</tr>
<tr>
<td>Sucker removal (4 times/yr)</td>
<td>100</td>
</tr>
<tr>
<td>Mowing (5 times/yr @ $20)</td>
<td>100</td>
</tr>
<tr>
<td>Weed control</td>
<td>100</td>
</tr>
<tr>
<td>Irrigation (Application costs)</td>
<td>150</td>
</tr>
<tr>
<td>Harvesting (Machine @30c/kg (2))</td>
<td>600</td>
</tr>
<tr>
<td><strong>Total costs</strong></td>
<td>1200</td>
</tr>
</tbody>
</table>

Notes:
(1) Yields equivalent to 3t/ha have been achieved at the Myrtleford research site. Commercial yields of 2t/ha are common in Oregon, USA.
(2) Estimated cost of mechanical harvesting using a contractor.

The overall economic viability of the enterprise can be improved through value adding, such as cracking nuts, roasting the kernels or using them to make some special products such as biscuits, or hazelnut chocolate.

At Glenbri Farm, Brian and Glenice Horner have equipment to crack nuts and value add to their kernels, which are all sold locally, see: http://www.rirdc.gov.au/champions/GlenbriFarmHazelnuts.html. Brian and Glenice have no difficulty in selling all they produce locally, indicating the potential for Australian grown, fresh hazelnuts.

**Key references**


**Source of planting materials**

Bristowe Farm Hazelnuts (Nursery), Mudgee, NSW. http://www.hazelnuts.net


Milan Paskas, 24 Olsen Road, Nar Nar Goon North, Victoria Phone 03 5942 8381

Mountain Greenery Nurseries Richard Salt, Daylesford, Victoria Phone 03 5348 7818 rsalt@bigpond.com
Key statistics

- Imports of hazelnut kernels 1997-2001
  - Total quantity: nearly 2000 t
  - Total customs value: $12 million
  - Unit value of imported kernels: $5-6/kg

Key messages

- Hazelnuts are a cool climate crop
- Hazelnuts valued at more than $12 million are imported annually into Australia
- Current Australian production of hazelnuts is small
- Hazelnuts have great potential as a crop, but careful selection of sites and varieties is important
- Long term potential exists for organic production and export to Northern Hemisphere countries

About the author

Basil Baldwin B.Sc. (Hons), Grad Dip Ed, M.Ag. Sci. is a Senior Lecturer at the Faculty of Rural Management, University of Sydney. His experience in agronomy includes developmental work with new crops to Australia, including oil-seed poppies and faba beans. Current research includes an evaluation of hazelnut varieties and factors influencing the growth and production of hazelnuts.

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Industry Association
Hazelnut Growers of Australia Ltd
http://www.hazelnuts.org.au/
## Wildflowers

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<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banksia and other proteacea</td>
<td>404</td>
</tr>
<tr>
<td>Blandfordia</td>
<td>414</td>
</tr>
<tr>
<td>Boronia</td>
<td>420</td>
</tr>
<tr>
<td>Eucalypts for cut bud, flower and foliage production</td>
<td>428</td>
</tr>
<tr>
<td>Flannel flower</td>
<td>434</td>
</tr>
<tr>
<td>Kangaroo paw</td>
<td>442</td>
</tr>
<tr>
<td>NSW Christmas bush</td>
<td>450</td>
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<tr>
<td>Smokebush</td>
<td>458</td>
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<tr>
<td>Thryptomene</td>
<td>463</td>
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<tr>
<td>Tropical rainforest foliages</td>
<td>469</td>
</tr>
<tr>
<td>Waxflower</td>
<td>476</td>
</tr>
</tbody>
</table>
Banksia and other proteaceae

Including Telopea (Waratah) and South African species

Christine Horsman

Acknowledgement is given to Margaret Sedgley, the author of this chapter in the first edition of this publication.

Introduction

In the last few years, there has been a resurgence of interest in the use of Australian wildflowers in floristry, largely due to the exposure received during the Sydney Olympics in 2000. In a flow-on effect, South African Proteaceae species (such as Protea, Leucadendron, Leucospermum and Serruria) have also become more popular. Demand has increased on both the domestic and export markets, but buyers have also become much more discerning. Since these species are no longer considered exotic, they must now compete against more traditional products in a marketplace where price is always a major issue.

There are several major constraints to the on-going success of the industry. Firstly, it remains fragmented.

There is still no truly representative national body, funds committed to research are minimal, the marketing chain is competitive rather than cooperative and coordinated promotion is almost non-existent.
Secondly, climate change has meant that many areas that once had reliable rainfall are either getting much less, or, precipitation patterns have changed so there is now insufficient run-off into storage dams. Increased UV radiation is also having a detrimental effect on flower quality in some regions. In other areas, urban development close to plantations has increased the potential for conflict arising from farming practices.

Thirdly, increased government regulations relating to environmental and income tax issues act as disincentives to many who consider entering the industry.

Significant quantities of Proteaceae are grown in South Africa, Hawaii and California, all of which have labour and/or freight advantages over Australia. New Zealand, while having a similar cost structure to Australia, has the advantage of an efficient and integrated export chain.

In spite of these constraints, there is still potential for growers to be successful, provided they: research the market properly before planting; choose a suitable site with reliable, good quality (low salinity) water, that is also relatively near transport facilities; make a commitment to grow and supply only quality blooms; and maintain close contact with other industry stakeholders.

Markets and marketing issues

Flowers are fashion items, and as such, the popularity of particular colours and types of flowers will wax and wane. These trends are set—often several years ahead—by overseas designers. This can make product selection difficult for growers of Proteaceae species that take several years to mature. On the positive side, trends do tend to be cyclical, so what is ‘out’ one year may be ‘all the rage’ the next.

Within Australia, the main market for Proteaceae is in Sydney, where growers from all over the country sell to wholesalers at the Sydney Flower Market. The wholesalers on-sell to florists, makers of bunch lines and sometimes to exporters. While some suppliers of top grade blooms receive an agreed price for their product, much is sold on consignment and, in periods of oversupply, prices can be significantly reduced. At times, the product may not be sold at all, especially if it is of poor quality.

There are smaller flower markets in Brisbane and Melbourne that also move significant quantities of product. Some growers sell directly to florists or through local produce markets, but these are generally not volume producers.

Overall, domestic market prices have not increased for many years. Although quality has improved, more than adequate supplies of many lines have kept prices down. The exceptions are new and attractive cultivars that have great appeal for florists.
While export markets remain the area of greatest potential for the industry, exporters have experienced severe setbacks in the last three years. The attack on the World Trade Centre, followed by the wars in Afghanistan and Iraq and then the SARS outbreak, all affected both the overall demand for flowers and the availability and cost of freight space. *Proteaceae* tend to be bulky flowers that occupy a large volume of space relative to their weight. This increases the freight cost per bunch compared to smaller flowers. Australia is a long way from its main markets (Japan, USA and Europe), so this increase adds significantly to the final cost to the consumer. The strength of the Australian dollar in 2003 has almost been the final ‘nail in the coffin’ for some exporters and per stem returns to growers have correspondingly decreased.

The challenge for the export side of the industry is to ‘work smarter’, with more large-scale growers producing high volumes of quality blooms that can be sold at lower margins. Unless they are able to supply very high-end niche export markets, small-scale growers generally achieve better returns on the domestic markets—provided that they grow top quality flowers and avoid species that glut in peak season.

**Production requirements**

All *Proteaceae* require well-drained, slightly acid soil, that is low in phosphorus, but there is variation between the species in their preference for sand or heavier loam. When selecting a site, it is advisable to research the history of the property with regard to past fertiliser and chemical use (high phosphorus levels in particular are detrimental to *Proteaceae*).

It should be confirmed that the land is allowed to be used for flower field crops and that a dam or bore can be constructed if required. Ample, low salinity water should be available all year round and particularly in times of drought. To grow the top quality product that is demanded by today’s markets, irrigation of the plantation is a necessity in most areas of Australia. Growers need to assess very long term climatic averages, especially rainfall and temperature, because factors like frost and drought can cause severe setbacks in production.

Some states require that the grower hold a licence to produce Australian native species, so check this before making any planting decisions. There are also environmental issues that must be taken into consideration, such as irrigation and fertiliser run-off and spray drift.

Most commercially grown banksias are native to Western Australia and are adapted to sandy soils, lacking in nutrition. They grow best in a Mediterranean climate with high light intensity, long hours of sunshine, low relative humidity and absence of frosts. In Australia, that means the coastal areas of south-western Western Australia and the sandier parts of South Australia, Victoria and New South Wales.

*Serrurias* likewise prefer winter rainfall and sandy soil, tending to have high death rates and very short productive life in heavier ground. Some success has been achieved using gro-bags in areas where the climate is satisfactory but the soil is not.

Proteas, leucospermums and leucadendrons will thrive in a wider range of soils and climates, but prefer winter rainfall. In regions where there is summer rainfall, these species are prone to suffer from fungal leaf diseases and *Phytophthora* root rot. Leucadendrons in particular grow extremely well in richer soils, with high rainfall, *provided that there is excellent drainage*.

Waratahs are adapted to summer rainfall, but also grow well in the cooler, wetter parts of South Australia, Victoria and Tasmania. They are less vulnerable to phosphorus toxicity than other species, but the soil must be very deep and well-drained.
Varieties/cultivars

Many of the most commonly grown cultivars, such as *Protea* ‘Pink Ice’, *Leucadendron* ‘Silvan Red’ and *Banksia spectosa* have periods of severe glut during peak season, which results in extremely poor farm gate prices—if indeed a market can be found at all. There is presently unfulfilled demand for the banksia species *B. praemorsa*, *B. menziesii* and *B. plagiocarpa*. *B. plagiocarpa* is unusual in that it thrives in the high humidity, high rainfall conditions of the east coast and produces both flowers and foliage that are saleable.

Variegated leucadendrons such as ‘Katie’s Blush’ and ‘Corringle Gold’ are popular on both domestic and export markets, but tend to be harder to grow successfully than more common species. There is demand for *L*. ‘Safari Sunset’ with large heads, good colour and long, strong stems, at either end of the season, but mid-season is well-supplied; *L. gandogerii* sells well, providing heads are large and the yellow colour is bright; *L. argenteum* is popular, but only grows well in cooler areas with deep, well-drained loamy soil. The new leucadendrons developed in Western Australia with RIRDC support show great promise and should give growers some interesting choices when they are released.

*Serruria florida* and white varieties and cultivars of species such as *P. cynaroides*, *P. neriifolia* and *Telopea* are all popular, particularly for the wedding market. Red flowers, like *B. coccinea* and *Telopea* species are in great demand if they can be supplied late in the season at Christmas time. Selected leucospermums in yellows and oranges, such as *L*. ‘Red Ribbon’ and *L*. ‘Veldfire’ are still in demand, particularly late in the year.

The hybrid *P*. ‘Grandicolor’ has been one of the most sought-after proteas in the domestic Sydney market for the last couple of years, mainly because of its unusual apricot colouring. *P. compacta* cultivars like ‘Christine’, ‘Trish’ and ‘Thomas’, which have large heads and bright colour, are also popular.

There are specialist *Proteaceae* nurseries in most states that are the best source of the latest hybrids and cultivars. It is no longer a sensible business decision to plant seedling-grown stock.
Banksia speciosa (Showy Banksia)
Leucadendron salignum (Salignum/Yellow)
Protea magnifica (Queen Protea)
Leucadendron coniferum (Sabulosum)
Leucospermum reflexum (Cape Gold)
Protea
Leucadendron "Safari Sunset" (Safari Sunset)
Leucospermum reflexum (Cape Gold)
Telopea speciosissima (Red Waratah)
Cultural practices/agronomy

It is vital that intending growers research both the market they intend to supply, and the ideal growing conditions for the products they would like to grow. For example, trying to grow most banksias in heavy soil, where there is high rainfall, is futile. The plants will probably not thrive and the quality of blooms will be inferior to those grown in ideal conditions. Grow what grows well in the area, provided that there is demand for it. It is advisable to plant a number of species that flower at different times, to spread the risk of losses due to weather or gluts and, to maximise use of labour and equipment resources. A trial planting will allow assessment of the viability of selected plants.

The ideal plantation has an easterly, north-easterly or northerly aspect, with a convex slope mild enough to allow safe tractor access to every point. On windy sites, windbreaks should be established, but the presence of some air movement is beneficial in reducing the incidence of fungal diseases.

Many growers these days have found that there are major benefits to adjusting the pH and soil nutrient levels, based on extensive soil analysis, before laying out the plantation. This gives plants the optimum start in life and ensures that the nutrients they require are available in a useable form.

To avoid root rot, the soil should preferably be deep-ripped, then shaped into parallel, mounded rows, far enough apart to allow machinery access when bushes are fully grown. Depending on the species and the machinery, this is usually 3–6 m. To minimise the time spent on weed control, the mounds are often covered with weedmat. The disadvantage is that on very hot days, it causes the soil to heat up, resulting in damage to roots that are near the soil surface. Using gravel or organic material as mulch is also an option.

Drip irrigation should be laid along the mounds, with drippers at spacings appropriate for the species:

- 1–1.5 m for leucadendrons
- 1.5–2.5 m for proteas and leucospermums
- 2.5–3.5 m for waratahs
- 2–3.5 m for banksias
- 1 m for serrurias.

It is advisable to get professional advice about ideal watering times and flow rates, which will vary significantly according to the soil type and depending on the weather. As a guide for assessing availability of sufficient water, many growers use 4 l/hr drippers for 2–3 hours, at least twice a week.

Planting can be done in autumn (unless there is the likelihood of frost damage) or spring (provided that there is ample water to supply the young plant over the summer months). Soil should be mounded away from the base of the plant, to allow best possible drainage and, if mulch is applied, it should be kept clear of the stem to avoid collar rot.

Fertiliser rates used on Australian flower farms vary enormously, but it is generally agreed that ‘fertigation’—applying fertiliser through the irrigation system—is the best method. Nitrogen, potassium and iron are all important nutrients, but actual requirements should be assessed based on skilled analysis of soil and leaves.

Training and pruning of bushes should be commenced early and continued throughout the life of the plant. Pruning aids weed and disease control, encourages good stem length and extends the useable life of the plant. It is usually done in winter or early spring until the plant begins to flower and thereafter, either during picking or after the plant has finished its flowering season.

The other major maintenance jobs are spraying (to control weeds, insects and diseases), and other methods of weed control, such as slashing and brushcutting. As a guide, about 2 ha of intensive planting is about as much as one person can properly attend to on their own.

In general, *Leucadendron* and *Serruria* will flower in their second year and *Protea, Leucospermum, Telopea* and *Banksia* in their third year, but another year is required for a commercial crop. The useful life of the plants varies with the species and the care they receive, but generally, it is about 10 years from maturity. Serrurias seem to be the exception, and only live about 5 years in most plantations. Waratahs and some proteas, such as *P. magnifica*, will live much longer, but as new hybrids are released, old varieties may become so unpopular
that a commercial decision must be made to remove them.

**Pest and disease management**

*Phytophthora cinnamomi* is the nemesis of Proteaceae growers everywhere. This soil-borne fungal disease causes root rot, collar rot and dieback and can result in widespread losses. Control of *Phytophthora* is extremely difficult, and prevention is the best option. Related species like *Pythium* and *Rhizoctonia* can also cause problems and again, prevention is better than cure. Buy plants only from accredited nurseries, make sure the plantation has effective drainage and keep plants well nourished and watered. Just like people, plants are more resistant to infection if they are in peak condition. To avoid spreading diseases during harvesting, it is best to disinfect secateurs when moving from one bush to another.

Most states now have a requirement that those using chemicals must have undertaken a course in the proper use and disposal of these potentially dangerous compounds. It is important to always read and follow label instructions carefully and get specific, professional advice about the best and most effective time to spray for a particular pest. Flowers grown for export may need to be sprayed every few weeks to meet quarantine requirements.

Scale is a very common and difficult pest to eradicate, but can be controlled with applications of white oil when the larvae are at the crawler stage (early and late summer).

Waratahs are attacked by leaf miners, mealy bugs, chewing caterpillars and bud-tip borers. These need to be managed by strategic spraying, especially from December to March, when the buds set. *Protea, Leucadendron* and *Leucospermum* may require fungicide applications to combat diseases such as *Elsinoe, Drechslera* and *Colletotrichum*, especially in summer rainfall areas.

*Bankia* species may suffer from *Phytophthora, Elsinoe* and *Diplodena*, an aerial canker. Tunnelling moth larvae (*Arotrophora* spp.) feed on the soft tissue in the centre of the flower, thus killing the bloom. As is the case with all diseased material, removal and destruction is essential.

**Harvest/postharvest**

For maximum postharvest life, flowers need to be picked daily, preferably in the cool of the morning, at the earliest stage that will allow them to mature. Over-mature flowers are often damaged by bees and drip nectar that can ruin other more saleable blooms. Ideally, flowers should be placed in water out in the field, but if this is not possible, keep them in a shaded area and return them to the packing shed no more than an hour after picking. Care must be taken to avoid bruising and damage to the blooms.

In the packing shed, flowers and leaves are checked for damage, colour and general quality, leaves are stripped from the bottom 10 cm (approximately) of stem, avoiding damage to the stem itself. The stems are recut, then blooms are graded and bunched according to stem length and species. Larger flowers like waratahs, King proteas and most banksias are sold as singles; average-sized proteas and leucospermums are bunched in 5s and leucadendrons in 10s, using rubber bands. Multi-headed leucadendrons and those with heavy cones are often sold in 5s. Different markets may have particular requirements, so ‘the customer is always right’!

The blooms should be put into buckets of clean water at room temperature, to which chlorine (1 g/10 l water) has been added, then placed on trolleys in a coolroom operating at 1–4°C and 98% humidity, which is lit by fluorescent gro-lights. A coolroom is an essential piece of equipment in today’s demanding market, because maintenance of the cool chain from farm to market is vital to maximise flower vase life for the consumer.
Flowers for export may need to be dipped in fungicide or fumigated. More detailed postharvest information can be found in the RIRDC Publication No. 02/021, which is a comprehensive postharvest handbook (see key references).

After cooling and hydration, flowers are usually packed in sturdy cardboard cartons and then either taken directly to market (local) or delivered to a freight-forwarder, who transports the produce in refrigerated trucks or by air (interstate and overseas).

Waratahs benefit from the use of a plastic liner in the cartons. This prevents drying out and the resultant browning of bracts. Plastic liners are not recommended for other Proteaceae, especially proteas, where excess humidity will accelerate leaf-blackening.

Financial information

Growing Proteaceae for profit is more likely to be successful if undertaken as an extension of some other agricultural activity on land already owned that has adequate water, otherwise, the capital costs of purchasing land, facilities and equipment could be prohibitive.

Main establishment costs are: preparation of the land; building windbreaks (if required); purchase and laying down of weedmat or other mulch (if used); irrigation mains and dripper lines; pump and filters (if not using mains water); packing shed and coolroom. Total expense will vary depending on the area planted out and the size of facilities, but expect to spend at least $50-60,000.

The plants themselves are a major expense, particularly if more advanced stock is chosen. Cutting grown plants in 75 mm pots cost about $3.50 (ex GST), while for those in 140 mm pots, the cost increases to around $7-8.50. At 1,500 to 2,000 plants/ha, depending upon the species, a minimum cost is still over $5000/ha. Although the larger plants cost more initially, they will begin producing sooner, so a cost/benefit analysis needs to be undertaken.

The number of saleable stems per bush will depend both on the species and the pruning strategy. When assessing the potential returns for a species, consider not only the number of stems, but also the work required to get that stem to market. For example, most leucadendrons do not return a great deal per stem, but there are many stems on a bush, they are easy to process and the picking can be done over an extended period. A stem of summer-flowering *P. repens* may sell for more than twice as much, but there are fewer stems on a bush. They need to be picked every day during the flowering period to avoid significant losses due to overblown flowers and, because of the extra labour required to trim off bypass shoots, cutting is expensive.

Table 1. Sample gross margin (per ha) figures for Banksia (mature plants)

<table>
<thead>
<tr>
<th>Income</th>
<th>Grade 1 (60 cm)</th>
<th>20,000 stems</th>
<th>$0.50</th>
<th>$10,000</th>
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<td>Total</td>
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<td></td>
<td>$16,000</td>
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<table>
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<th>Supplies</th>
<th>Labour</th>
<th>Total</th>
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<tr>
<td>Gross margin/ha</td>
<td></td>
<td></td>
<td>$6,400</td>
</tr>
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</table>

Chart published in Floriculture News December 2003. Used with permission of Gerry Parlevliet, Dept. Agriculture WA. Figures collected as part of a benchmarking project funded by Agwest, Flowerswest and RIRDC.
About the author

Chris Horsman has been growing South African Proteaceae commercially in the Adelaide Hills since 1982. She has written many informative articles about the production of proteas and was closely involved in the making of several training videos for protea growers. Chris was National President of the Australian Flora and Protea Growers Association (now called Wildflowers Australia) for five years, so has an intimate knowledge of the wider industry and of the challenges and satisfaction that come from growing wildflowers. She is currently a member of the RIRDC Wildflower Advisory Committee.

Key references


RIRDC has funded a number of other projects that may provide useful information to growers of proteaceae. Visit the RIRDC website www.rirdc.gov.au click on ‘Publications’ and then on ‘Wildflowers and Native Plants’ for further details.

Disclaimer

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Key messages

- Research markets before planting anything
- *Proteaceae* production is labour intensive
- Ample fresh water is vital
- Consider cost of transport to market
- Quality, quality, quality

the return per hectare of plantation could actually be less than for the leucadendrons.

“Costs are forever going up and are still one of the areas growers can look at to significantly improve the profit margin. The largest cost in growing banksias is the cost of labour at about 60-70%. Most other costs are relatively small. However, knowing the cost of your operation and the costs of producing and preparing the flowers for sale is critical for long-term sustainability of the business.” (Floriculture News December 2003)


All these figures are a guide only. Actual prices achieved will depend upon the season, the markets, the quality of the flowers and how well they are presented. Ongoing costs will vary according to the efficiency and scale of the operation.
Key contacts

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Key statistics

Collection of industry statistics is fragmented and sometimes inaccurate. Quoted figures are therefore a guide only.

- Nearly 50% of Australian fresh flower exports are to Japan
- Fresh flowers constituted 87% of flowers exported in 2001
- Total export sales of all wildflowers amounted to 4,500 t in 00/01
- Over 380 t of proteas, valued at nearly $3 million were exported in 2002
- Total domestic sales of all wildflowers amounted to $96 million in 2000
Blandfordia

Introduction

The suitability for cultivation of Blandfordia (Christmas bells) was recognised as early as 1803 (Australian National Botanic Gardens, 1987), when B. nobilis entered cultivation as a glasshouse plant in England. In Australia, the genus has been exploited as a bush-picked seasonal cut flower crop for many years on the domestic market. For the export markets however, cultivated flowers must be provided to meet the high quality standards of the international markets.

From 1989 there were investigations conducted on Blandfordia at various institutions in New South Wales. The Australian Rural Research Fund (now RIRDC) funded a 3 year study of the biology and development of Blandfordia species as a new native ornamental crop and that study was conducted by the author at UTS (Johnson, 1994). At the same time Dr Peter Goodwin at Sydney University was granted funds to develop

Blandfordia – Flower type yellow-red

Current production area

Key messages

- Blandfordia is a unique Australian flower
- Its habitat is under pressure
- Its potential as a cut flower is only minimally utilised
- It is popular with the world markets
- Its cultivation, postharvest and marketing have been researched
- Blandfordia requires reasonable establishment time
production and export technology for *Blandfordia*. In 1993, the Department of Agriculture was funded by RIRDC to investigate postharvest disinestation and management of *Blandfordia* (Worall & Wade, 1996).

The formation of a group of growers, researchers, advisers and other interested parties, in 1989, known as Blandfordia Research and Extension Group (BREG), has consolidated its efforts to develop and market *Blandfordia* as a commercial cut flower. This has proved an innovative way of encouraging communication and cooperation aimed at developing a new crop. There has been a lot of enthusiasm, energy and willingness in this group that has endeavoured to put this beautiful plant on the international map. At the time of writing, *B. grandiflora* is grown as a commercial cut flower crop by a few growers in New South Wales (Port Macquarie and the Central Coast of NSW).

The natural habitat of the genus has been disappearing since the time of European settlement, and it would seem that the whole genus may be under threat in the wild, since its distribution, along the eastern coast of Australia includes some of the most heavily populated and rapidly developing areas of the continent. Because of its protected native plant status a licence is required to grow *Blandfordia* for commercial purposes (http://www.austlii.edu.au/au/legis/nsw/consol_act/). Licences are available from the New South Wales National Parks and Wildlife Service on application to the local NPWS area office. The licence conditions are described in Protected and Threatened Plants in the Cut-flower Industry—Management Plan 2002-2005, and apply to all commercial growers and harvesters from the wild. The objective of this new management plan, is to phase out wild harvesting of the genus altogether by 2005 (NSW NPWS, 2002).

*Blandfordia* is considered the ‘best bet’ for cultivation of all native flower crops (pers, com.). It has very attractive flowers with long vase life and high value to freight volume. The biggest constraints however, in establishing commercial production of *Blandfordia* are the lack of uniform planting materials, selections or cultivars that would satisfy the fundamental requirements of the industry: predictability of flowering, colour, size, number of florets in the inflorescence and vigour of the planting material. These traits however, so important to the industry have not been fully investigated to date.

### Market and marketing issues

None of the species were cultivated until 1989, when commercial cultivation for cut flowers of *Blandfordia* has commenced. This species is a relatively new cut flower crop with a very attractive focal flower, wide range of colours, an attractive shape and a long vase life. Eleven types of the flower colour (from red to yellow) and eight different shapes were identified (Johnson 1996). *Blandfordia grandiflora* is a very slow growing crop taking at least three years to produce its flowers. It has quite specific requirements for soils, water and nutrients. It is also subjected to weed infestation, and requires close husbandry. A good understanding of horticultural practices and postharvest handling is required to grow the crop successfully.

Other species in the genus also present horticultural potential, but there have not been investigated in detail so far. *B. nobilis*, for example, with petite bells has great potential as a pot plant. *B. cunninghamii* presents qualities other species do not possess. Its beautiful long gracefully drooping leaves and spectacular bells suggests this would also make a very good cut flower or a pot specimen. *B. punicea*, that is endemic to Tasmania has usually scarlet red flowers finished off with brilliant yellow wings. This species also has cut flower potential.

At present the growers from Eastern Australia (Port Macquarie area, see map) are the only world suppliers of this novel cut flower variety. It is understood however, that attempts are being made by other countries such as Zimbabwe, Israel and Japan to investigate *Blandfordia* as a commercial cut flower crop. A knowledge of the plant’s specific needs, diligence and harvesting practices will be required for successful growing.

*Blandfordia* flowers October-January (early summer, Christmas). Remembering the scarcity of flowers during the Northern hemisphere winter this product meets a ready market. The contribution of income from this genus to the Australian economy, could be substantial if the number of growers increased.

*Blandfordias* are grown and packed for market on the farm. Those destined for the domestic market are forwarded directly to agents at the metropolitan flower markets or to local retailers. Flowers destined for export must be carefully checked for quality and freedom of pests and diseases. They are graded and dipped prior to packing on the farm, and kept in cool storage until transported to the exporter. They are again checked by Australian Quarantine...
Inspection Services before being dispatched to overseas destinations. On arrival, flowers are checked again by the importers’ Quarantine Services before being auctioned and distributed to the customers.

In recent years Blandfordia has been shipped to USA and Canada as well as small quantities to Belgium, Switzerland, The Netherlands and Germany, but the main market remains Japan. The quantities being exported are much smaller than the markets could absorb. The average price in recent years has been AU$ 1.00 net return (per stem for a grower (pers. com.).

**Production requirements**

The natural habitat of *B. grandiflora* is the moist areas of coastal heathland with an annual rainfall of 1000-1600 mm, and a temperature range of 0°C-35°C.

The preferred growing medium for Blandfordia is a mixture of equal quantities of peat and coarse clean sand. The pH should be in a range of 4.0 - 5.5. For young plants the proportion of peat can be reduced to 25%. Pine bark ‘fines’ and / or composted hardwood sawdust can be used to replace the peat in the growing medium.

The amount of water required by Blandfordia plants of different ages has not been determined, but it has been suggested that the older plants require less frequent watering. A considerable need for water has been observed especially during budding and flowering. Through the summer daily watering is required. In winter plants are watered less frequently (Gollnow et al. 2003).

**Varieties/cultivars**

The need for consistent and improved cultivars of Blandfordia has been recognised, therefore a very systematic approach to selection and breeding was required to achieve the desired results. The initial micropropagated material using vegetative buds did not perform to expectations. More success has been achieved in recent attempts using floral buds for micropropagation. The Australian domestic market looks for red flowers, but in Japan yellow and orange colours are very marketable. Good selections have been made by the leading growers, and at present, there is adequate clonal material available for planting.

**Cultural practices/ agronomy**

Blandfordia can be propagated from seed, however seed propagated plants give a wide range of characteristics that are often undesirable in the cut flower production. However, to get started seeds can be used as they are easy to germinate. The seed material however, should be obtained from recognised sources. Germination usually takes three weeks, but it can be faster in warm, humid weather and much slower in winter. Seeds do not require germination pre-treatment and should be planted in a mixture of 50% peat and 50% sand with the pH adjusted to a round 5. The main dangers in the germination stage are fungal attacks, hence regulation of watering is critical. Excessive water and shade can also encourage moss growth, which can retard and choke the seedlings. Growth in the seedling stage is slow and takes 4 – 5 months for seedlings to reach a height of 5-6 cm. Complete fertiliser solution (half the normal rate at fortnightly intervals) may be used when the first true leaf appears. Plants take 2-4 years to produce flowers from germination.

For cut flower production, the preferred strategy should be vegetative propagation from the underground rhizomatous corn (with highly impressed internodes). The central growing point is located at the centre of the crown, and becomes active when flowering occurs. At the sides and around the crown of the corn lateral side buds may arise. These may produce young shoots.
that give rise to a new clone, but this method of propagation is very slow. Clumps of *Blandfordia* can be subdivided into single plants every 2-3 years giving 2-3 new plants that take about 2 years to regain the flower production stage.

It seems clear that plant tissue culture will become the essential propagation technology as the demand for new improved cultivars increases (Johnson 1998, Johnson and Burchett 1996). Micropropagation has become a useful tool enabling the rapid build up of stock of selected clones showing desired attributes. Moreover, the need for the development of new hybrids resulting in plants bred for qualities such as vigour, yield, and consistency of performance makes micropropagation a desired technology for the cultivation of the genus.

From the commercial perspective, the need for supply of not only the quantity but also the quality of propagation material is of prime importance at this stage of *Blandfordia* crop development. The development of this genus, for both domestic and overseas markets, as cut flowers, pot-plants or garden specimens, and its conservation, which will involve both *ex situ* and *in situ* cultivation, all require speedier approaches than those of conventional propagation methods alone. Vegetative meristems or flower buds can be used for micropropagation of *Blandfordia*. The appropriate media for multiplication and rooting have been selected from a very wide range of media used in the micropropagation experiments (Johnson 1994, Bunn and Dixon 1996). Long term investigations however, indicate that the flower bud material of selected hybrids or cultivars is favoured as the starting material.

*Blandfordia* has been grown commercially in 5-7 litre plastic planter bags with 3 plants per bag, but root-binding and crowding is apparent after 4 years of growth. This has not changed the frequency of flowering however, and the number of flowering stems has not decreased. An alternative is to plant into beds at density 35 x 40/m².

*Blandfordia* grow in nature in the understory of heathlands rarely exposed to full sunlight. Hence provision of shade is recommended. Thirty percent shade cloth is being used by a number of growers who have felt that 50% was too heavy, and flowers produced under it tended to be pale. Shade cloth also provides physical protection against birds and insects, and reduces wind damage.

Although *Blandfordia* grows naturally in poor soils it does much better with a suitable fertiliser regime. If plants do not receive appropriate nutrient the growth becomes retarded. A range of slow releasing fertilisers may be incorporated into the mixture. To maintain good growth, a two-part soluble fertiliser is applied regularly. This regular application of fertiliser at fairly low concentrations together with slow release fertiliser is giving excellent results. Fairly light fertiliser use has been the rule, however, the optimum nutrient regime for *Blandfordia* is still to be established. Dick (2004) has reported boron and calcium deficiencies in cultivated *Blandfordia* plants, however, the optimum doses are yet to be established.

Present applications of water by *Blandfordia* growers are based on personal judgement, rather than sound scientific studies (Dick et al., 1996). Studies on *B. grandiflora* flowering response to temperature conducted by Goodwin and Watt in 1994, concluded that it requires a chilling period of six weeks with temperatures below 10°C. It has been observed that plants flower after three years from planting, however there have been few cases observed that plants flowered after two years from planting. The number of stems/plant increases with plant maturity and later tillering. The capacity for increased stem production has a considerable significance for future commercialisation and profitability of this crop.

**Pests and diseases**

*Blandfordia grandiflora* appears to be susceptible to soil borne pathogens namely *Pythium* sp. and *Phytophthora* species (Stovold, pers. comm., 1995). Wet conditions and poor drainage must be avoided in the cultivation of *Blandfordia*. *Botrytis* flower rot has been observed in storage or shipment. It may be caused by hot humid periods, the preharvest fungicidal sprays or too low storage temperatures.

*Helicoverpa armigera* (corn earworm) *Epiphyas postvittana* (light-brown apple moth),
Pseudococcus longispinosus (long-tailed mealy bug), and thrips have been identified as the principal insect pest of Blandfordia. The mealy bug (Pseudococcus longispinosus) has proven to be the most intractable pest problem to date. Others are scale, aphids and rats which can attack corms, especially in pots and planter bags. Use of oil spray and insecticides gives good protection.

Blandfordia does not compete well with other vegetation and can be choked out especially by stoloniferous invaders. Liverworts and mosses can be harmful, especially for young plants. Recommendations as to the use of herbicides in future production are required, as well as to cultivation and use of mulches.

Harvest and handling

At present, Blandfordia flowers are harvested when one flower per cluster is splitting. The use of floral preservatives; 8-hydroxyquinoline sulphate (HQS), sucrose and silver thiosulphate does not improve the keeping quality of Blandfordia stems (Worrall & Wade, 1996). Blandfordia stems respond well to cool storage and appear not to be sensitive to ethylene. Flowers can be stored at 1°C for up to at least 30 days. At 1°C there is no bud opening at 2 weeks, however, when flowers open they are of paler colour. It is recommended that stems are stored at 4°C and the cold chain is maintained through to markets. This will assure vase life of 12 or more days (Dick, pers. com.). Progress has been made in packaging Blandfordia. To prevent the movement of the blooms within the box, five graded stems are clamped together to form self-supporting bunch. The stems are secured with rubber bands just below the florets and again, near the stem bases. Use of sleeves is recommended on each bunch to keep the florets securely together. Bubble plastic liners are used on the bottom and top of each box to insulate from temperature extremes, provide shock resistance and retain humidity in the box. For harvesting, a cold room and packing shed are requirements.

Financial information

The following points must be observed at present when exporting Blandfordia flowers:

Flower colour

From a range of eleven colours 1-11, from light yellow to dark red with various patterns of these colours on a perianth. Most are accepted for sale, as the present production comes from the seedling material. However, four basic types have been identified as most popular by the industry for export markets; yellow, orange, yellow-red and red types (Fig.3-6). When clonal material is available, flowers will be graded by variety, which, by definition, will include standardised colour combinations.

Flower stem

Must be free from natural or induced deformities, with good proportions between flower head size and stem length.

Stems for export are graded according to stem length and the number of florets per stem.

(a) Stem length:
- 30cm-100 cm long have been exported

(b) The number of florets per stem:
- 30 cm stem - minimum 3 florets
- 40 cm stem – minimum 4 florets
- 50 cm stem - minimum 5 florets
- 60 cm stem – minimum 6 florets
- 70 cm stem – minimum 7 florets

(c) Grades:
- only boxes with stems of 60 cm or more are labelled as ‘AAA’ class, or stems with more than 11 florets are labelled ‘Super’

About the author

Dr Krystyna Johnson is the editor of major text Native Australian Plants, Horticulture and Uses published by the University of NSW Press. Author and co-author of many research papers in area of plant tissue culture, conservation and horticulture of Australian plants. Her work includes species such as Blandfordia, Ceratopetalum gummiferum, Doryanthes excelsa. She is currently a Senior Lecturer and Supervisor of Honours, Masters and PhD students at UTS.
Optimal harvesting stage

- when the first bud tip is starting to split.

To get started a new grower will require:

- a suitable area of land with good water
- a system of irrigation (dripper lines are suitable for in-ground plantings, but overhead sprays may be used, especially with pots or poly bags)
- initial 50,000 plants which can be purchased from reputable nurseries
- selected clonal plants are also available.
- 50,000 (1 year - 18 months old) seedlings or de-flasked, rooted plantlets will cost around $20,000 - 25,000
- a simple shade house design will cost around $15.00/m².
- a packing house (about 40 m²) can be built for about $10,000
- Power and water need to be connected
- a cold room (about 2.4 m²) will also cost about $6,000
- tables, benches, stools and sink are also required.

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Key references


Boronia

Jonathan Lidbetter and Julie Plummer

Introduction

Boronias belong to the citrus family, Rutaceae and are known for their floral displays and scent. Like so many wildflowers boronias were originally bush picked. Today Boronia heterophylla, and to a lesser extent B. megastigma, B. serrulata, B. clavata and B. muelleri are cultivated for fresh, cut flowers. Boronia megastigma is also cultivated for the essential oils in its blossom. Boronias are very popular although often unreliable garden plants.

Boronia heterophylla can produce long stems of vibrant pink flowers. Bushes are commercially productive for three to five years. Postharvest life is adequate and there is strong export demand. The main limitations for expanding boronia production are the restricted flowering period, colour range in cultivation and susceptibility to root diseases. Boronia heterophylla is the dominant crop both domestically and for export. Unfortunately in most areas the harvest is over within a few weeks.

Some varieties of B. megastigma are cultivated but the market is much smaller as the postharvest life is short and the perfume is unattractive in Asia, making it...
unsuitable for export. Production of other species is quite limited. Until recently *B. megastigma* was the only species that had been surveyed for superior varieties.

Boronias are currently grown for cut flowers on the east and west coasts of Australia, New Zealand, California, Israel and to a lesser extent in South Africa and Europe with trials commencing in South America. They are susceptible to root rots and rust and require good site selection and careful management.

**Markets and marketing issues**

Fresh cut flowering stems of *Boronia heterophylla* have been exported to Japan for over 15 years and markets are growing in Singapore, Hong Kong, Taiwan, Europe and Canada. An import ban on Rutaceous species prevents boronia from entering the United States of America. An import ban on Rutaceous species prevents boronia from entering the United States of America. A range of flower colours and flowering periods exist but only a few species have been commercially exploited.

Field planting of Boronia 'Lipstick' in southern NSW

in 2002 and 2003 for the Western Australian industry. Drought impacted heavily on eastern states growers in 2003 with a number of growers running out of water and facing severe plant losses.

The industry is centred in southern Western Australia, Victoria and southern New South Wales. Western Australian production for 2003 is estimated in the order of 150,000 stems and production from the eastern states approximately 100,000 stems, with more than 20% sold on the domestic market. Western Australian sales are dramatically down from an apparent peak of 408,000 stems in 1999 (AQIS export figures) and eastern states production has steadily grown from less than half the current figure in the corresponding period. Growers and exporters alike have suggested 2003 production was a significant drop on previous years.

**Production requirements**

Boronias require a period of cool conditions (winter nights less than 10°C) to initiate flowers. Warm conditions can lead to the failure of flower development or flower abortion at certain stages of flower development. Inadequate chilling is often seen as vegetative growth at the tips of stems and this reduces stem value. Boronias have been successfully cultivated across a range of latitudes from the hot dry conditions of Coorow, WA (30°S) to the cool temperate conditions of Tasmania (42°S) and even the South Island of New Zealand. Many species are frost tolerant but areas with regular moderate to severe frosts should be avoided. Strong winds will damage shoots and weaken roots and so windy sites should be avoided or wind breaks constructed or planted.

Although some boronias naturally grow in wet areas, in cultivation they prefer well-drained, slightly acidic soils. Soils with a very high residual phosphorus level should be avoided. Sites should be tested for the presence of *Phytophthora* and nematodes. Three *Phytophthora* species; *P. cinnamomi*, *P. cryptogea* and *P. dreschleri*, were regularly identified in association with severe plant losses in plantings of *B. heterophylla* and related hybrids, with *P. cryptogea* the most regularly isolated species. Greenhouse assays have confirmed the pathogenicity of all three species. Also avoid sites with root attacking nematodes, such as *Meloidogyne* or *Pratylenchus*, or treat the area with a suitable soil fumigant or nematocide.

**Varieties/ cultivars**

The genus *Boronia* (Rutaceae) is represented throughout Australia and species are found in a wide range of soil and climatic conditions. A range of flower colours and flowering periods exist but only a few species have been commercially exploited.
Consult with your exporters, local nurserymen and experienced growers to determine the best varieties for your area.

*Boronia heterophylla* is an upright shrub 2–3 m tall from Western Australia. It bears a profusion of vibrant, pink, bell-shaped flowers about 1 cm long which provide a spectacular floral display. This species is the most widely grown for cut flowers. The flowering period for individual plants is usually less than two weeks in late August/early October and flowers fade if left on the bush. Older flower colour selections have been registered including, ‘Moonglow’ (white), ‘Cameo’ (pale pink), and ‘Lipstick’ (mid-pink) and ‘Morandy Candy’ (deep pink), which may be hybrids. New selections continue to become available with several released over the last few years including Stella\(^6\), Cascade\(^6\) and Purple Rain\(^6\). These varieties offer a greater range of colour and flowering time. A breeding program examining a wider genetic base within the genus *Boronia* is in progress and has already resulted in promising new hybrid varieties including the *B. heterophylla* x *B. megastigma* hybrid Purple Jared\(^6\).

*Boronia heterophylla* is fast growing and responds well to pruning. It can withstand moderate to heavy frosts. Plants prefer dappled shade or partial sun but will grow well in full sun if roots are kept moist and cool. Plants are also susceptible to stem twisting or breakage in strong winds and need protection.

*Boronia megastigma* is an upright, dense shrub 1–3 m tall. It is found in wet or seasonally wet sites in Western Australia. Individual plants flower from late July to October. The bell-like flowers are usually dark to reddish brown on the outside and yellow on the inside and are not showy. Flowers are very fragrant. *Boronia megastigma* used to be extensively grown as a cut flower in Victoria but rust (*Puccinia boroniae*) wiped out the industry. Selections, based on morphological characters desirable for cut flowers, include forms where the outside of the petals are red, such as ‘John Maguire’s Red’, ‘Arch Chandler’s Red’ and its sport ‘Harlequin’ which has vertical reddish-brown and yellow stripes, and ‘Lutea’ a yellow-green form. Unfortunately these selections have poor vase-life and do not transport well. The perfume, which is the main attraction in Australia, is less desirable in Asia. Much variation exists in flowering time, flower colour, fragrance, oil content and growth habit.
Boronia muelleri is from the southern coast of New South Wales and Victoria. Flowers are 1.5 cm across and vary from white to pale pink. Flowers are borne on terminal clusters from August to November. At present production is limited.

Boronia purdieana is a small shrub from the coastal sandplain north of Perth and it probably requires well-drained soils and will grow in hotter/drier areas than B. heterophylla. It bears a profusion of perfumed, greenish-yellow flowers from July to August. This early flowering species has short stems (30–40 cm) but it is sought after as a cut flower. Cultivation is still limited by cutting propagation difficulties although grafting is an option. Low yields may also limit the transition of this crop from wild harvested to cultivated crop.

Boronia pinnata is a small shrub from New South Wales. It bears pink clusters of flowers from August to November and is in demand from florists. It has 5–8 days of vase life.

Boronia serrulata is a small shrub 1.5 m tall from New South Wales which produces abundant rose pink flowers. Individual plants produce flowers for 4–8 weeks but flowering in natural habitats occurs from late July to November. A short vegetative flush occurs from December to January and this can be extended in cultivation with irrigation. Plants produce cut flower stems up to 40 cm in length.

Cultural practices/agronomy

For cut flower production, boronia should be propagated vegetatively. Clonal propagation will provide uniformity in flower quality, stem length and harvest date. Propagation is primarily by cuttings, but grafting is opening up opportunities for difficult to strike varieties and in areas where plant losses to root diseases are unacceptably high. For cuttings, choose a reputable nursery and allow at least four months between ordering and delivery. Grafted plants may take a little longer. Tip cuttings are most successful when taken from new shoots in summer and autumn. High concentrations of auxins, basal heat and misting improve rooting. Losses through damping off can be reduced with good hygiene and by avoiding root damage. Grafting may be done at any time of year under the right conditions depending on the availability of suitable rootstocks or the ability of cutting grafts to strike roots.

The ground should be prepared and weeds controlled before planting. Good planning at this stage is critical. Remove any large tree roots and cross rip. Remove soil from machinery before use to reduce the risk of introducing Phytophthora to the site. Plants should be ready to plant in winter to capitalise on the growth flush over spring/summer. Plants should be disease free, 10 cm high with well formed roots. Ensure plants are not root bound. Remove plants carefully and do not disturb the roots when planting.

Planting design will depend on your irrigation system, management practices and the species selected. Blocks of single or double rows of plants with roads for machinery access between blocks are the most common designs. Plants in single rows are 1.5 m apart with 0.7 m between plants with a spray row where required. Double rows with 1–4 m centres have 0.7 m between plants down the row and 0.5–1 m across the row. Rows are aligned north to south. In Western Australia the usual planting density of B. heterophylla is 7,000–10,000 plants/ha, whereas in Tasmania, densities of up to 19,500 plants/ha are used for B. megastigma.

Irrigation or reliable rainfall throughout the year is essential for successful production. Boronias are shallow rooted and B. heterophylla, for example, produces a mat of roots in the top 30 cm of soil. The soil therefore needs to be kept moist. Roots are susceptible to root rot and collar rot fungi and so should be grown in free...
draining and not waterlogged soils. Mature boronia plants require 2–10 litres of water/day depending on conditions. Micro-irrigation supplied several times a day is preferable in very sandy soils but a full root zone soaking every couple of days is more appropriate for heavier soils.

Mulching is highly recommended due to its beneficial effects on water use, soil temperature, and disease and weed control. Artificial mulches include plastic mulch, weed mat and organic mulches such as wood chips or straw. Organic mulches can substantially reduce water loss from evaporation. They also keep the roots cool which reduces plant losses from water stress and slows the growth of root rots. Composted straw and other organic mulches give some control of diseases, such as Phytophthora, by encouraging organisms antagonistic to these pathogens. Organic mulches however may run the risk of introducing weeds especially if of poor quality. In California plastic has been used with a covering of straw to obtain the benefits of each type of mulch.

Mulching generally gives good weed control. This is particularly important in boronia as root disturbance often leads to plant death. Grasses can be controlled with selective herbicides. Broad-leaved weeds are more difficult but may be controlled with a hooded wand using a non-selective herbicide. There are no selective broadleaved weed herbicides registered for use on boronias.

Boronias require fertiliser application, especially nitrogen. For spring flowering species, vegetative growth occurs from mid-spring to autumn with a peak over summer. Stem length is critical for profitable cut flower growing and fertilising during the growth phase is essential. However late application of fertiliser, particularly nitrogen, can reduce flowering especially of shoot tips, and should be avoided. Fertiliser can be applied as a solid or in liquid form through fertigation. Greater control of fertiliser application is possible with fertigation and split applications are recommended for solid fertiliser to avoid plant death or nutrient loss through leaching by heavy rain. The NPK requirement will vary depending on soil type but applications of N:P:K::90:10:130 kg/ha/year have been used for B. heterophylla in Western Australia and N:P:K::50:79:100 kg/ha/year for B. megastigma in Tasmania. Trace elements should be applied in areas deficient in micronutrients. Plants should be analysed to determine any nutrient deficiencies.

**Pests and disease control**

A number of pests attack cultivated boronias including nematodes, black beetle, stem borers, grasshoppers, Rutherglen bug, scale and psyllids. Mealybugs and two-spotted mite are pests primarily of boronias grown under cover. Nematodes and black beetle are best controlled by a pre-plant pesticide application. Other insect control measures should be applied when required. Even insects which do not cause damage to flowers are a major problem in export shipments and will lead to rejection in most importing countries. Therefore field control of insects is essential. Depending on export requirements, cut flowers may still have to be treated for pests and diseases with disinfection fumigations or dips. Consult your exporter.

Boronias are susceptible to root diseases, especially Phytophthora and Pythium. Boronia often suddenly die and this is probably due to infection from these pathogens after wounding from insects, wind damage or water stress. Phosphorous acid and other fungicides can be used to help control both Phytophthora and Pythium but will rarely eliminate the disease. Rust (Puccinia boroniae) causes brown pustular growths on boronia and may cause leaf drop. Contact your local horticulturist for suitable methods of control. Boronias are also susceptible to Botrytis and require fortnightly treatment from
bud initiation to harvest, especially during wet conditions with a fungicide rotation to prevent fungicide resistance developing.

**Harvest, handling and postharvest treatments**

Vegetatively propagated *B. heterophylla* will flower within 15 months of planting but because the plants are small, this initial harvest will only yield 8–12 stems/plant. By the second year 20–30 stems can be harvested, then 30–60 stems annually. Commercial plant life is usually 5–6 years on sandy soils but even with the best management an annual loss rate of 5% is not uncommon.

Commercial plant life for cut grown plants is heavily reduced and loss rates increased on heavier soils and in warmer climates.

Grafted plants have yet to be commercially tested but greenhouse tests have proven the benefits of *Phytophthora* tolerance in extending plant life.

Immature floral buds do not open after harvest and so stems are harvested when most flowers are at least partially open. Practices vary, but most boronias are pruned to a height of 23–35 cm at harvest with some horizontal laterals left intact. One-year-old plants can be pruned harder. The main concern is to leave enough vegetative material to reduce the root system ‘shock’, minimising the risk of disease development and providing an adequate base for the future year’s stem production.

Cut stems should have abundant flowers for most of their length. At least 50% of flowers need to be open at harvest. Clean straight stems of *B. heterophylla* 60–70 cm, with 50–70% of blooms open and no wilting are regarded as first grade cut flowers by the Flower Export Council of Australia. Second grade stems are less than 60 cm but should have a minimum length of 50 cm, 50–70% of flowers open, no wilting and clean stems with no more than 5% curve. A premium is paid for >80 cm stems. Stems are bunched in fives or tens for Japan, while most other markets require the product to be sold by weight.

Without treatment, vase life is short. Standard postharvest care, including placement in clean water, removing field heat as soon as possible and storage at 1–5°C, greatly improves quality and longevity. Delays in cooling greatly reduce flower quality. Pulsing with a biocide, such as 8-hydroxyquinoline citrate (HQC, 800 mg/L) overnight (8 hours) increases vase life.

Flowers are usually provided bunched to the exporter, who handles packaging and consignment to domestic and export markets. Check requirements for handling with your exporter.
Financial information

Establishment costs although significant are a minor cost of total production costs with picking, grading, packaging and disinfestation the major on-farm costs. Returns to growers are dependent on stem length, branching and flower number, stem straightness; uniformity of stems within bunches and postharvest handling including pulsing, cool storage, disinfestation treatment and packaging. Choice of packaging and presentation can have a major influence on both market price and return to grower.

Growers in the eastern states usually disinfect and pack their own product before delivery to the exporter ready for sale. In the west, exporters may pay for the domestic transport of bulk packed material which they disinfect and pack in their cartons.

Timing of your crop will greatly affect your returns as the price varies significantly. For example New South Wales and Victorian 'Red' *B. heterophylla* is usually harvested well before Western Australian product, and the variety 'Lipstick' is generally earlier still. Product which appears on the market earlier usually obtains a better price. Grower returns depend on many factors beyond supply and demand including quality, presentation, freight availability and the exchange rate. Who bears the responsibility for risk will also affect prices. This includes quality claims against the product and quarantine claims. Whether this is the grower’s or the exporter’s risk will depend on the agreement you have with your exporter and will affect potential return and associated risk. A summary of prices paid by exporters to growers is presented for 2003.

### Table 1. Range of average returns to grower per stem of boronia from exporters produced on the east and west coasts of Australia in 2003*

<table>
<thead>
<tr>
<th>Product</th>
<th>East Coast§</th>
<th>West Coast§</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>B. heterophylla</em> 'Red'</td>
<td>21-34c</td>
<td>NA</td>
</tr>
<tr>
<td>50cm</td>
<td>21-34c</td>
<td>NA</td>
</tr>
<tr>
<td></td>
<td>($2.00-2.20/ 400g bunch)</td>
<td></td>
</tr>
<tr>
<td>60cm</td>
<td>30-63c</td>
<td>30-38c</td>
</tr>
<tr>
<td>70cm</td>
<td>38-85c</td>
<td>38c</td>
</tr>
<tr>
<td>80cm</td>
<td>57-90c</td>
<td>50-80c</td>
</tr>
<tr>
<td>100cm</td>
<td>60c-$1.00</td>
<td>NA</td>
</tr>
<tr>
<td>'Lipstick'</td>
<td>≤10% discount</td>
<td>≤10% discount</td>
</tr>
<tr>
<td>'Purple JaredA'</td>
<td>≤10% premium</td>
<td>≤10% premium</td>
</tr>
<tr>
<td>'Moonglow'</td>
<td>≥10% premium</td>
<td>≥10% premium</td>
</tr>
</tbody>
</table>

* Returns to growers vary depending on date of harvest, quality, postharvest treatment, packaging and domestic and export freight charges. These values were kindly supplied by a number of exporters from WA, NSW and Victoria.

§ Discounts and premiums quoted are in relation to *B. heterophylla* 'Red' prices for corresponding lengths.

### Key references


Growing Boronia Agriculture WA Farmnote No. 47/96 (Agdex 282/220).


About the authors

Jonathan Lidbetter is a Research Horticulturist for NSW Agriculture. He has investigated the role of Phytophthora spp. in sudden death of Boronia and the development of grafting combinations to overcome this problem.

Dr Julie Plummer is a Senior Lecturer in Plant Sciences at the University of Western Australia. She has selected boronias which are currently being tried out and is breeding boronias using a range of species.

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Collina Exports
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IHM Australia
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Longford Flowers
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Muchea Gold
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Sunglow Flowers
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The Australian Flower Company
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Total Flower Exports
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Floratrade
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Fax: (03) 9338 4455

Key statistics

• Virtually all Boronia heterophylla in Australia are currently harvested in a few short weeks

• Most production of cut flowers occurs in Western Australia, Victoria and New South Wales

• Most Boronia grown for essential oils are grown in Tasmania and Western Australia

Key messages

• Choose your site and varieties carefully

• Talk with your wholesaler/exporter

• Know the demand for your product before you plant

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Eucalypts

for cut bud, flower and foliage production

Introduction

Eucalypts are cultivated for cut stems with foliage, buds, flowers or gumnuts, but the various products require different species and management. Eucalypt foliage has been cultivated for many years in southern France, Italy, the USA and more recently in Australia. The market is based upon the attractive juvenile growth of species with crowded, round or oval waxy leaves which have a silvery sheen. Once the tree attains the adult state, the foliage assumes the green, elongated leaf form and its value for foliage stems is decreased. Hence the trees must be heavily pruned to maintain juvenile growth. In contrast, mature material is required for flowering stems, and the priority is attractive buds, flowers or gumnuts which contrast with the foliage.

Precocious species with these attributes have formed the basis of a more lucrative cut floral stem trade.

With over 500 species the Eucalyptus genus has wide adaptation to temperate, subtropical and tropical climates. Eucalypts are tolerant of most soil types and have a range of uses. In addition to cut flowers and foliage, they are used for amenity horticulture, revegetation, timber, pulpwood, fuelwood, shelter belts, soil amelioration, honey production, salinity alleviation and water table lowering.

The main constraint to industry development is lack of cohesion in the cut flower and foliage industry, and reluctance to communicate and cooperate. A further constraint is the lack of superior cultivars in Australia, which results in low uniformity in yield and
quality of product. Export of fresh cut flowers and foliage is the area with most potential for expansion.

The most important personal skill requirement for the eucalypt flower and foliage industry is recognition of the intensive nature of production. Plant care is essential for quality production and hence for success.

Markets and marketing issues

Stems are sold on both domestic and export markets. High quality and long stem length are important for the export market, and Australian exporters generally deal direct with overseas importers.

Stems are packed into florist size boxes for direct sales as well as through the auction system.

Key statistics

- Total Australian flower exports were over 5,000 tonne in 1999/2000 (Fresh 4,000 t, dried 1,000 t).
- Destinations in 1999/2000 were Japan 2,000 t, USA 1,000 t, Netherlands 500 t, Canada and Germany <100 t.

Key messages

- Export potential to Asia, Europe and USA
- The Japanese market is undersupplied
- Wide climate and soil tolerance
- Peak industry body is Wildflowers Australia (formerly AFPGA)
- Supply northern hemisphere off season

Niche markets for Australian product have been identified in Asia, Europe, USA and Canada. Both buds and foliage are handled through these channels.

The best period for sending product to Japan is from October to April when supply from northern hemisphere countries is in short supply.

Common names have been developed for some of the species to aid in market identification.

Production requirements

Current production is mainly in coastal areas (see map). Most species require a minimum of 200 mm rainfall per year, and many growers supply drip irrigation to ensure reliable production levels.

Regular watering is especially important during spring and summer in regions with a Mediterranean climate.

Soil type, salinity and pH tolerance vary widely across the genus, with species adapted to most areas across Australia.

Eucalypt buds and flowers fit into three main categories: filler bud, feature bud/flower and focal bud/flower. Filler buds have small, brightly coloured buds and are used as a background to accentuate the focal flowers. Generally, production is high per tree but the product has low value. Feature bud/flower species have medium sized, coloured buds and flowers and are used as a focus of an arrangement. They produce a reasonable number of stems per

Varieties

As yet, there are no superior eucalypt varieties for flower or foliage production available in Australia. A breeding programme for ornamental eucalypts has been underway at the University of Adelaide since 1989, and many superior selections are currently under evaluation (Sedgley and Delaporte 2003).

The main species grown for foliage production are *E. gunnii*, *E. pulverulenta* and *E. cinerea*. Many others have potential for foliage production including *E. albida*, *E. bridgesiana*, *E. cordata*, *E. crenulata*, *E. crucis*, *E. gillii*, *E. globulus*, *E. kruseana*, *E. perriniana* and *E. tetragona*.

Eucalypt buds and flowers fit into three main categories: filler bud, feature bud/flower and focal bud/flower. Filler buds have small, brightly coloured buds and are used as a background to accentuate the focal flowers. Generally, production is high per tree but the product has low value. Feature bud/flower species have medium sized, coloured buds and flowers and are used as a focus of an arrangement. They produce a reasonable number of stems per

E. macrocarpa buds, flowers and foliage. (Photo: University of Adelaide)
tree, and can be sold in a bunch or as single stems, with a higher value than that of filler buds. Focal buds and flowers are large and dramatic, and are the central focus of the arrangement. The number of stems per tree is low, but each stem achieves a high price.

Filler bud species include *E. leptophylla*, *E. fraseri/E. lesuefii*, *E. gillii*, *E. hypoclamydea*, *E. transcontinentalis*, *E. uncinata*, *E. yalatensis*, *E. pterocarpa*, *E. crucis*, *E. georgei* and *E. torquata*. Feature bud/flower species include *E. caesia*, *E. erythrocorys*, *E. forrestiana*, *E. stoatei*, *E. tetragona* and some larger forms of *E. pterocarpa* and *E. torquata*. Focal bud/flower species include *E. pyriformis*, *E. macrocarpa* and *E. youngiana*, and larger forms of *E. caesia* and *E. erythrocorys*

Other attractive species with potential include the filler bud species *E. aniceps*, feature bud/flower species *E. conveniens*, *E. ficifolia*, *E. miniata*, *E. pachypylla*, *E. phoenicea*, *E. preissiana*, *E. globulus* and *E. preissiana*, and the focal bud/flower species *E. ptycocarpa* and some larger forms of *E. ficifolia*, *E. miniata*, *E. pachypylla*, *E. phoenicea* and *E. preissiana*.

The most popular eucalypt currently grown is *E. tetragona*, which can be sold as foliage or with capsules (nuts). Prices remain consistent during the season, an indication of a good balance between supply and demand. Production time varies with climate. The Australian cut flower best bets program places eucalypt buds (reds, yellows, gold), and *E. tetragona* in the top 12 best crops (Slater and Carson 2003).

**Agronomy**

Plantings are established using seedling material, although vegetative propagation via rooted cuttings and grafting is possible for some species. Seedlings are planted out when they are 30 cm high. Planting is done in spring or autumn, and the land should be deep ripped to 30 - 50 cm a few months before planting when the soil is moist and friable. Plant spacing is dependant on machinery, topography, climate, species and end use, with spacing ranging from 1.5 to 5 m within rows, and 1.5 to 10 m between rows. The currently recommended spacing for bud and flower species is 5 m x 10 m. Wide spacing avoids reduction of flower initiation for floral stems, whereas 30 cm within row spacings are sometimes used for intensive foliage production. Some growers use mounded beds to increase aeration of the root zone, drainage and salt leaching, or contour banks to avoid erosion on slopes. Weed mat can be used, and black plastic also increases root zone temperature. Tree guards are advisable in areas where rabbits are a problem. Dolomite or lime improves establishment in acid soils, and sulphur serves the same purpose in alkaline soils.

Fertiliser is often applied via the irrigation system, although top dressing is advisable on sandy soils to avoid leaching. In frost prone areas, nitrogen should be avoided after mid summer, as the new growth may burn before it hardens off. Eucalypts benefit from regular applications of complete fertiliser, including trace elements, and this can be applied via organic or inorganic preparations. Nutrient deficiencies are common if harvesting is regular and fertiliser application is inadequate, and common symptoms include chlorosis, leaf spot and purpling.

Pruning is essential for optimum production, but differs depending on the end use of the crop. For foliage production the tree must be heavily pruned to maintain juvenile leaves and encourage long stem length. At 18 months of age, the main stem is pruned to one metre and major lateral branches
are removed flush with the trunk. Stems for harvest derive from buds under the bark of the trunk or of the basal swelling or lignotuber. In temperate climates, pruning in late winter stimulates stems for harvest in late summer, and trees are pruned annually. More flexibility is possible in frost free and tropical climates, where irrigation can be used to control production and vary harvest time. High foliage yields are produced by *E. globulus* and *E. bridgesiana*. Average yields for most species are ten bunches per tree, of 10 -12 stems 65 - 70 cm in length, at three years of age.

For bud, flower or gumnut production, the plant must attain the adult state, so pruning is less severe. The tree should be pruned prior to one year old to stimulate branching and create maximum shoots for flower initiation. At harvest, some leaves should be left below the cut to provide further branches for flower production.

Response to pruning varies with species and type of tree (mallee/multi-trunk or single trunk). Tips of new seedlings should be picked out to encourage branching once the tree is about one metre tall. Mallee types may not require any tip pruning as they are naturally bushy. Some species must attain a certain height and maturity before flowering (eg *E. pterocarpa*), so tipping should be done with care, with leaders that are 30 cm long left to grow. As the trees get older, low growing and/or diseased branches should be removed regularly, as well as any diseased or poor performing trees. Mallee types respond well to hard pruning (to one metre), producing numerous long stems that flower two years after pruning. Tall, bud-producing species should be pruned after harvest, by one third of their height, for yearly stem production. Hard pruning will produce better quality product, however there is a two year delay to flowering.

**Pest and disease control**

Many insect pests attack eucalypts, including sawfly larvae (*Perga*), leaf miners (*Perthida, Phylacteophaga*), sucking insects (*Creiis, Eriococcus, Cercopidae*) borers (*Cerambycidae, Phoracantha*), gall forming insects (*Apiomorphinae, Strongylorrhinus*), mites, caterpillars (*Uraba, Mnesampela, Doratifera, Oenochroma*), beetles (*Catasarcs, Liparcterus, Chrysomelidae, Paropsis*) and grasshoppers. The leaf-eating beetle *Paropsis* can defoliate plants within a short space of time. Pests can be controlled with a range of standard insecticides. The most devastating disease of eucalypts is *Phytophthora cinnamomi*, which causes root rot. Care must be taken to avoid introduction of the disease, as eradication is impossible. If a property is infected, then tolerant species should be grown, such as *E. cinerea, E. cordata, E. crenulata*, *E. globulus*, *E. gunnii, E. perriniana* and *E. pulverulenta*. *Phytophthora* sensitive species, such as *E. caesia, E. crucis, E. erythrocorys, E. forrestiana, E. kruseana* and *E. tetragona* should be avoided.

Leaf spot and shoot blight fungi can cause problems in eucalypt plantings, particularly in humid climates. Fungi involved include *Phoma, Microsphaeropsis, Mycosphaerella, Colletotrichum, Botrytis, Stemphylium* and *Alternaria*. They can be controlled using standard fungicides.

Careful consideration of plantation layout and good hygiene practices

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**About the authors**

Margaret Sedgley is Professor of Horticultural Science at the University of Adelaide, Discipline of Wine and Horticulture. She has worked on improvement of native plants for ornamental horticulture for over 20 years. Margaret leads the ornamental eucalypt breeding programme at the University of Adelaide, which commenced in 1989 and is funded by RIRDC and industry.

After working in the cut flower industry for several years, Kate Delaporte completed a Bachelor of Agricultural Science, Horticulture Major, with First Class Honours for a thesis entitled “Banksia Improvement – Genotype Identification and Postharvest Vase Life” at the University of Adelaide (UA) 1992-1995. In 2000, Kate achieved a PhD degree at UA, supported by the Playford Memorial Trust, studying the development of ornamental eucalypts with the thesis “Eucalypts for Ornamental Horticulture: Selection, Interspecific Hybridisation and Postharvest Testing”. She now works as a postdoctoral fellow at UA, with Professor Margaret Sedgley, funded by RIRDC and industry, to further develop ornamental eucalypts.
will reduce the need for excessive pesticide applications. There are no chemicals registered for eucalypt cut stem production.

**Harvest, handling, packaging, storage, post-harvest treatments and processing**

Foliage stems should be harvested into water during the coolest part of the day, and the stems recut under water. The leaves are carefully stripped from the basal 15 cm of the stem. Stems may be dipped into anti-transpirants to reduce water loss. Holding solutions of 2% sucrose with germicide are beneficial in extending vase life, but pulsing has no effect. Stems have a vase life of two weeks when kept in holding solution, or one week following dry transport. Stems should be dry before packing, and box liners are often used.

_Eucalyptus_ foliage is sometimes preserved using glycerine. This gives an attractive sheen combined with supple texture. One part of glycerine is mixed with two parts of water, and stems will take up the mixture over a period of up to a week, or they can be immersed in a more concentrated solution. Dyes can be used to colour the foliage. The stems are then hung to dry.

Stems with buds, flowers and nuts vary in their postharvest requirements. Small bud species can be picked straight into water, whilst larger bud species benefit from short periods of cool dry storage. Different species also vary in their response to sucrose and glucose: generally low levels of sucrose result in faster flower opening, higher levels may result in detrimental bud and leaf blackening. Cold storage (2°C) is beneficial for all types.

Stems for export must be free of pests, and stems with gumnuts are generally sold on the domestic market as seed predators are difficult to eradicate.

**Financial information**

Economic analyses for new crops should be treated with caution, especially as so many eucalypt growers produce other crops as well.

Upfront expenses per ha for a eucalypt foliage farm are estimated at $1,800 for plants, $1,500 irrigation, $1,500 weedmat, $750 soil preparation, $2,250 labour, and $150 contingencies (Carson, 2000). Approximate annual expenses include fertiliser $400, chemicals and spraying $450, harvesting and packing $7,500, packaging $3,000, freight $1,250, pruning $650 and contingencies $300. Gross return at Year 5 is $16,000 (Carson, 2000). Based on noted annual expenses, this equates to a net return of $2,450 per ha.

Upfront expenses per ha for a eucalypt bud or flower farm are estimated at $480 for plants, $400 irrigation, $600 weedmat and guards, $250 soil preparation, $600 labour, and $150 contingencies (Carson, 2000). Approximate annual expenses include fertiliser $100, chemicals and spraying $120, harvesting and packing $2,300, packaging $1,600, freight $500, pruning $700 and contingencies $300. Gross return at Year 5 is $15,440 (Carson 2000). Based on above mentioned annual expenses, this equates to a net return of $9,820 per ha.

**Key references**


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Introduction

Flannel flower (*Actinotus helianthi*) is a cut flower crop whose potential is beginning to be realised. The Australian Best Bets Program (Slater and Carson 2003) assessed it as a clear leader from 77 other cut flower crops studied in terms market potential and economic return. Until recently the majority of flannel flowers sold as cut flowers were bush-harvested. However the percentage of the total bush picked is falling rapidly with greater restrictions being placed on their harvest and declining natural populations. Cultivated product is also more reliable in terms of quality and supply. In addition there are a number of short stemmed, bushy flannel flower selections that have considerable potential for the pot plant or bedding market.

Considerable progress has been made in recent years in the production of flannel flower, both as a field crop and in protected cultivation. This is due to a greater understanding of its cultural requirements and its interaction with root diseases combined with the introduction of new, high yielding varieties, especially one that flowers continuously. High yields and better quality flowers have made the production of...
flannel flower under protected cultivation economically viable. Both horticultural (growing, harvesting and packaging) and marketing skills are very important in the successful culture of flannel flower. There have been a number of significant failures where the importance of these skills was not appreciated. Currently, flannel flowers are mainly produced commercially in coastal New South Wales, the region of origin. The main constraints to production appear to be varietal availability, root diseases, and lack of knowledge of nutritional requirements and postharvest treatments.

Markets and marketing issues

Flannel flower is in demand as a cut flower, both on the domestic market and overseas, especially in Japan where the highest returns have been obtained. Other Asian markets have shown interest as well as Europe, Canada and the west coast of the USA. The season for both bush picked and field production in New South Wales is August to February with the greatest yield and highest returns in October. Previously bush harvesting produced about 1 to 2 million stems per year (of variable quality), depending on seasonal conditions, and as a consequence presented a threat to cultivated material by reducing the ‘base’ price. In 1996, less than 2% of the flowers produced were cultivated. However bush picking has recently been curtailed both by increasing legal restrictions and declining natural populations. In 2002 over 0.5 million stems were produced in field cultivation.

Production in protected (green house) cultivation is also increasing rapidly. In early 2004 about 0.25 million stems pa were being produced in protected cultivation, by 2005 it is anticipated that over 1 million pa will be produced. The flowers produced in protected cultivation have the added advantages of out of season production and high quality-commanding a premium price for most of the year.

Best sale prices (per stem) have been achieved by long-stemmed flannel flowers (> 80 cm) with some prices as high as $A2.70/stem- although the average is much lower. However, test shipments have demonstrated that good export prices can be obtained for material as short as 20 cm. The return to the grower per box was actually much higher than longer material due to the greater number of flowers in the box. The average return to the grower in 2003 was between $0.01 and $0.02 per cm of stem (ie $0.50 and $1.0 for a 50 cm stem)- varying with the time of year and flower quality. Prices on the domestic market are $A3.50–7.00/bunch (of 10) depending on stem length and time of year. The quantity of flowers sold on the domestic market is not known as many are sold directly to florists. However with year round availability sales are expected to increase. There is also much less risk in marketing the flowers locally.

Although bush harvesting is decreasing it is still a threat to the development of flannel flower markets. Most of the bush-harvested flowers are exported, the perception of them is poor and makes high prices for quality product difficult to achieve. This, and the export markets expectation of quality, are good reasons to develop economical systems for cultivation of this species.
Flowers may be directly exported by larger growers, through grower groups or through agents. In Japan, flowers may be sold at auction or directly by arrangement through importing agents. Remember different markets may have different preferences so do your home work.

Production requirements

Flannel flowers (*A. helianthi*) grow naturally on sandstone areas along the NSW coast from Tura Beach in the south to south-eastern Queensland in the north. The species also occurs in isolated pockets inland. The climate in these regions varies considerably from high rainfall on the coast to low precipitation further inland. The number and severity of frosts also varies across these areas, and the humidity ranges from high to low. The species is not uniform across this area. For example inland types are more resistant to frosts. However even coastal types will withstand 0°C under protected cultivation i.e. heating is usually not necessary.

Flannel flowers require a very well-drained, slightly acid growing medium, whether using amended natural soils or artificial medium.

Use of artificial media means that the crop can be grown in areas with unsuitable native soils. Despite having a reputation as being sensitive to fertilisers, especially those containing phosphorous, in practice they have a high fertiliser requirement, especially when grown in artificial media. Use of fertigation to supply nutrients on a regular basis has been very successful in commercial practice. Trickle or microject irrigation is preferred. The foliage should be kept as dry as possible. In most cases irrigation will also be required for field grown material. Although plants will grow in the full sun, better quality flowers and longer stems will be achieved with light shade, which can also provide wind protection.

Proximity to appropriate transport and cool storage facilities is also essential for production of a premium product.

Varieties

Selection of suitable seed lines or clonal material is extremely important to the success of the venture. Prospective growers must ensure that the source of their stock material is suitable for cut flower production, i.e. long stemmed forms. Currently most material available is grown from selected seed forms. However a number of nurseries are beginning to vegetatively produce flannel...
Flannel flower

Actinotus helianthi flowers vary between 3 and 14 cm in diameter (Photo: Royal Botanic Gardens)

Flannel flowers by cuttings and tissue culture. Mt Annan Botanic Gardens has produced a number of varieties suitable for cut flower production that are multiplied by tissue culture eg ‘Starbright’. As yet it is not clear which method of propagation will produce the greater economic returns although currently all methods appear to give reasonable returns. However seed germination of flannel flowers is notoriously unreliable and they produce the most variable plants. Further work is required to improve the reliability of germination.

Currently year round production of flannel flowers largely relies on one selected seed line. Although all seedlings of this selection flower continuously there is considerable variation between plants with some producing flowers too short to be economically viable. Growers intend replacing the seedlings with selected clones propagated by cutting for this reason.

It is clear that there is a need for new varieties that have better flowers and yields, out of season production and resistance to root diseases. Although the colour is currently limited to white or cream, pink occurs in a closely related species and may be added as the result of future breeding programs.

Cultural practices/agronomy

Field cultivation. Cultivation site preparation is similar to other Australian native plants; that is, soil is cultivated and generally raised into beds 1 m wide and 20–30 cm high. Weed matting and mulching with wood chip or straw can control weeds and maintain soil moisture. Irrigation should be drip or trickle and is necessary in most areas, particularly during dry and/or hot periods. Flannel flowers are best planted out into the field while still small, approximately 3–5 cm high. Root systems are easily damaged and so avoid unnecessary disturbance at all stages including planting out. Planting in spring or autumn is best for active growth, although summer planting may be satisfactory if the plants are irrigated. For maximum production per unit area, plants should be planted in two rows with 30 cm between rows and plants. This spacing also provides maximum interplant support against wind, which may easily blow over this shallow rooted species. Flannel flowers are considered a short-lived perennial and should be treated as a biennial. Under some circumstances, flannel flowers may be productive into their third and fourth years, but rarely beyond.

While still young, the growing shoot of flannel flowers should be pinched out to encourage low branching in the plant and thus increase flower yield. This pinching (or pruning in older plants) should be carried out in autumn, but it should be noted that if this operation is carried out too late then stem length will be reduced in the following spring.

Protected cultivation. Plants are currently grown in containers of 4-10 litre capacity and generally raised off the ground onto benches for disease control. It is important that the growing medium be very well aerated. Media, mostly composed of pine bark less than 12 mm with added coarse sand, lime and other fertilisers, i.e. one that is usually used in potting mixes seems to be satisfactory. The growing structure should be very well ventilated. Plastic appears to be a satisfactory cover. Since, with the clones used, plants flower year round they can be planted at most times of the year, except during very hot periods. Plants are usually spaced at 10 per m² in rows of four to allow sufficient space for walkways. String or stakes may be required to support plants.

Although from areas of low natural fertility, flannel flowers in cultivation respond well to added
fertiliser. Trials using slow-release fertilisers in pot plants (Nutricote® Total N13:P5.7:K10.8 and N18: P2.6:K6.6) indicate that increased stem number and earlier flowering are achieved at higher nutrient levels (5–10 kg/m³ potting media). Low to medium levels of available phosphorus (0–82.5 mg/kg) can be tolerated by flannel flowers and toxicities have only been seen at very high levels (290 mg/kg found at one grower site).

**Pest and disease control**

The most serious diseases of flannel flower are root rots. These are the most common cause of plant death in cultivation and losses can be serious or even total. Death can occur within a week. The two most serious pathogens causing root rot are *Pythium* and *Fusarium*, although other fungi have been implicated (*eg* *Rhizoctonia* and *Phytophthora*). It is thought that several species/strains of the fungi genera are implicated and they have differing effects on the plants, however further research is required to clarify the situation. The most effective control is hygiene and cultural practices. It is essential the growing medium is very well aerated and that the plants are not overwatered. If the growing conditions are good the root rots will normally only have a small effect on plant growth. No effective fungicides have yet been found to control the rots, however research is continuing. During the propagation of flannel flowers, grey mould caused by *Botrytis* sp. is common and may be controlled by reducing humidity, avoiding overcrowding, regular removal of dead material, use of fungicides and keeping temperatures in the range 20–25°C.

A number of pests attack flannel flower. However they are usually relatively easy to control and cause little damage if detected early. Some recorded pests are mealy bug, aphid, thrips, mites and caterpillars. It is important that the number of insects be kept low because of the need for disinfestation for export. Even spiders may be a problem.

**Harvest, handling and postharvest treatments**

Seasonally flowering flannel flowers will produce saleable blooms in the first spring season if planted at least by mid summer of the previous year (approximately 8 months) They may produce a second crop in late summer although stems lengths will be reduced. Production will generally be higher in the second flowering season. Depending on the size of transplant continuously flowering clones will produce flowers in 2–4 months after transplanting.

Flowering heads are ready for harvest when approximately 15–20 individual florets are open in the centre of the disc of the main flowering head. The exception is the continuously flowering clone that may be harvested when the head is fully formed, without any individual flowers being open, to all of them being open without a reduction in vase life. Harvesting should be done in the morning and the stems placed directly into cool water. Stems should be cut as long as possible but never cut into...
the oldest part of the stem as this may kill the plant. Blooms can be stored in a cool room (2–4°C) either dry or standing in water, for several weeks although maximum vase life (7–35 days depending on variety) is achieved if they are transported (in water) immediately or overnight.

The use of chemical treatments such as citric acid and bleach may assist in prolonging vase life and controlling fungal diseases. Addition of sucrose, as a pulse or to vase solutions has not been found to extend vase life (see Faragher et al 2002 for further information). Further work is required on postharvest treatments to maximise shelf life. Flannel flowers are graded according to stem length: 40 cm is the shortest marketable length for field grown material; the export markets prefer stems 60–80 cm and longer if available. Flowers as short as 20 cm produced under protected cultivation are also saleable due to their out of season production and higher quality. Stems are bundled in groups of 10 and placed in cartons containing, depending on length, up to 200 stems. More stems can be put in a box using bunches of different stem length but importers may have their own preference. Bunches in microperforated sleeves and a plastic box liner present well and suffer less damage during transport.

Skin irritation may occur in some people when handling flannel flowers due to the fine hairs on the stem. Due care should be taken during handling and especially harvesting when gloves, long sleeves and a mask should be worn, especially during very dry conditions. The potential for skin irritation is greatly reduced after the flowers are dipped.

Financial information

One person can manage about 1 ha of field production with additional labour for harvest processing and packaging. However, normally the crop will be grown in association with others to spread labour and risk. Without previous experience in the growing and marketing of flannel flower the planting of large areas is inadvisable due to the risks involved.

For flowers grown in protected cultivation one person can manage about 1,500 m² of greenhouse space. In this area, the year round flowering clone is capable of producing over one million stems per annum, thus the need for additional labour for harvest processing and packaging is obvious.

Since the production of flannel flowers under protected cultivation is still in the development stage, a gross margin is presented for field production.

A number of assumptions have been made. The average return to growers for product exported to Japan in 2003 was between about $0.01 and $0.02 per cm of stem. It is assumed that an average return for a 50 cm stem was $0.75. Prices could be much higher or lower than this. Also prices of the individual components will vary greatly between enterprises. The crop was assumed to last for 2 years. Capital costs are not included.

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Key messages

- A key focal filler
- Expanding industry with good growth potential
- Production shifting from bush picking to both field and protected cultivation
- Root diseases are the major constraint to cultivation
- A seasonal crop but year round production now expanding

Key statistics

- Production largely in coastal New South Wales, Victoria and Queensland
- One to two million stems exported annually
- Production of cultivated product approaching one million stems p.a.
About the authors

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Lotte von Richter (MScAgr) has worked at Mount Annan Botanic Garden for 9 years primarily on the development of flannel flowers as a cut flower crop. Current work is in seed research studying the biology, dormancy, germination and storage of Australian species.

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Kangaroo paw

Ross Worrall and Ken Young

Introduction

Kangaroo paw (*Anigozanthos* and *Macropidia* species) is Australia’s second largest export cut flower. However it is facing increasing competition from overseas producers, especially from central America and southern Africa. The appreciating Australian dollar is also placing pressure on financial returns. Exact production figures are not known, however it is thought that growers are exiting the industry due to poor financial returns. Australia has been the major source of new varieties, although Israel is now also producing them. There is a need for higher yielding, more disease resistant clones, especially of the brighter colours, particularly yellow, and to extend the flowering season. Few successful new varieties have been developed in recent years.

Any potential for the expansion of the industry in the short term mostly lies in expanding the domestic market through promotion and expanding availability throughout the year. To compete more effectively on the overseas markets, new and novel varieties, out of season production (especially earlier), a reduction in costs and a relatively lower Australian dollar are required. Both horticultural (growing and harvesting–packaging) and marketing skills are very important in the production of kangaroo paws. They are not considered a difficult crop to grow compared with many other cut flowers, especially the *flavidus* hybrids. However, proper
scheduling of harvesting and marketing is quite important.

**Markets and marketing issues**

The farm gate price has been decreasing in recent years with the average price per stem in 2001-$0.50, 2002-$0.38 and 2003-$0.32 for red and yellow 50-110 cm flowers to Japan. There is also a large price differential between early and late flowers. For example red flowers marketed in 2003 before mid October averaged $0.45/ stem, those later averaged $0.25/stem. However the price can also be very volatile; very low or negative returns are also possible. Rapid feedback from overseas markets is very important to determine if flowers are to be harvested and exported without incurring a loss. For example if prices are a week out of date two or three additional shipments may have been sent after a price crash.

The declining price is largely due to the appreciating Australian dollar, especially against the Yen and keen competition for the overseas markets from other large producers. Major competition for the European market is from Israel. Whilst Israeli production is ‘off-season’ to ours, Israel’s closeness to Europe and relatively low freight rates means it can sell at a lower price than us and achieve a satisfactory return. This tends to ‘stabilise’ returns from Europe to that for a generic commodity. In the Southern Hemisphere countries directly competing with Australia for the Japanese market are Zimbabwe and other southern African countries. Production is also expanding in central America, especially under protected cultivation. The USA and Canada

**Key messages**

- Increasing competition from overseas countries
- Declining production and returns except for niche products with significant numbers of growers ceasing production
- Relatively easy to grow crop
- High labour input in processing
- Need for new varieties to expand industry

**Key statistics**

- Second largest cut flower export crop
- Over 4 million stems produced in 2000 but no reliable recent statistics available
- Significant domestic market
- Large losses due to frost and drought in 2003- over one million stems
- Many flowers not harvested later in the season due to declining prices
take only small volumes of flowers in the 60–90 cm stem-length range.

Flowers may be directly exported by larger growers, or through agents. In Japan, flowers may be sold at auction or directly by arrangement through importing agents. Different markets may have different preferences. For example, Japan prefers longer stems (up to 150 cm) and flowers with 'clean' vibrant colours, especially yellow. The strongest market is in September to October. In contrast, there is a niche market in Europe at Christmas time, mainly for red kangaroo paws 70 - 100 cm long, with smaller volumes in the New Year. Colour preference changes frequently.

Production requirements

Soils must be well drained, with slightly acidic sandy loams preferred. Some varieties are particularly sensitive to phosphorus, which is exacerbated by nutrient imbalances. A soil test is recommended, especially for previously cultivated areas. Sites should be frost free. Although the foliage may not be damaged, flowers may be severely degraded by a light frost (i.e. –0.5°C), even in the bud stage. There were wide spread losses in 2002 and 2003 due to heavy frosts. Plants may be grown in well-ventilated greenhouses for earlier flowering and to protect them from weather damage. However, high temperatures and/or lower light levels may result in severe flower fading, especially of the red varieties. High summer temperatures limit production areas to approximately south-eastern Queensland and south in the eastern states and the south-west of Western Australia. *A. flavidus* and its hybrids are generally much harder.

The approximate limits of commercial production are given in the accompanying map. However, many microclimates in this area may not be suitable for the reasons outlined above. Similarly, it may be possible to grow plants in other areas. This can be determined only by trial plantings before starting full-scale production.

Adequate irrigation using high quality water is usually necessary for maximum production and to extend the flowering season, although production areas with high summer rainfall on the east coast may have little need for irrigation. Extended periods of wet weather will also exacerbate disease problems. Provided that

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Some of the exciting new colours of kangaroo paws that are becoming available (Photo: NSW Agriculture)

Macropidia fuliginosa (Black kangaroo paw) is a variety of kangaroo paw in high demand, but difficult to grow (Photo: NSW Agriculture)

*Anigozanthos manglesii*, flowers in the wild. It is the floral emblem of Western Australia. Limited bush picking of this species occurs (Photo: NSW Agriculture)
the area is well drained, and flood and frost free, flatter areas are preferred for ease of cultural operations and harvesting. Availability and cost of transport to market or export airports should also be considered.

**Varieties**

Most plants cultivated today are hybrids or selected clones, usually produced by tissue culture. *A. flavidus* hybrids are especially popular, especially in the more humid areas of the eastern states due to their resistance to most of the common pests and diseases. There are at least 40 varieties exported with well over 100 cultivars available. Many of the cut flower varieties have also been grown for many years and there is a need for hardy new varieties, especially of *Macropidia*, early yellows and perhaps late flowering reds.

Taller (approximately 1 m) varieties with clear bright colours, especially yellow, are favoured for cut-flower production. However, smaller varieties may have a place in the mixed bouquet market. Some of the varieties grown as cut flowers include Autumn Harmony, Big Red, Bush Dawn, Bush Gem, Bush Glow, Bush Emerald, Bush Harmony, Bush Haze, Bush Noon, Bush Ranger, Bush Ruby, Bush Sunset, Copper Charm, Crisp Pink, Gold Fever, Golden gem, Orange Cross, Regal Claw, Royal Cheer, Ruby Delight, Yellow Dawn, Yellow Gem, Yellow Mist and Yellow Sunrise. Some species that are grown include *Macropidia*, *A. manglesii* and *A. bicolor*, and *A. pulcherrimus* (orange and yellow forms).

**Cultural practices/agronomy**

After a suitable site is selected and drainage installed, if necessary, a basal dressing of fertiliser or chicken manure is incorporated into the beds, especially in poor sandy soils. In the field, the distance between beds (usually 3–4 m) will depend on the equipment to be used for cultivation and transport of flowers. Failure to allow for free movement will greatly increase production and picking costs.

Within beds, there may be up to three rows 1 m apart, and plants are usually spaced 1 m apart within rows. Break rows every 50 m or so to allow for efficient vehicle movement. Beds are often raised to provide better drainage, especially in the eastern states, where the use of weed mats and mulches is also common. Planting in spring/autumn to avoid very hot weather is preferred, especially on black weed mat. Applying fertiliser through the irrigation system is the most satisfactory method of fertilising kangaroo paw, especially if weed mats or mulches are used.

Fertilising should be carried out during the growing season, especially from mid autumn to mid spring.

Plants will first flower about 6 months after planting, then at their normal time each year. Full production will be achieved in the second to third year. The number of flowers will increase beyond this but the quality will be reduced, necessitating severe pruning (slashing).

Some species, such as *A. manglesii*, are best treated as annual or biennial crops. The most time and labour-critical operation is harvesting. Flowers must be harvested at the right stage for maximum quality, and processed, packed, cooled and transported to market promptly. Most varieties have flushes; therefore a mixture will help to even out production over a greater period.

Basic equipment and facilities required are a processing shed with facilities to treat flowers with fungicide/insecticide and to grade, bunch and box flowers, forced air cool room, buckets, chemicals, good quality water, tractor/ transport vehicles for site preparation and movement of flowers, slasher, spray equipment for pest and disease control, an irrigation system and access to refrigerated transport.
Pest and disease control

Ink disease of kangaroo paws (blackening of the leaves and flowers) is a widespread problem, especially in the more humid areas (e.g. coastal New South Wales) and under protected cultivation. Some varieties are much more susceptible than others. Ink spot is a response to a wide range of stresses e.g. insect damage, nutrient imbalance and pathogens (esp. *Alternaria*).

Rust (*Puccinia haemodora*) is also a serious disease which causes typical rust pustules (blisters) on the leaves. Development of rust is favoured by hot, wet conditions, as are a range of crown and root rots caused by a variety of fungi (e.g. *Pythium*, *Fusarium*, *Phytophthora*, *Sclerotinia*, and *Rhizoctonia*). Young plants in poorly drained soils are especially at risk. Petal blight or grey mould (*Botrytis cinerea*) may also be a problem, especially in cool damp conditions. Severity of infection of these diseases can be minimised by the use of resistant clones (usually *flavidus* hybrids), avoidance of environmental stresses, good air circulation and trickle irrigation to avoid wetting of foliage, and use of fungicides. An annual slash or slash and burn may be effective in removing infected material. Disease-free planting material is also essential, especially since Tomato Spotted Wilt Virus has been detected in kangaroo paws. How wide spread this problem is, however, not known.

Compared with many exotic flower crops kangaroo paws are relatively free of pests. However, for the production of high-quality blooms a pest-control program may be necessary, especially if flowers are to be exported. It is essential to reduce insect populations to low levels before harvesting because most disinfestation treatments are only partly effective at levels that do not damage the flowers. Some problem insects are aphids, leaf miners, bud worm, thrips and small, leaf-chewing caterpillars. Most of these pests are relatively easily controlled by the application of an appropriate insecticide. Slugs and snails may also be a serious pest, especially of young plants in the greenhouse and in cooler areas. Susceptibility of species/clones to slugs and snails varies widely, with *A. flavidus* and hybrids generally being more resistant. Control is by good hygiene and spray or pellet application of a molluscicide.

Birds may cause extensive damage to flowers by breaking stems and biting off flowers, especially if other flowers are scarce. Control is by netting or human presence.

Weeds may become a major problem, especially in the eastern states. Mechanical control on a large scale is often difficult due to the herbaceous nature and habit of the plant. Plastic weed mat or mulches are very popular with commercial cut-flower growers in summer rainfall areas, especially to control broadleaf weeds. Care, however, must be taken with black weed mats due to elevated temperatures that occur under the mat. Small plants are especially vulnerable. Mowing or knock-down herbicides are used for interrow weed control. Grasses can be controlled with post-emergent herbicides. Some herbicides may cause damage to, or reduce the growth rate of kangaroo paws. Phytotoxic effects may vary with the rate, method of application and clone. Check to ensure that the herbicides you want to use are registered in your State for the intended purpose.

Harvest / handling / postharvest treatments/processing requirements

Flowers are usually harvested when the first one to three florets on the spike have opened. Harvesting at an earlier stage (in bud) may cause a condition known as ‘bent neck’. As soon as possible after harvesting, flowers should be placed in water or a preservative solution to prevent wilting.
Flowers must also be cooled as soon as possible.

After harvest, stems are usually re-cut to the desired length and bunched into five-stem units (10 stems if short, i.e. < 70 cm). Bunches are then usually sleeved into a micro-punched flower sleeve. Flowers are then disinfected by complete immersion in a Cislin® and Rovral® (or similar) mix to kill insects and to control Botrytis. Some growers, especially in Western Australia, disinfest with the above mixture and dry the flowers before sleeving.

Currently, insecticidal dips such as Cislin® would appear to offer the most effective means of disinfesting flowers. Treatment of kangaroo paws with aerosols, such as dichlorvos or pyrethrin, is moderately effective. Some growers use a combination of insecticidal dip followed by aerosol treatment. Before using pesticides check that they are registered for use on flowers in your State.

Freedom from live insects is necessary for the export of flowers from Australia, especially to countries with strict quarantine requirements, such as Japan and the USA. Live insects on flowers will require fumigation or destruction of the flowers in these markets. Fumigation may damage the flowers and will cause a reduction in auction prices, delays in selling and a reduction in consumer confidence. Insect contamination causes similar problems on the domestic market.

Use of pulsing solutions containing sucrose and other chemicals after harvest can extend the vase life of kangaroo paws. However, considerable variation exists in current recommendations, which range from 2–20% sucrose and above. Clean buckets and water should be used at all times.

Kangaroo paws should be stored at low temperatures (~2°C) and a high relative humidity (95–98%), including during pulsing. Forced air cooling should be used to reduce flower temperatures as soon as possible after harvesting, and again after flowers are packed into cartons. Flowers should be at less than 5°C at dispatch. The vase life of kangaroo paw flowers is reduced by cold storage and storage on the farm should be limited to no more than a few days. The maximum total storage time should be no more than about two weeks, and preferably less than one week over the entire marketing chain.

Financial information

The ‘typical’ estimated start-up costs for one hectare, not including land, machinery, clearing, labour, fencing or structures, is about $25,000 in New South Wales and south-eastern Queensland. This includes operating costs for one year. It is emphasised that costs will vary widely from site to site, even in the same locality.

The kangaroo paw export industry has reached a relatively mature stage with significant quantities having been exported for a number of years. There are also a number

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Sleeved and packaged kangaroo paw ready for export (Photo: NSW Agriculture)
of competitors on the international market.

A ‘typical’ gross margin analysis is presented below for flowers exported to Japan. It should be emphasised that the net return to the grower (after sales and freight) can vary considerably with variety (over a twofold difference) and time of year (over a fivefold difference).

As can be seen from the gross margin figures, if other sale prices are substituted, both a profit and loss are possible, depending on variety and time of year.

Marketing knowledge and skills are needed to maintain profitability.

It may also be very difficult to sell certain types at particular times of the year. Any change in the sale price, freight costs and the Yen/$AUD exchange rate, all of which are largely outside the control of the grower, will also have a dramatic effect on the gross margin.

Due to these risks, and to spread costs and labour, it is recommended that kangaroo paws be grown in conjunction with other crops and that a range of varieties be grown.

Processing, packaging, sales and freight costs will be very much reduced for the domestic market due to the less stringent quality requirements. The sale price is also often much lower and the market relatively small. Losses, especially late in the season when prices usually decline, can be minimised by not harvesting flowers. However timely market feedback is required for this decision.

### Table 1: Indicative gross margin analysis at year 2-3 for Japanese export material, 7000 plants/ha (NSW Coast)

<table>
<thead>
<tr>
<th>Costs (not including overseas costs)</th>
<th>$/stem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harvesting &amp; processing &amp; packaging</td>
<td>0.19</td>
</tr>
<tr>
<td>Production costs</td>
<td>0.05</td>
</tr>
<tr>
<td>Establishment costs</td>
<td>0.04</td>
</tr>
<tr>
<td>Plant replacement costs</td>
<td>0.02</td>
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<tr>
<td>Total costs</td>
<td>0.30</td>
</tr>
<tr>
<td><strong>Returns</strong></td>
<td><strong>$/stem</strong></td>
</tr>
<tr>
<td>Sale price ($/stem- farm gate, av. 2001-3)</td>
<td>0.40 *</td>
</tr>
<tr>
<td>Gross margin/stem ($)</td>
<td>0.10</td>
</tr>
<tr>
<td>No. of stems (30 stems/plant)</td>
<td>210,000</td>
</tr>
<tr>
<td><strong>Gross margin/ha ($)</strong></td>
<td><strong>$21,000</strong></td>
</tr>
</tbody>
</table>

* Will vary greatly with time of year and exchange rate.

**Key references**


Carson, C (ed) (2000) *Should I Grow Wildflowers?* Agrilink (Department of Primary Industries, Queensland)


Also other publications on the RIRDC web site: www.rirdc.gov.au


Other State Departments of Agriculture, especially WA, have numerous publications on Australian native cut flowers in general, and kangaroo paws, in particular.

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Introduction

NSW Christmas bush (*Ceratopetalum gummiferum*) has been grown and sold as a filler cut flower in the Sydney area for well over a century. It makes an excellent cut flower. The vase life of quality ‘flowers’ (the red sepals develop after the white flowers) can be up to three weeks. As its name implies, it has become associated with Christmas, particularly because the bright red sepals, which contrast well with the green foliage, develop around that time of the year. Association with Christmas has proved to be more a strength than a weakness, i.e. reducing demand at other times of the year. The foliage alone also has some use in flower bunches.

Demand is strong on the local market immediately before Christmas, with the price dropping dramatically afterwards. Flowering times are quite variable. Often the red sepals develop after Christmas in the Sydney area, when the price is low. Efforts to establish an alternative name for the product, e.g. festival bush, have only been partially successful.

The quality of flowers on the local market is generally lower in...
terms of grading and postharvest
life. There is a strong demand
for high quality flowers in the
Japanese market in November
and December, and in the
United States after Thanksgiving
(26th November).

Current production is largely based
on one early variety, ‘Albery’s Red’. New varieties need to be developed
to spread harvesting times in
any one locality. There are also
various challenges facing the
culture of Christmas bush. Hot
dry winds, especially at flowering
time, may cause a complete loss
of the flowers, as do severe frosts.
Nevertheless, although there have
been some losses under adverse
conditions, plants should last many
years if properly cared for. The
range of environments in which
Christmas bush can be successfully
grown commercially has yet to be
fully determined.

Both horticultural (growing,
harvesting and packaging) and
marketing skills are very important
in the production of Christmas bush. Especially critical is the
ability to schedule harvesting and
marketing.

Markets and marketing
issues

Bunches sold on the domestic
market have variable stem lengths
and sizes within and between
bunches. Flowers for export are
more carefully graded, principally
on stem length. Other factors also
taken into account are the number
of sepals on the stem, their colour
and how they are presented, and
the total perceived volume of the
stems. Perceived volume relates
to flower density and ratio of stem
width to length. Top quality AAA
stems occupy a visual width of two
thirds their height, so fewer stems
are needed by the florist to fill a
space. These stems have the classic
pyramidal ‘Christmas tree’ shape,
and command premium prices in
the Japanese market. There are
also a specified number of stems
in a bunch. Although the export
price received is much higher than
from the domestic market, grading
costs and proportion of product
not meeting the specifications are
also much higher.

Domestically the principal market
for fresh cut flowers is Sydney.
Relatively small quantities are
sold in Brisbane and little in
Melbourne. Early season prices
are better in Brisbane than in
Sydney. Large quantities are also
sold directly to wholesalers and
florists. Japan and the United
States are the main export markets,
with smaller quantities sold
in Canada, and the Euro area.
Flowers are usually consolidated by
Australian export agents, but some
larger growers or grower groups
export directly. North American
sales are on a fixed price basis,
and product for Japan is usually
shipped on consignment. In Japan,
flowers are placed by importers
into the auction system. They are
either sold at auction or by pre-
selling, including on the internet,
with the auctions functioning as a
logistic and payment centre.

The timing of sales is critical in
all markets to achieve the best
price. Higher prices are currently
obtained for best quality flowers
on the Japanese market. Japanese
prices recovered somewhat from
low and erratic levels in 2002 to
viable levels for good product in
2003. In line with world trends
of generally falling flower prices,
Christmas bush returns have never
returned to the ‘gold rush’ levels
of the 90s. Supply has increased
considerably since 1998, and the

Frost protection with overhead sprinklers (Photo: NSW Agriculture)

Effect of shading on colour development of Christmas bush. Left- full shade; Right- full sun
(Photo: NSW Agriculture)
higher level of the Australian dollar has been the biggest factor impacting on grower returns in 2003. USA prices are currently about the same or slightly higher than domestic prices, but much larger volumes can be sold.

Production requirements

The primary requirement for the production of quality flowers is protection from hot dry winds, especially at flowering time. These can cause an almost complete loss of flowers in a matter of days, or at least a significant reduction in quality, especially vase life. Degree of shelter from dehydrating conditions is the most significant factor in determining product vase life. Damage can occur even when soil moisture is sufficient. Adequate water is also important, especially from flowering time to harvest. Plants should be irrigated regularly. Two to three year-old plants require about 4 L/day. Established plants will tolerate moderate frosts to about -4°C.

Soil type does not appear to be important, provided drainage is good. Soil pH is best between 5.3 and 5.8. Christmas bush is intolerant of salty water.

The species occurs naturally in moist gullies and slopes in coastal New South Wales. It has been grown commercially near Toowoomba in Queensland and coastal areas of Victoria. Its commercial performance in other parts of Australia such as south-west Western Australia is not known. However, in a suitable microclimate it may well be successful. It should also be noted that, even within areas shown, some parts may not be suitable due to local conditions. Recent drought conditions in 2001–2003, with severe frosts and record high temperatures in the pre-harvest period, have demonstrated the relatively narrow band of climatic suitability in which this crop is consistently reliable and has a competitive advantage.

Varieties

It is strongly recommended that selected clones be used rather than seedlings, which may be highly variable. The most commonly grown variety is ‘Albery’s Red’. This is compact, dark red in colour, and early and free flowering. Almost all current plantings are of this variety. It is well accepted in the Japanese market and often brings the best price on the Australian market. There remains a need, however, to extend the flowering season and introduce a greater range of colours.

One variety which shows particular promise is ‘Festival’, a cross of ‘Albery’s Red’ and ‘Shiraz’. ‘Festival’ has larger and darker flowers, although flower density is lower than ‘Albery’s’. It flowers...
1-3 weeks later than 'Albery’s Red', and is particularly suitable for the USA market due to its darker red (poinsettia-like) colour. It is also more vigorous and productive than both its parents. ‘Shiraz’ flowers 2-4 weeks later than ‘Albery’s Red’, depending on location, and is a darker red with slightly cupped flowers. It is well accepted by the Japanese market and brings good stem prices but packouts are lower due to wide branch angle, and it is less productive than ‘Albery’s’. Two good white varieties are ‘Silent Night’ and ‘Mirrabooka’. There has been a good response from the Japanese market to trial shipments, although there are some problems with brown spots on white sepals. The spotting can result from rain, overhead irrigation or condensation. There is also a range of other colours available, especially pinks, some of which show particular promise in terms of plant form and vase life of the flowers.

**Agronomy**

After a suitable site is selected, and drainage installed if necessary, a basal dressing of fertiliser, usually including lime and a phosphate source and chicken manure, is incorporated into the beds. A soil test should be used to determine requirements. In the field, the distance between beds (usually 4 m) will depend on the equipment to be used for cultivation and transport of flowers. Failure to allow for this will greatly increase production and picking costs. Within beds, plants are usually spaced 1-2 m apart. Beds are often raised to provide better drainage and weed mats/mulches are also commonly used to control weeds. Planting in spring/autumn, and winter in frost-free areas to avoid very hot weather is preferred, especially on black weed mat. Trickle or drip irrigation is generally used, so as to avoid wetting the foliage.

Commercial production starts 1-2 years after planting, depending on the size of transplants. The most time and labour critical operation is harvesting. Flowers must be harvested at the right stage for maximum quality and processed, packed, cooled and transported to market promptly. Picking of varieties at any one location generally takes place over 2-4 weeks, depending on exact orientation of blocks and temperatures. A mixture of varieties will help to extend production over a greater period.

Christmas bush responds well to fertiliser the application of which is essential for commercial production. However, no fertiliser should be applied for 3-4 months before harvest, to reduce the risk of new shoots overgrowing the ‘flowers’, and thus reducing quality. Fertiliser application of NPK and minor elements combined with pelleted chicken manure applied in January and April, appears to give satisfactory results. Quantities and formulations should be determined after soil and leaf tests. Generally plants need high nitrogen after harvest for stem regrowth, with increasing amounts of potassium and calcium and phosphorus moving into autumn/winter, up to flowering. Use of organics such as chicken manure is beneficial for soil structure and micro-organisms, important for sustainable production of a long-term woody crop.

As a guide, 20-30 grams of high analysis fertiliser should be applied to one to two year-old plants (at least 1.5 m high) with an equal amount, in terms of nutrient content, of pelleted fowl manure. Solid fertilisers may be supplemented with additional liquid fertiliser applied through the irrigation system. Plants require at least moderate levels of phosphorus and other fertilisers for maximum growth.

Proper pruning of the bush is vital for maximum production and usually takes place as flowers are harvested or immediately afterwards. Any unharvested branches are cut back to 25-50% of their original length. The main trunks should be cut back to 2-2.5 m to facilitate harvesting. The general aim is to leave about 25% of the original foliage or regrowth will be reduced.
Pest and disease control

The main insect pests are leaf-curling psyllids, which often appear on new growth. They are difficult to control, even with repeated applications of insecticide.

Scale insects can also be a persistent problem, particularly if plants are not growing strongly. Other pests are aphids, caterpillars and thrips which can attack new shoots and flowers, although they have not been a major problem to date. It is important to reduce pests and other insects to a low level in the field, especially if flowers are to be exported. Major markets, Japan and the USA, require 100% freedom from insects.

The disinfestation treatment commonly used is an insecticidal dip. This is only partially effective, therefore the chance of live insects contaminating flower shipments is greatly reduced if the insect population is reduced before harvest. Root diseases may also become a serious problem in sites that are not well drained.

Use of weed mats or mulches will greatly reduce the need for weed control. Glyphosate may cause damage by root transfer from perennial grasses under some circumstances (especially in very light sandy soils) and its frequent use can no longer be recommended. Contact herbicides may be safer for the plants, if not for the operator. Always read and follow the label directions for use, especially regarding personal protective equipment. Note that it is essential to check the registered uses of pesticides in your State before applying them.

Harvest, handling and postharvest treatments

Basic requirements for production and handling are a processing shed with facilities to treat flowers with fungicide/insecticide and to grade, bunch and box flowers, a forced-air cool room, buckets, chemicals, good quality water, tractor/transport vehicles for site preparation and movement of flowers, a slasher for weed control, spray equipment for pest and disease control, an irrigation system and access to refrigerated transport.

Harvest time is late October to late November in coastal Queensland, early November to mid December on the north coast of New South Wales, late November up to Christmas in cooler and higher altitude areas away from the coast, and New South Wales central coast and Blue Mountains, and late January to early March on New South Wales south coast, Victoria and New Zealand. Christmas bush is sold by the stem in 30, 40, 50, 60, 70, 80, 90 and 100 cm lengths for export markets.
Financial information

One person can handle about a one hectare planting of 2,000, with additional labour required at harvesting time.

However, due to the strongly seasonal nature of labour requirements and risks (growing and financial) associated with a single crop, it is recommended that NSW Christmas bush be grown in association with other cut flower crops. Current commercial plantings range from about 400 to 4,000 plants, however growers need enough plants to justify the required capital expense of cost-efficient processing facilities. Processing costs (harvest, postharvest and packing) are the biggest costs in production, with labour the biggest component. Some mechanisation is possible, such as air or electric cutting tools, rotating grading tables, conveyors, trolleys, bunch tying and box strapping machines, mechanised winch dipping and spin-drying systems. Use of these tools can lower costs considerably by increasing labour productivity; this may be the grower’s best defence against uncontrollable external factors such as currency fluctuations.

The estimated start-up cost for a hectare, not including land, machinery, clearing, labour, fencing or structures, is about $20,000 in coastal New South Wales. This includes operating costs for one year. With little mechanisation, up to one year’s labour could be required to establish 2,000 plants. Growing and harvesting the Christmas bush for export accounts for only about 4% of the final wholesale price. Processing and packaging also account for only 14% of the final sale price. By far the greatest costs are sales and freight-in total accounting for 45% of the total cost of production. Any change in the sale price, freight costs and the yen-dollar exchange rate, all of which are largely outside the control of the grower, will have a dramatic effect on the gross margin. Processing, packaging, and sales and freight costs will be very much reduced for the domestic market due to the less stringent quality requirements. In the long term a gross margin of $25,000 - $30,000 per ha would be realistic for material sold on the export market. If all labour was costed, the gross margin in 2003 selling all material on the domestic market would have been between approximately $10,000 and $15,000/ha, depending on time of harvest. It is obvious that the export market is more profitable, but it requires a higher quality product.

Table 1. Typical gross margin analysis at year 5 for Japanese export material, 2000 plants/ha (NSW mid north coast)

<table>
<thead>
<tr>
<th>Costs</th>
<th>$/stem</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sales &amp; freight</td>
<td>0.63</td>
</tr>
<tr>
<td>Packaging &amp; processing</td>
<td>0.20 #</td>
</tr>
<tr>
<td>Harvesting &amp; growing</td>
<td>0.19</td>
</tr>
<tr>
<td>Plant costs</td>
<td>0.08</td>
</tr>
<tr>
<td>Total costs</td>
<td>1.10</td>
</tr>
<tr>
<td>Returns</td>
<td>$(/stem)</td>
</tr>
<tr>
<td>Sale price ($/stem)</td>
<td>1.40 *</td>
</tr>
<tr>
<td>Gross margin/stem ($/stem)</td>
<td>0.30</td>
</tr>
<tr>
<td>No. of stems (50 stems/plant)</td>
<td>100,000</td>
</tr>
<tr>
<td>Gross margin/ha ($)</td>
<td>$30,000</td>
</tr>
</tbody>
</table>

# some mechanisation is required to achieve this cost
* Prices are lower for USA and domestic markets; sales, packaging & processing costs are also lower

The domestic market prices by the bunch, which may be from 5–25 stems, depending on their size and fullness. Export bunches for USA are made to buyer’s specifications, usually 5–10 stems in 40, 50 & 60 cm grades. Bunches for Japan have an exact stem number and need to be all the same in a bunch, graded in 10 cm increments.
**Key references**


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**About the authors**

Ross Worrall (Ph D) is a senior research horticulturist with NSW Agriculture. Since 1972 he has been involved in the breeding and development of Australian native flowers for both cut flowers and pot plants.

Paul Dalley is a cutflower grower, nurseryman and consultant with extensive experience in the development of eastern Australian native cutflower crops for export. He is one of the founders of GrandiFlora Growers Pty. Ltd., a grower-owned marketing group known for its premium quality branded Christmas bush export products.

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**Key messages**

- Well established domestic industry
- High-growth major export crop for eastern Australia
- Premium export returns for best product
- No significant competition from overseas countries as yet
- Needs specific climatic conditions
- High labour input in processing

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**Key statistics**

- There are about 100 commercial growers of Christmas bush, most on the north coast of New South Wales (82%).
- In 2003 approximately one million stems were exported with an additional 500,000 sold on the local market.
- Production in 2003 was reduced due to frost and drought, as well as softening prices, mainly due to the appreciation of the $A, particularly against the yen

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Smokebush

**Introduction**

Smokebush (*Conospermum* spp.) commonly occurs along highways north of Perth and appears as extensive fields of white to grey woolly flowers, which are said to resemble clouds of smoke. There are 53 species of *Conospermum* occurring throughout Australia, 80 of them found in Western Australia. Smokebush is mainly bush-picked and offers an opportunity for development as a cultivated export wildflower with a diversity of colours (white, grey, pink and blue) and varying flower displays. Cultivated material from trial plots in Perth, Western Australia was test marketed in 1996. The flowers were well received on the local and Japanese markets.

*Conospermum* species can be propagated vegetatively but some species are often difficult to strike and tissue culture is increasingly being used by propagators. A range of species is available from commercial nurseries. Methods of cultivating these plants are being developed by Agriculture Western Australia with financial support from RIRDC. To date, several commercial stands of smokebush have been established using results from these investigations.
Grey-white flowered smokebush is used mainly as a filler flower, similar to Geraldton wax, but some of the blue forms may be used as feature fillers commanding a higher price. Introduction of new selections with form and colour variation provides an opportunity to compete with established feature filler products such as Gypsophila and statice.

**Markets and marketing issues**

Over 99% of smokebush entering the market is picked from natural populations. Flowering stems are available, depending on species, from July to February and are exported to Japan, the USA and Europe.

Stems are sold fresh (e.g. *Conospermum stoechadis*) or preserved and dried (e.g. *C. crassinervium*). Prices are low for the bush-picked product; e.g. 5–10 cents/stem. With the introduction of selected lines, it is expected that this situation will change with the availability of higher quality cultivated material.

Currently 100,000 stems/annum are exported (CALM 2003), 99% from bush picked material. With today’s unfavorable exchange rates export prices have been down and growers can expect to return farm gate 20 to 30 cents per stem for white and 50 cents/stem for blue.

The cultivated material includes blue species which command the higher price. For white smokebush prices are limited while there is good quality bush picked material available. This may change as new selections gain popularity.

**Production requirements**

*Conospermum* species occur in 250–900 mm rainfall areas with yearly mean maximum/minimum temperature ranges from 23/13°C to 20/10°C.

They prefer sandy to sand over gravel soils with good drainage and a pH in the range 4.5–5.5 (1:5, CaCl). Species have some degree of frost tolerance to -1°C for short periods.

Plants require 3–8 ML of water/hectare/annum, depending on planting density (3,300–13,200 plants/ha) and potential evaporation. They are best established in spring using drip irrigation. The soil surface needs to be kept moist during establishment.

It is expected that *Conospermum* spp. could be grown in sandy locations in the areas of Australia indicated on the accompanying map.

### Table 1. Cut flower characteristics of Conospermum species from surveys of several naturally occurring and cultivated populations and cultivated stands

<table>
<thead>
<tr>
<th>Species</th>
<th>Flower colour</th>
<th>Average stem production per plant</th>
<th>Range of stem lengths (cm)</th>
<th>Growth habit</th>
<th>Flowering time</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>C. caeruleum</em></td>
<td>blue</td>
<td>medium</td>
<td>50–65</td>
<td>spreading</td>
<td>July-Oct.</td>
</tr>
<tr>
<td><em>C. crassinervium</em></td>
<td>white</td>
<td>low</td>
<td>80–90</td>
<td>upright</td>
<td>Dec-Feb.</td>
</tr>
<tr>
<td><em>C. eatoniae</em></td>
<td>blue</td>
<td>high</td>
<td>50–80</td>
<td>upright</td>
<td>July-Sept</td>
</tr>
<tr>
<td><em>C. floribundum</em></td>
<td>blue/white</td>
<td>high</td>
<td>7–15</td>
<td>upright</td>
<td>July-Oct.</td>
</tr>
<tr>
<td><em>C. incurvum</em></td>
<td>white</td>
<td>medium</td>
<td>20–35</td>
<td>upright</td>
<td>Aug-Oct.</td>
</tr>
<tr>
<td><em>C. stoechadis</em></td>
<td>grey/white</td>
<td>high</td>
<td>50–800</td>
<td>spreading</td>
<td>July-Oct.</td>
</tr>
<tr>
<td><em>C. triplinervium</em></td>
<td>white</td>
<td>high</td>
<td>50–90</td>
<td>upright</td>
<td>June-Nov.</td>
</tr>
</tbody>
</table>

1 Low < 25 stems, medium 25–50, and high > 50 stems per plant
Varieties

The main *Conospermum* species with potential as cut flowers are *C. caeruleum* (slender smoke), *C. crassinervium* (tassel smoke), *C. eatoniae* (blue smokebush), *C. floribundum* (blue/white smokebush), *C. incurvum* (feather smoke), *C. stoechadis* (common smokebush), and *C. triplinervium* (tree smoke). These have a range of flower colours, flowering times and growth habits, as summarised in Table 1.

*C. eatoniae* is suited to drier regions, while *C. caeruleum* prefers cooler climates. They have the potential to yield more than 50 stems/plant for 2-year-old bushes in cultivation.

*C. triplinervium* is a high yielder, producing strong, 90 cm long stems with panicles of white flowers. These species are currently available commercially in Western Australia.

Recently three White smokebush have been released for cultivation as cut flowers. These are Morning Cloud (*C. boreale*) a very early season, Misty Cloud (*C. stoechadis*) an early season narrow leaf type and White Cloud (*C. wycherleyi*) a mid season thick or elk stem type (Table 2). Several blue flowered species of *C. eatoniae* with varying shades of blue and flowering times have been identified but require commercialisation.

Agronomy

*C. eatoniae* requires a weed and disease-free sheltered site with a low nutrient status such as a sand. Planting is done in beds 3 m apart. For *C. triplinervium* each bed has a single row with 1 m between plants, and for *C. eatoniae* double rows 0.6 m apart and from 0.5 to 1.0 m between plants. Beds should be mulched to help weed control, reduce soil temperatures in summer and keep the soil surface moist.

Plant should be planted into moist soil and watered regularly during

| Table 2. Cut flower characteristics of white Conospermum species suitable for cultivation |
|----------------------------------------|-------------------|------------------|-------------------|
| **Cut flower characteristics** | **Morning cloud** | **Misty cloud** | **White cloud** |
| Flower colour | White | Grey/white | White |
| Flower display | Cascading racemes | Dense clusters of flowers | Pendulous thick racemes giving an ‘elk’ appearance |
| Flowering time | V. early (May–Sept) | Early (June–August) | Mid season (July–Sept) |
| Flowering stem | Glossy green leaves up woody brown coloured flowering stem | Narrow green/grey leaves up brown coloured flowering stem | Thick green/grey leaves at base of thick stems covered in white hairs flowering stem. Stem |
| Stem length | Medium (60-70 cm) | V. long (80-110 cm) | Long (70-90 cm) |
| Stem production per mature bush | Medium (70 stems) | High (100+ stems) | High (90+ stems) |
| Vase life | 13 days | 14 days | 15 days |
| Establishment in cultivation | Good | Good | variable |
establishment. Irrigation should be applied through drippers to maintain the soil at field capacity. Plants grow best when small amounts of nutrients are supplied regularly by fertigation. In a sandy soil, stem production was maximised with the application of 40 mg/plant/day of nitrogen and potassium and 5 mg/plant/day of phosphorous plus trace elements. *C. eatoniae* should be protected from wind damage and supported in the first year of growth by one layer of trellising (150 mm x 150 mm mesh) (Cyclone®) located at 200 mm above the ground, similar to that used for carnations. Pre- and post-planting weed control is needed. Plants established in spring will have harvestable stems by the next flowering season with yields increasing in subsequent seasons. Stems should be pruned immediately after harvest.

**Harvest and handling**

Harvesting should begin as soon as flowers appear and, to prevent loss of quality, should cease before flowers loose freshness. Flowers must be picked in the cool of the day and the stems placed in water as they easily dehydrate. No special solution treatment after harvest is needed and vase life of these species is at least 10-12 days with proper postharvest handling. It is easier to grade and bunch in the packing shed than in the field. Care needs to be taken to ensure that bunches are uniform. Bunches of five stems are suitable for *C. eatoniae*, and 10 stems for *C. caeruleum*. For other species, the stem number per bunch varies between 10 and 15. Bunches of *C. eatoniae* are packed in perforated sleeves to keep stems from tangling, and allow bunches to be packed more tightly. Flowers can be treated for insects before export by aerosol fumigation with Insectigas D/Pestigas P. Bunches should be cooled to 2°C before export shipment.

**Financial information**

There are no data available on the economics of producing these wildflowers. However, they can be produced using the existing infrastructure for growing other wildflowers provided drip irrigation and fertigation is possible.

Being an unusual flower with little good quality product available on the market, smokebush, carefully marketed as a cultivated quality product, can command higher prices particularly during festivals. The availability of smokebush over an extended season through sourcing from different climatic zones and use of varieties such as early season Morning Cloud overlapped with Misty Cloud and finishing off the season with White Cloud.
Key references


Key messages

- Large range of unusual flower types
- Vibrant blue and white flowered species
- High production wildflowers

Key statistics

- Currently 100,000 stems/annum are exported, 99% from bush picked material
- Farmgate prices received range from 20 cents for white to 50 cents per stem for blue

About the author

Dr Kevin Seaton has conducted research into the agronomy, management and postharvest treatment of a range of wildflower species. He has developed methods for managing the nutrition and irrigation requirements of wildflowers, has researched tissue culture and root system development, flowering physiology and developed a number of postharvest insect disinfestations treatments for entry into quarantine sensitive markets. His research focuses on the introduction of new wildflowers for export.

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Introduction

There are various genera in the family Myrtaceae which have stems with numerous attractive flowers borne in the leaf axils. Genera such as *Thryptomene*, *Micromyrtus*, *Scholtzia*, *Corynanthera*, *Malleostemon*, *Astartea*, *Baeckea* and several undescribed but related genera have been used as both landscape plants and cut flowers.

The largest commercial industry is based on *Thryptomene calycina*, commonly known as Grampians thryptomene or Victorian laceflower. The industry is almost entirely based near the Grampians Range in western Victoria, with small plantings elsewhere in Victoria, New South Wales, South Australia, Queensland, New Zealand and California. Production has been increasing by approximately 10% per year due to continued expansion of plantings.

The best material of Grampians thryptomene represents a world class filler flower which greatly enhances feature flowers in arrangements. The opportunities for this crop are many, since the industry in Victoria has a virtual monopoly over both world production and germplasm. The limited production in California, which is based on inferior cultivars, does not compete with our industry because flowering in the USA is from November to February. Much of the Victorian production is however a second class product because of limited use of elite cultivars, poor husbandry, poor post harvest handling and inadequate marketing. The industry is slowly developing better post harvest facilities, and one major grower has adopted quality standards.

Production of export quality Grampians thryptomene requires considerable skills in interpretation of seasonal cultural requirements, including supplementary irrigation, pest and disease management and post harvest handling. There are also opportunities for growing other species of *Thryptomene* including *T. australis*, *T. denticulata*, *T. baeckeacea*, *T. stenophylla* and *T. saxicola* from Western Australia, *T. elliottii* from Kangaroo Island, *T. micrantha* from Victoria and Tasmania, *T. parviflora* and *T. hexandra* from Queensland, and *T. maisoneuwei* from central Australia. These, except for *T. elliottii* produce inferior flowering stems to *T. calycina* (Grampians thryptomene) (Beardsell 1996). The following discussion thus
concentrates on Grampians thryptomene.

**Markets and marketing**

Most of the annual production (10 million flowering stems) of Grampians thryptomene is exported. Approximately 3 million stems are sold annually on the domestic market in the eastern states. It is the largest flower export from Victoria with between 250,000-300,000 kg sold annually to markets on the west coast of the USA. Although Asian markets like small white flowers, the generally poor quality of the product has limited its acceptance in the Japanese market. Early in the 1996 season, prices were high and this led to an oversupply of inferior flowers on the USA market causing a crash in the price. Such uncoordinated marketing almost ruined the reputation of thryptomene, although prices improved later in the season.

The wholesale price of Grampians thryptomene varies from $1.40 to $1.60 a bunch with between $0.90 and $1.20 returning to the farmgate. Export prices at the start of the ‘97 season were A$3.20 a bunch for quality product, with the grower receiving $1.80 a bunch.

In Victoria and California, Grampians thryptomene is used in a similar role to gypsophila: as a filler in floral arrangements complementing other major flowers such as roses. Flowering stems suitable for marketing are available from late May (with many flowers in bud on stems) until early September. Peak flowering occurs in Victoria in July-August, although this varies with both cultivar and the season. While the quality of flowers has improved dramatically in recent years, flower quality is variable in the season following a very dry summer-autumn. Attractive stems with unopened flowers can be picked in May and June, but stem quality falls quickly in September as spent flowers and fruits start to abscise and soft new season’s growth occurs. Late season flowers are more prone to fungal rots during transport, possibly due to the increase in nectar production or because of the soft new growth of stems. A quality assurance program is needed to define the standards for this crop. This is being developed by a major grower wanting to supply consistently high quality produce to the export market.

There has been little attempt to properly market *Thryptomene calycina*, and it is still sold as ‘thryptomene’ (in Australia), ‘Grampians thryptomene’ (in Victoria) and ‘calycina’ (in California). It needs to be actively promoted under one name, ‘Victorian laceflower.’ The adoption of quality assurance and market promotion should alter the image of this crop and increase its market value.

**Production requirements**

In Victoria, *T. calycina* is grown mostly on sandy well-drained soil, although it is also grown on heavy soils in the Black Range.

Nothing is known about the cultivation of the arid zone *Thryptomene* species, although they may be difficult to grow in areas with more than 300 mm annual rainfall and in heavy soils. Most of the non-arid land species are native to heathlands and are also difficult to grow outside of their natural habitats. All species cultivated so far need well-drained soils free of root rotting pathogens such as *Phytophthora cinnamomi*. The only species known to be a hardy plant in horticulture is *T. saxicola*.

The arid zone *Thryptomene* species, including those in Western Australia, occur in sandy soils where the rainfall is only 150-250 mm per year. In south-west Western Australia, *T. australis* and *T. saxicola* occur on soil pockets on granite outcrops. *Thryptomene micrantha*, *T. oligandra* and *T.
*parviflora* grow in moist sandy soils. The climate suitable for growing most species is temperate, although inland species would require sunny, hot climates for optimal growth and survival.

**Varieties**

Development of superior cultivars which are clonally propagated is a major requirement for cut flower production. The natural variability of Grampians thryptomene has enabled selection of plants with large flowers, even flowering, early or late flowering, short or long flowering laterals, plants with pink sepals, and anthocyanin-free flowers. The two main superior varieties are 'Ivory Lace' and 'Coral Lace' which were selected at the Department of Primary Industries, Knoxfield. Limited numbers of these are available from several nurseries and plant propagators in Victoria. The selection of early- and late-flowering clones of Grampians thryptomene will extend the harvest period to April-October. Superior clones can also be used in breeding programs. Interspecific hybrids can be produced between most members of Western Australian *Thryptomene*, but reproductive barriers limit hybridisation between these and members of the genus from eastern Australia. Breeding programs should aim to improve both flowering characteristics and resistance to diseases such as *Phytophthora cinnamomi*.

**Agronomy**

Sites need to be free draining, and frost hollows should be avoided. For cut flower production, rows of Grampians thryptomene should contain plants spaced at 0.5-1.5 m. Hilling-up should be done in heavier soils, and should closely follow land contours. Plants can be planted out as tubestock in autumn and watered in; subsequent irrigation depends on seasonal conditions. Tree guards may help early establishment. Early losses may occur from root diseases, corellas, cockatoos and rabbits.

While little is known about the nutritional requirements of *Thryptomene* and related genera, they are often found growing in soils of low fertility. Unlike some Australian plants they do not appear to be sensitive to high levels of phosphorus in potting mixtures. The only fertiliser required would be to replace nutrients removed in harvested flowers. This should be applied after flowering to enhance new shoot growth which provides the next season’s flowers. Excessive fertiliser can result in soft shoot growth during spring which reduces the quality of flowering stems. Without irrigation in the Grampians region, shoot extension is not great enough to allow harvesting of all stems on a bush each year. Growers selectively harvest the longer stems and leave the short new leads to ensure a yearly harvest from individual plants.

Species from low to very low rainfall regions are very slow growing and supplementary watering to enhance shoot growth may ensure adequate stem length and flower production. The flowers of most of these species occur in the axils of leaves, and thus promotion of extension growth should produce more flowers. Supplementary watering in dry seasons also reduces flower and leaf abscission, thus enhancing flower quality at harvest time. Both drip and microjet irrigation has been used successfully in plantations of Grampians thryptomene in Victoria. Water used from dams should be chlorinated or chlorobrominated at 3 ppm for 4 minutes to prevent the spread of *Phytophthora cinnamomi*.

Depending on the size of planting stock and after-care, flowering stems can be harvested in the second or third season. Although harvesting of Grampians thryptomene only occurs from May to September, weed control, irrigation and maintenance of facilities make growing high quality flowers a full time operation.

Flowers can be damaged by severe frosts (below -3°C). Frosts of -5°C will kill bushes of Grampians thryptomene and *Thryptomene saxicola*; the bark splitting down to ground level. Inland species may have greater frost tolerance.

Most of the Western Australian species are easy to propagate from cuttings. Little is known about propagation of the central and South Australian species, although *T. maisoneuevi* has proven difficult to strike (W. Tregea pers. comm.). The eastern Australian species *T. calycina, T. micrantha* and *T. parviflora* can be propagated from tip cuttings of semi-firm shoots which are not in flower, but which may have flower buds. The strike rate varies enormously during the season with the highest rates achieved in early and late summer. Rooting is improved with treatment with 2,000-4,000 ppm Indole Butyric Acid.

No information is available on the use of growth regulators on any of these plants. Cyclocel (CCC)R, AtrinalR and BonziR need to be tested, as they may be effective in inhibiting the undesirable soft new growth which occurs on many species towards the end of the flowering season.
Pests and diseases

A number of pests and diseases have been found on Grampians thryptomene (Beardsell 1992). The main threat to this species in cultivation, both as a cut flower plant and a landscape plant, is its extreme sensitivity to the root rotting pathogen *Phytophthora cinnamomi*. It can however be readily grafted onto the more adaptable *T. saxicola* which has some resistance to *Phytophthora* (Meyers 1993, Beardsell 1993). Tip die-back of branches also occurs from an interaction of the pathogens *Botrytis* sp., *Pestalotiopsis* sp. and *Phoma* sp., which can be controlled by application of Mancozeb® (Beardsell 1992). Large losses of cuttings have also occurred from the soil-borne fungus *Cylindrocladium scoparium*. Cuttings and young plants in the field of *Thryptomene* species are sensitive to dampening-off fungi from the genus *Pythium*. This disease only affects plants less than 10 cm high. To remove the threat from these fungal diseases, all plantations should be regarded as quarantine areas, with limited access to vehicles, machinery and persons from outside. All materials and equipment brought into plantations should be disinfected. Troughs containing a disinfectant should be located at the entrance of farms.

Webbing caterpillars (*Strepsicrates ejectana* (Walker)) feed on the foliage and borers can ring-bark stems. Thrips feed on the nectar and pollen produced by the flowers, and if exporting, these need to be controlled by fumigation or by dipping stems in an insecticide, otherwise shipments may be rejected by overseas quarantine authorities.

Harvesting, handling and post harvest treatment

Harvesting is usually done with secateurs and stems are tied into bunches for storage and transport. Limited post-harvest handling treatments are used, but the flowering stems have a shelf life of up to 14 days if the stems are quickly placed in a cool store in buckets containing a flower preserving solution or covered with moistened hessian covers. Covering with dry hessian does not extend shelf life. One of the main causes of poor quality of flowering stems of Grampians thryptomene and related species in florist shops is poor handling. After harvest the flowers should be cooled, placed in a preserving solution and marketed as soon as possible. Cooling to approximately 1°C is very important before and during all stages after harvest, including transport (Beardsell 1988). Rehydration of flower stems after storage and transport improves quality and vase life. This involves immersion of the lower parts of the stems in a solution containing a germicide and an acid (0.5 g/L citric acid) or commercial preservative for 24 hours (Jones et al. 1993).

Vase life varies between species and even within species. One clone of Grampians thryptomene has a vase life of nearly 14 days at 20°C whereas most clones only last 7 days. However these times can be dramatically improved by appropriate post-harvest handling treatments such as using flower preservatives, recutting stems and regularly changing vase water.

Stems of Grampians thryptomene can be stored for several weeks if treated with a fungicide and packed in boxes lined with moist newsprint. If they are properly rehydrated, there will only be a small reduction in subsequent vase life. This means that boxes of Grampians thryptomene could be sea freighted if treated correctly (Jones et al 1993).
Financial information

A farm growing quality flowering stems of Grampians thryptomene would need a small tractor or all terrain vehicle. The vehicle should be outfitted to spray the crop with insecticides and fungicides. Weeds should be controlled with mowing, herbicides or cultivation. The vehicle should have a trailer for harvesting and bringing the flowers back to the shed in buckets for grading and storage. A shed is required for sorting, grading and processing the flowers. Scales, trimming and banding equipment will be required. A cool room is required to cool the flowers as soon as they are processed, and access to reliable refrigerated transport is needed to take flowers to markets, wholesalers or exporters. Access to a good supply of quality water is important and water disinfection equipment may be required.

A much better return for Grampians thryptomene will be attained only by developing improved varieties, better cultural practices, better postharvest handling, reduced production of poor quality flowers, and better market promotion and product imaging.

The establishment costs for a 1 hectare plantation of Grampians thryptomene is shown in Table 1.

The estimation of the expected gross margin returns for a 1 hectare plot of Grampians thryptomene is shown in Table 2 (data from 1997).

### Table 1. Establishment costs for thryptomene

<table>
<thead>
<tr>
<th></th>
<th>Plants per ha</th>
<th>Plant costs</th>
<th>Irrigation*</th>
<th>Basal fertiliser</th>
<th>Buckets</th>
<th>Weed-mat*</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3,300</td>
<td>$2,640</td>
<td>$2,800</td>
<td>$200</td>
<td>$300</td>
<td>$4,000</td>
<td>$9,940.00</td>
</tr>
</tbody>
</table>

* Not all plantations use irrigation and weed mat

### Table 2. Expected gross margin returns for thryptomene

<table>
<thead>
<tr>
<th></th>
<th>year 1</th>
<th>year 2</th>
<th>year 3</th>
<th>year 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assumptions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant life</td>
<td>10 yrs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No stem/plant</td>
<td>0</td>
<td>10</td>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>No plants/ha</td>
<td>3,300</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No stems/bunch</td>
<td>10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Return per stem</td>
<td>export grade $0.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bunches/plant</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Bunches/ha</td>
<td>0</td>
<td>3,300</td>
<td>6,600</td>
<td>13,200</td>
</tr>
<tr>
<td>Stems/ha</td>
<td>0</td>
<td>33,000</td>
<td>66,000</td>
<td>132,000</td>
</tr>
<tr>
<td>Gross return/ha</td>
<td>0</td>
<td>5,940</td>
<td>11,880</td>
<td>23,760</td>
</tr>
<tr>
<td>Farm maintenance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour @ $12/hr planting</td>
<td>60 plants/hr</td>
<td>660</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertiliser</td>
<td>1,800</td>
<td>1,800</td>
<td>1,800</td>
<td>1,800</td>
</tr>
<tr>
<td>Chemicals</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Operating expenses</td>
<td>2,000</td>
<td>2,000</td>
<td>2,000</td>
<td>2,000</td>
</tr>
<tr>
<td>Subtotal</td>
<td>5,440</td>
<td>4,780</td>
<td>4,780</td>
<td>4,780</td>
</tr>
<tr>
<td>Harvest/postharvest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour @ $12/hr harvesting</td>
<td>60 bunches/hr</td>
<td>0</td>
<td>660</td>
<td>1,320</td>
</tr>
<tr>
<td>Counting, dipping, boxing</td>
<td>0</td>
<td>990</td>
<td>1,980</td>
<td>3,960</td>
</tr>
<tr>
<td>Boxes @ $4.50/ea</td>
<td>0</td>
<td>495</td>
<td>990</td>
<td>1,980</td>
</tr>
<tr>
<td>Freight @ $2.50/box</td>
<td>0</td>
<td>275</td>
<td>550</td>
<td>1,100</td>
</tr>
<tr>
<td>Subtotal</td>
<td>5,440</td>
<td>7,695</td>
<td>10,610</td>
<td>16,440</td>
</tr>
<tr>
<td>Gross margin</td>
<td>-5,440</td>
<td>-1,755</td>
<td>1,270</td>
<td>7,320</td>
</tr>
</tbody>
</table>
Future developments

Several species including *T. ericaea*, *T. elliottii*, *T. micrantha* and *T. parviflora*, and related genera such as *Baeckea*, *Astartea*, *Micromyrtus* and *Scholtzia* could be potential cut flower crops if research is done on selection of good varieties, propagation methods, cultivation and post harvest technologies. More information is needed on the arid zone species before they could be introduced into cultivation in dry regions.

Key references


Key messages

- Grampians thryptomene has the potential to be a world class filler flower if only high quality flowering stems are marketed and promoted.
  - This market will be undermined if poor quality flowering stems continue to be produced
- Most species of *Thryptomene* are not well known in cultivation and much work needs to be done to develop them into high quality, profitable crops

Key statistics

- Most of the annual production (10 million flowering stems) of Grampians thryptomene is exported
- Approximately 3 million stems are sold annually on the domestic market in the eastern states
- Thryptomene is the largest flower export from Victoria with between 250,000-300,000 kg sold annually to markets on the west coast of the USA

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Introduction

Five new native cut foliage products are being developed in north Queensland with the help of a RIRDC and industry funded research project. *Grevillea baileyana*, *Athertonia diversifolia* and *Lomatia fraxinifolia* are endemic to rainforests in north Queensland and have been identified as having significant potential as cut foliage. *Stenocarpus* ‘Forest Lace’ PBR, and *Stenocarpus* ‘Forest Gem’ PBR have been developed from parent plants endemic to north Queensland rainforests and both varieties are protected by Plant Breeders Rights owned by Yuruga Nursery P/L.

Geraldton wax flower has been grown on the Atherton Tablelands previously, however the industry has declined significantly, which has been partly due to the devastating effects of *Phytophthora* and *Botrytis*. Researchers have now turned their attention to growing Australian plants native to north Queensland in an attempt to overcome potential disease problems.

The three species and two varieties being developed grow very well in a range of climates on the Atherton Tablelands.
Stenocarpus ‘Forest Gem’ and Stenocarpus ‘Forest Lace’ are new products to the market, whereas Grevillea baileyana, Lomatia fraxinifolia, and Athertonia diversifolia have been available to the market in small volumes for a few years. The two Stenocarpus varieties are considered filler foliages; Stenocarpus ‘Forest Lace’ is unlike any other cut foliage currently available and Stenocarpus ‘Forest Gem’ is similar in appearance to Persoonia longifolia, otherwise known as Snotty Gobble or Barker Bush. Grevillea baileyana, Lomatia fraxinifolia and Athertonia diversifolia are considered feature foliages and have their own unique characteristics.

The industry is in its infancy, however is developing quickly. All five foliages have recently been planted on farms on the Atherton Tablelands and on the Sunshine Coast. Small volumes of Athertonia diversifolia, Lomatia fraxinifolia and Grevillea baileyana have been produced on farms on the north coast of New South Wales for a number of years.

Markets and marketing issues

Foliage from north Queensland is marketed to local florists in the Cairns region and through a wholesaler at the National Flower Centre (NFC) in Melbourne. Foliage produced on the New South Wales north coast is sold through the Flemington markets in Sydney and the NFC in Melbourne. Currently, the industry in north Queensland does not produce enough material (of any species/variet) to support export markets, however trial shipments of the foliages have been sent to a number of overseas clients. Comments from export markets have been encouraging and export trials will be carried out more regularly over the coming years. Domestic and export market research is very important for the further development of all five foliages and is the subject of a proposed RIRDC project.

All five foliage products have unique characteristics that allow the foliages to display a point of difference in the market place. Grevillea baileyana has a strong bronze colouring on the underside of the leaves, which creates a dramatic contrast to the green topside of the leaf. Lomatia fraxinifolia leaves are striking, glossy and dark green and can be used as a base or backing in an arrangement. Athertonia diversifolia leaves are deeply lobed and very glossy and have a vase life of 21 days. Stenocarpus ‘Forest Lace’ is fern-like in appearance however in contrast to other ferns, it has a vase life of over 21 days and can produce stems of 60-80 cm in length. Stenocarpus ‘Forest Gem’ is filler foliage with a vase life of over 21 days; it is similar in appearance to Persoonia longifolia.

All five foliages mix very well with traditional and native flowers in arrangements and bouquets. The following table details the form in which each product has been traded to date and indications of prices paid to growers. The prices paid to growers will depend on a number of factors including quality, stem/leaf length and the particular market in which the product is sold.

Production requirements

Athertonia diversifolia and Lomatia fraxinifolia are suited to the climatic conditions of the upper Tablelands in high rainfall and high altitude areas (700 m – 1,000 m above sea level). Both species prefer reasonably fertile soils and humid conditions. Production of these two species is recommended in the areas surrounding Yungaburra, Atherton, Malanda, Millaa Millaa, Topaz, Tarzali and Kairi. Lomatia fraxinifolia has also been grown successfully on the Sunshine Coast and on the north coast of New South Wales. Athertonia diversifolia has been grown previously at Coffs Harbour in sheltered areas.

For best results, plants should be grown under shade cloth, as this reduces wind and sunburn damage to leaves. Plants should be irrigated using drippers or sprinklers.

Table 1. Wholesale price estimates for all five native foliages based on stem/leaf length and number of stems/leaves per bunch

<table>
<thead>
<tr>
<th>Product</th>
<th>Stem or leaf</th>
<th>Number of stems/leaves per bunch</th>
<th>Length of stems/leaves</th>
<th>Estimated wholesale price per bunch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grevillea baileyana</td>
<td>stem</td>
<td>5</td>
<td>40-60cm</td>
<td>$4.50 + GST</td>
</tr>
<tr>
<td>Athertonia diversifolia</td>
<td>leaf</td>
<td>5</td>
<td>30-60cm</td>
<td>$3.00 + GST</td>
</tr>
<tr>
<td>Lomatia fraxinifolia</td>
<td>leaf</td>
<td>5</td>
<td>30-60cm</td>
<td>$3.00 + GST</td>
</tr>
<tr>
<td>Stenocarpus ‘Forest Lace’</td>
<td>stem</td>
<td>5</td>
<td>60-100cm</td>
<td>$3.00 + GST</td>
</tr>
<tr>
<td>Stenocarpus ‘Forest Gem’</td>
<td>stem</td>
<td>5</td>
<td>60-100cm</td>
<td>$3.00 + GST</td>
</tr>
</tbody>
</table>
Recent trials have shown that *Stenocarpus* ‘Forest Gem’ and *Stenocarpus* ‘Forest Lace’ grow well in all climatic conditions and soil types on the Atherton Tablelands at a range of altitudes (400 m – 900 m above sea level). Production on poorer soils will require better nutritional management and both varieties can tolerate windy conditions without any adverse affects. *Stenocarpus* ‘Forest Gem’ has been grown successfully on the Sunshine Coast in Queensland and it is anticipated that *Stenocarpus* ‘Forest Lace’ will also. Both varieties have been irrigated using drippers, sprinklers and solid set overhead sprays with good results.

*Grevillea baileyana* is suited to climatic conditions of the lower Tablelands and does not cope with the cold conditions experienced at higher altitudes (800 m – 1,000 m above sea level) in the Upper Barron and Ravenshoe areas of the Atherton Tablelands. *Grevillea baileyana* can be grown on a range of soil types and production is recommended in the areas surrounding Yungaburra, Atherton, Tolga, Mareeba and Dimbulah. This species has also been grown successfully on the Sunshine Coast and on the north coast of New South Wales. Protection from prevailing winds is preferred and plants can be irrigated with drippers, sprinklers, or solid set overhead sprays.

The information provided in this section is based on research being carried out and is relevant to the range of growing conditions available on the Atherton Tablelands.

It is anticipated that all species/varieties will adapt to the climatic conditions in frost-free areas of southeast Queensland and northern New South Wales.

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**Species/varieties**

**Lomatia fraxinifolia**

– Proteaceae. This species is widespread in north Queensland rainforests at mid to high altitude. Propagation is primarily from seed collected from wild stands. *Lomatia fraxinifolia* is available in forestry tubes from Yuruga Nursery in north Queensland and from other native plant nurseries in southeast Queensland.

**Athertonia diversifolia**

– Proteaceae. This species is found growing in very wet rainforest (low to high altitude) from Cape Tribulation to the southern Atherton Tablelands. Propagation is primarily from seed collected from wild stands. *Athertonia diversifolia* is available in forestry tubes from Yuruga Nursery in north Queensland and from other native plant nurseries in southeast Queensland.
**Grevillea baileyana**

– Proteaceae. This species is widespread in north Queensland rainforests at low to mid altitudes. Propagation is primarily from seed collected from cultivated plants and wild stands. *Grevillea baileyana* is available from a number of native plant nurseries in Queensland.

**Stenocarpus ‘Forest Gem’**

– Proteaceae. This variety is not found growing in the wild and has been selected by Yuruga Nursery Pty Ltd. The propagation of this plant is protected by Plant Breeders Rights owned by Yuruga Nursery. This variety is only available from Yuruga Nursery in north Queensland. Unauthorised propagation of this variety is an infringement under the Plant Breeders Rights Act 1994.

**Stenocarpus ‘Forest Lace’**

– Proteaceae. This variety is not found growing in the wild and has been selected by Yuruga Nursery Pty Ltd. The propagation of this plant is protected by Plant Breeders Rights owned by Yuruga Nursery. This variety is only available from Yuruga Nursery in north Queensland. Unauthorised propagation of this variety is an infringement under the Plant Breeders Rights Act 1994.
Agronomy

The following agronomic information is relevant to all five species. However, there may be slight variations for individual species/varieties, which are not included in the text. See key contacts for further information.

Ground preparation is an essential part of establishing the plantation and the layout will be determined by the production system chosen (i.e. single rows, double rows or multi rows). Prior to planting, the ground must be sufficiently ripped and rotary hoed to produce a well-tilled soil for planting. Rows should be raised up 40-50 cm to assist with drainage and disease control. The irrigation system should be installed and operational prior to planting, so the ground can be well watered before planting.

Young plants need to be sun-hardened by exposing the plants to full sun for three weeks before planting. They also need to be well fertilised, preferably by the supplying nursery prior to the sale of the plants. A basal application of fertiliser is not required at planting. However newly planted tube stock needs to be well watered for the first six to eight weeks. A suitable mulch should be applied to rows to suppress weed growth and reduce evaporation. Peanut shell and grass hay have been used in trials on the Atherton Tablelands with good results. Weed mat would also provide sufficient control of weeds.

The first application of fertiliser should be approximately three months after planting, providing this falls in a warm time of the year. Tube stock planted from January to April will not require fertiliser until the September of the same year, providing soil is relatively fertile. Plants should be fertilised a total number of four to five times per year after pruning and harvesting. Early indications suggest that plants can be harvested two or three times per year. Fertilisers recommended for use on these species include:

- CK77(S) – 250 kg/ha
- Nitrophoska Blue Special – 250 kg/ha
- Nitram – 85 kg/ha

All five species should be pruned (by cutting back the main stem) approximately six to eight months after planting, or when they are obviously well established and have reached a height of 1 m. Pruning should always be carried out hygienically using sharp secateurs and pruning should be avoided during wet weather. To sterilise secateurs spray with methylated spirits between each plant, or if this isn’t practical sterilise at least every 10 plants. To prevent fungal infection of the pruning cut, it is recommended that growers apply a sealant to the wound. Commercially available pruning and grafting compounds such as ‘Steriprune’ are suitable.

Efficient management of nutrition and pruning in the first year will enable the first stems/leaves to be harvested at the end of the second year. Efficient nutritional management should be based on the results and recommendations of a soil test. This takes a lot of the guesswork out of nutritional management, providing the nutrition consultant has experience with Australian natives.

Pest and disease control

Over the past year, a number of different pests and diseases affecting the native foliages have been sampled and identified. At the time of writing, three more pests (leaf miner, looper and hairy caterpillar) are being grown out in preparation for identification. Once identified, chemicals will be tested on these pests. The pests and diseases identified at this stage are:

**Grevillea baileyana**

*Coccus longulus* (Douglas) – long soft scale. For control apply white oil at a rate of 1-2 litres per 100 litres of water – two applications 14 days apart.

**Stenocarpus ‘Forest Gem’ and S. ‘Forest Lace’**

*Coccus longulus* (Douglas) – long soft scale. Same control as for *Grevillea baileyana*.

**Stenocarpus ‘Forest Gem’**

*Rhyparida discopunctulata* – swarming leaf beetle. Control not determined.

Harvest/storage and post harvest treatments

Leaves and stems of the three species and two varieties must only be harvested when mature. Material that is immature will not last after harvesting and will therefore not arrive at the market in acceptable condition. Product specifications addressing maturity will be developed over the next couple of years for each species. It is always best to harvest foliage early in the morning when turgor pressure in the foliage is high. Prepare buckets with post harvest solution prior to harvesting so that foliage can be transferred directly into it after harvest. A recommended post harvest solution is Chrysal Clear Professional 3, which can be purchased from major garden and nursery suppliers. Pulse the foliage in this solution, preferably in a coldroom at 14°C for a period of 6-12 hours prior to packaging. It is anticipated that the foliage
can be stored at 4°C without any adverse affects however good results have been achieved with storage at 14°C. Stenocarpus ‘Forest Gem’ and Stenocarpus ‘Forest Lace’ have been packaged with 3 five stem bunches in a single sleeve. Placing perforated sleeves around the foliage means it can be packed neatly and tightly to allow for a maximum number of bunches per box. This is essential when freighting long distances, such as from north Queensland to Melbourne markets, to reduce costs and damage. Athertonia diversifolia, Lomatia fraxinifolia, and Grevillea baileyana have not been supplied to the domestic market from north Queensland in significant volumes. Athertonia diversifolia and Lomatia fraxinifolia leaves bruise easily and future research is planned to assess different methods of packaging for these two species. It is anticipated that Grevillea baileyana stems can be packaged in a similar way to the two Stenocarpus varieties.

Product specifications for each foliage product will depend on market requirements. It is best to work closely with your agent or customer to develop specifications on stem/leaf length, stems/leaves per bunch, leaf colour and maturity, stem thickness and packaging and handling protocols.

Financial information

The financial information in the following table has been calculated using early estimates of yields and farm gate prices. More accurate information will be available in the coming years as a result of the research project. The information provided is based on a double row production system with dripper irrigation.

| Table 2. Investment inputs required and expected returns for all five native foliage products |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| **Costs**                      | Stenocarpus ‘Forest Gem’ and Stenocarpus ‘Forest Lace’ | Lomatia fraxinifolia and Athertonia diversifolia | Grevillea baileyana |
| Investment inputs required (not dependent on number of hectares) | | | |
| Soil analysis and recommendations | 200 | 200 | 200 |
| Packing shed | 15000 | 15000 | 15000 |
| Industry association membership | 500 | 500 | 500 |
| Consumables | 500 | 500 | 500 |
| Tractor, ripper and rotary hoe | 140000 | 140000 | 140000 |
| Working Capital | 9600 | 6465 | 7426 |
| Total Investment Inputs | 165800 | 162665 | 163626 |
| Investment inputs per hectare | | | |
| Plants | 8250 | 4500 | 800 |
| Ground preparation | 1600 | 1600 | 1600 |
| Irrigation equipment | 4000 | 4000 | 3000 |
| Mulch (weed mat) | 3520 | 3520 | 2520 |
| Total Investment Inputs (per ha) | 17370 | 13620 | 7920 |
| Recurrent inputs (per hectare per year) | | | |
| Soil analysis and recommendations | 200 | 200 | 200 |
| Replacement plants | 100 | 100 | 100 |
| Irrigation equipment maintenance | 100 | 100 | 100 |
| Water | 42 | 42 | 10 |
| Fertilisers | 400 | 400 | 100 |
| Herbicide | 200 | 200 | 200 |
| Pesticides | 1128 | 1128 | 1128 |
| Industry association membership | 500 | 500 | 500 |
| Sleeves | 1140 | 900 | 456 |
| Cartons | 1290 | 645 | 1032 |
| Freight | 4500 | 2250 | 3600 |
| Total Recurrent Inputs (per ha per year) | 9600 | 6465 | 7426 |
| Estimated yield per hectare per year | | | |
| Number of bunches | 12000 | 12000 | 4800 |
| Return to growers per hectare per year | | | |
| Dollar returns per hectare | 36000 | 36000 | 21600 |

Please note these costs, estimated returns and yields are only indications at this stage. Returns will depend on a number of different factors such as stem length and quality. This information should be used only as a guide and calculations have been based on the north Queensland industry. Recurrent inputs will vary between regions. It is recommended that Lomatia fraxinifolia and Athertonia diversifolia be grown under shade house conditions. Costs of establishing this production system have not been included in this financial evaluation.
Key references


Key statistics
- 6,500 plants in ground (5 species)
- 6,000 plants on order (5 species)
- 9 growers (mostly north QLD)
- Average of 720 plants per grower
- Significant increases in plant numbers expected

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Introduction

Waxflower is the generic term for the Geraldton wax, *Chamelaucium uncinatum*, and other *Chamelaucium* species and hybrids. Together they are Australia’s most significant commercial native cutflower, and Australia’s leading export flower. They are popular because of their vase life, floral display and productivity. They are used primarily as feature fillers although some of the newer hybrids are now being used by some florists as feature flowers in their own right. The superior floral display and vase life is likely to increase demand for the newer hybrids. Vase life will become increasingly important for all flowers as production areas move further away from the major market centres.

Waxflowers are grown in many countries for sale in local and major international trading centres. Major production areas include California in the USA, Israel, Australia, Peru, Chile, and South Africa, with interest now being shown in China.

Australian growers will find it increasingly difficult to compete with growers from other Southern Hemisphere countries such as Peru and South Africa as these...
areas produce at similar times of the year and have far lower labour and freight costs. Northern Hemisphere growers complement the Australian growing season and provide product to the market when Australian growers cannot.

The future for Australian growers lies in developing and accessing new varieties using the genetic resource in Western Australia and targeting the premium quality part of the market, while at the same time reducing production costs.

Growing waxflower requires hard physical work and long hours. Like operators of most rural enterprises, those with practical skills and the ability to improvise and learn will have an advantage. Business and management skills and the ability to adapt to changing market conditions are also highly beneficial.

Markets and marketing issues

Australian produced waxflower is sold primarily to Japan and North America, with some product also going to Europe. The Japanese and European markets are normally provided with bunches based on stem number, while the North American markets receive product based on weight. The Australian market is also growing, particularly in Sydney and Melbourne. Product for the Japanese and European markets is normally sent to the flower auctions, although direct selling is becoming more prevalent in Europe. Product for the USA is normally sold pre-ordered to wholesalers.

Product is airfreighted overseas after being packed in boxes that weigh between 2kg and 16kg gross, depending on market destination. A 3kg box packed for the Japanese market can hold either fifty 70cm stems or seventy 60cm stems.

Larger sized boxes may be repacked once they reach Japan. A 16kg box destined for Europe will hold seventy 5 stem bunches while the same sized box packed for the US market will hold about forty 400g bunches.

Many growers sell to locally based wholesalers or exporters who then arrange sale and shipping to the market. These dealers mostly pay a rate per bunch, with the price dependent on variety and the amount of value adding, through bunching, and post-harvest treatment. From time to time, commission agents have also been part of the market, taking a percentage of the selling price for putting the product in the market.

Growers may receive better returns for their product through using such agents, but they also have higher risks as they are responsible for any transport chain or market failures. Some of the larger growers handle the export chain themselves and often buy product from smaller growers.

Waxflower performs well as an export product if the cool chain is unbroken from harvest through to the final market destination. However product is often unloaded during transit, sometimes onto hot airport tarmacs, leading to serious quality decline.

Australia produces up to 30 million waxflower stems per annum, with the major production centres being Western Australia and Queensland. A significant quantity of waxflower is also grown in Victoria and South Australia and to a lesser extent in New South Wales.

The major production area internationally is in the regions adjacent to the San Diego area in California, USA. Production is between 300 and 500 million stems per year, nearly all of which is sold on the US domestic market. Israel produces around 70 million stems per annum, for the European market. Growers in South America, particularly Chile and Peru, are expanding their operations, mainly targeting the US market, and also the European market. Waxflower growing is also expanding in South Africa, and China is showing interest in this crop.
Waxflower

Relevant text:

**Recent prices and trends**

Prices received for waxflower will vary depending on season, variety, quality and market. Data from the Ota Floriculture Auction in Japan indicate significant price variation (Table 2).

The price received of about 35 yen average over 4 months at 67 yen exchange rate equates to about $5.20 for a 10 stem bunch. For the same product at a 50 yen exchange rate, the price received equates to $7.00, while at an exchange rate of 80 yen it is $4.38. Therefore exchange rate can have a severe impact on profitability, to the extent that it may cost the grower or exporter money to sell product in that market.

Growers also need to be aware there are significant costs of getting the product to market (Table 3). In this example the supply chain is in deficit unless the stem price is about 50 yen or higher. This is without taking into account reasonable profit margins for the exporters.

Exporters would make significant losses at the average price of 35 yen shown in table 2, if the figures in table 3 reflected the true costs of the supply chain. In such a situation they would be forced to significantly lower the price paid to growers. Growers therefore need to understand their costs of production, to determine the level at which they will lose money putting their product on the market.

**Production requirements**

Waxflower is endemic to Western Australia, occurring in the South West Botanical province. The species and varieties used for production, or those used as parents to produce artificial hybrids, mostly occur in well drained slightly acidic to neutral soils. These natural conditions are a good guide to their tolerances in cultivation. Sandy or sandy loam soils are preferred for cultivation. Waxflower is intolerant of poorly drained soils, particularly heavy clays or waterlogged conditions. Most varieties do not tolerate alkaline soils, although a few selections are better adapted to soils with a pH between 7.5 and 8.5.

Waxflower is intolerant of frost (screen temperature less than 0°C) which is likely to render the crop unmarketable due to flower and growing tip damage. Severe frosts can kill the whole plant. Warm humid conditions are also undesirable because the plants and flowers can be severely affected by the grey mould *Botrytis*.

Waxflower prefers high light intensity and does not flower well in shaded conditions. Plants

---

**Table 1: Australian waxflower exports**

<table>
<thead>
<tr>
<th>Year</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002-03</td>
<td>$8,104,000</td>
</tr>
<tr>
<td>2001-02</td>
<td>$7,128,000</td>
</tr>
<tr>
<td>2000-01</td>
<td>$5,245,000</td>
</tr>
<tr>
<td>1999-00</td>
<td>$4,233,000</td>
</tr>
<tr>
<td>1998-99</td>
<td>$3,850,000</td>
</tr>
<tr>
<td>1997-98</td>
<td>$2,175,000</td>
</tr>
<tr>
<td>1996-97</td>
<td>$1,667,000</td>
</tr>
<tr>
<td>1995-96</td>
<td>$1,791,000</td>
</tr>
</tbody>
</table>

Source: ABS and Western Australian Department of Agriculture

**Table 2: Ota Floriculture Auction 2002 prices**

<table>
<thead>
<tr>
<th>Month</th>
<th>Stems sold</th>
<th>High price (yen)</th>
<th>Average price (yen)</th>
<th>Low price (yen)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>20,040</td>
<td>60</td>
<td>32</td>
<td>3</td>
</tr>
<tr>
<td>August</td>
<td>27,495</td>
<td>100</td>
<td>48</td>
<td>10</td>
</tr>
<tr>
<td>September</td>
<td>42,270</td>
<td>90</td>
<td>35</td>
<td>5</td>
</tr>
<tr>
<td>October</td>
<td>32,080</td>
<td>80</td>
<td>33</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Sourced from Global Market news records on http://emi.h.chiba-u.ac.jp. The exchange rate was approximately AUD=67yen

**Table 3. Estimated costs of the waxflower supply chain to Japan. Figures are indicative only**

<table>
<thead>
<tr>
<th>Price per stem at auction Japan (A$1=67yen)</th>
<th>30 yen</th>
<th>50 yen</th>
<th>70 yen*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price received per bunch (10 stems) (A$)</td>
<td>$4.50</td>
<td>$7.50</td>
<td>$10.50</td>
</tr>
<tr>
<td>Auction commission (10%)</td>
<td>$0.45</td>
<td>$0.75</td>
<td>$1.05</td>
</tr>
<tr>
<td>Japanese agent fees (10%)</td>
<td>$0.45</td>
<td>$0.75</td>
<td>$1.05</td>
</tr>
<tr>
<td>Japanese clearing/internal freight cost</td>
<td>$0.50</td>
<td>$0.50</td>
<td>$0.50</td>
</tr>
<tr>
<td>Airfreight $/bunch</td>
<td>$2.10</td>
<td>$2.10</td>
<td>$2.50</td>
</tr>
<tr>
<td>Handling, fumigation and packing $/bunch</td>
<td>$0.70</td>
<td>$0.70</td>
<td>$0.70</td>
</tr>
<tr>
<td>Freight to packing shed from farm $/bunch</td>
<td>$0.15</td>
<td>$0.15</td>
<td>$0.20</td>
</tr>
<tr>
<td>Grower price (fixed price $/bunch)</td>
<td>$2.20</td>
<td>$2.20</td>
<td>$2.50</td>
</tr>
<tr>
<td>Total costs of supply chain $/bunch</td>
<td>$6.55</td>
<td>$7.15</td>
<td>$8.50</td>
</tr>
<tr>
<td>Supply chain (Deficit)/Surplus $/bunch</td>
<td>$(2.05)</td>
<td>$(0.35)</td>
<td>$(2.00)</td>
</tr>
</tbody>
</table>

*Longer stems receive higher prices, but are also heavier and cost more to ship.*
should be positioned where they get maximum sunshine. If the planting location has significant topographical variation avoid south facing slopes, particularly in the higher latitudes.

Waxflower needs to be well watered for optimum production, with total soluble salt levels less than 270 millisiemens per metre (about 1500 ppm) desirable. Water volume needs to be about 70% of pan evaporation for best results. Monitoring water use through tensiometers can be an excellent agronomic management tool.

The areas most suitable for producing waxflower are those with a Mediterranean type climate (cool wet winters, hot, dry summers) but with water available for irrigation during summer, their period for maximum growth under cultivation.

Varieties/cultivars

There are over 100 named varieties of waxflower, most of these being selections of the Geraldton wax, *C. uncinatum*. By far the most popular of these is ‘Purple Pride’, which has been grown for many years and has become an industry standard. It is floriferous with a reasonable vase life and little ongrowth. This variety is known as ‘Violet’ in Israel. ‘Mullering Brook’ is another popular *C. uncinatum* cultivar. It is a mid season variety with long straight stems with terminal light pink flowers about 12 mm in diameter. ‘Alba’, a vigorous mid season white flowered variety was widely grown in the late 1980’s to early 1990’s, but has declined significantly recently due to the availability of superior white flowered hybrid varieties.

Newer varieties are predominantly hybrids, with superior vase life and floral display. Some of the most sought after are hybrids between *C. uncinatum* and the large waxflower, *C. megalopetalum*. These hybrids have commercial yields inherited from *C. uncinatum*, combined with the floral display and extended vase life of the *C. megalopetalum* parent.

Examples of white flowered hybrids with this parentage include Bridal Pearl(l), Esperance Pearl(l), Denmark Pearl(l), Crystal Pearl(l) and Ivory Pearl. These higher quality white flowered hybrids are collectively known as Pearlflowers, to distinguish them from the generic waxflower.

Examples of hybrids between *C. uncinatum* and *C. megalopetalum* with coloured flowers include Purple Gem(l), Pastel Gem(l) and Painted Lady(l). These higher quality coloured hybrids are collectively known as Gemflowers, to distinguish them from waxflower.

Intergeneric hybrids between *C. uncinatum* and *Verticordia plumosa* are also becoming generally available. These varieties have small terminal massed flowers with pale to deep pink colours. They are generally more tolerant to ethylene than other cultivars. Examples include Jasper(l), Southern Stars(l) and Eric John(l). These are collectively called Starflowers.

Some of the newer hybrids are only available from licenced propagators, as they are protected under Plant Breeders Rights legislation. Contact your local Department of Agriculture, or industry body for contact details of licenced propagators. Older, common varieties should be widely available from most reputable propagators.

Cultural practices/agronomy

Soil conditions on the site on which you are planning to grow waxflower should be tested for soil pH. As discussed in ‘Production requirements’ the soil pH should be slightly acidic to neutral for most varieties. Growing waxflower on soils with a pH outside this range is likely to result in nutrient deficiencies and greater management requirements to overcome such deficiencies, adding to the costs of production. Growers in Israel have significant issues with yellowing foliage due to iron deficiency because of their alkaline soils.
The levels of soil nutrients should also be determined prior to planting, particularly if the area has been used in the past for crop or animal production. For instance, high levels of nitrogen will cause excessive tip growth past the flowers prior to harvest, leading to a drop in quality. High levels of phosphorous could have a detrimental effect on some varieties, particularly intergeneric Verticordia hybrids.

Prior to planting or ordering planting stock, the site chosen should be tested for soil pathogens, and treated accordingly if present. The plants should be purchased from a reputable propagator, preferably one who is accredited under the national nursery accreditation scheme. Buying high quality stock reduces the risk of introducing soil pathogens to the site in the potting mix. Growers have been known to introduce Phytophthora spp. to an otherwise uninfected site through purchasing plants grown in infected mix, leading to high death rates and an ongoing management problem.

Plants should also be checked for rootbinding before planting. Rootbinding is probably the highest cause of plant death in waxflower plantations. If there is any sign of root curling at the base of the tube, or roots encircling the insides of the tube rather than growing straight down, then the roots need to be pruned to ensure the roots are vertical. The top of the plant should also be pruned at the same time to prevent excessive moisture loss through transpiration that a reduced root system will be unable to compensate for.

Wind breaks are beneficial, particularly for young plants. However, if using trees, shading and root competition are issues that will affect later growth and flowering. Protecting young plants with a growing bag for the first 3 to 6 months increases early plant growth and increases plant survival, particularly in harsher climates.

Site preparation will depend on which varieties are to be planted, as plant spacing will differ depending on the vigour and spread of the variety. Most new plantings are now in single rows. Between row spacing is often dependent on the size of machinery used in spraying and/or harvesting although 3 or 4 metres is fairly common. C. uncinatum cultivars often have within row plant spacings of 2m, while many of the interspecific Pearlflower and Gemflower types are planted at 1.5 m spacings. Intergeneric Verticordia hybrids can be planted at 1 m within row spacings.

Weed matting can be beneficial, particularly in the first year or two, to prevent young plants being out-competed by weeds, and to allow control measures to be effective without harming the plant. However, the warm moist conditions under such matting may increase the incidence of soil borne pathogens.

**Equipment and facility requirements**

Growers will need access to spray equipment suitable for penetrating dense foliage and the machinery to apply it, such as a tractor or a 4 wheeled motor bike. A pump, irrigation and fertilising equipment is also essential.

Harvesting and pruning equipment may include various hand picking tools, hedge trimmers, and/or machinery adapted or designed for mechanical harvesting and pruning.
Irrigation requirements
In the light sandy soils often found in Western Australia waxflower can benefit by irrigating up to three times per day in summer for optimum production. This allows the plants to access the water they need for maximum growth. Applying water less frequently at higher volumes can make the water unavailable as it will drain past the root zone, often taking valuable nutrients with it. For medium to large plantations such watering frequency requires a sophisticated irrigation system and a professional should be consulted.

Waxflower grown in heavier soils with better water holding capacity, normally requires less frequent irrigation.

A well managed crop provided with the optimum levels of water and nutrition can provide a harvest 12 to 15 months after planting, which is good for the cash flow of the enterprise. However most growers get their first returns in the second year after planting.

Pest and disease control
Pests and diseases need to be controlled both pre and post harvest. Harvested material must be free of insects, spiders, snails and other organisms that could be a quarantine issue. Levels of tolerance for the presence of pests and/or diseases vary depending on the market to which the flowers are sent.

Insects
A range of thrips, bugs, beetles, wasps, ants and bees are attracted to waxflower for the nectar and/or pollen. Some beetles will also chew the flowers. Field numbers need to be reduced through the application of insecticides as post-harvest disinfestation on its own does not kill high enough numbers for effective quarantine treatment.

Consult your local Department of Agriculture or chemical supplier, for the most up to date registered insecticides.

Gall wasp can be a serious pest in Australia in some seasons. The wasp causes tiny galls on young leaves reducing the market appeal and causing a quarantine problem. Control of gall wasp can be difficult as regular spraying can severely reduce the numbers of natural predators, and may lead to increased infestation. Some varieties are more susceptible to this pest than others.

Waxflower can be ring-barked below the soil surface by the larvae of a weevil native to Western Australia, causing severe damage or death. Control is through an annual soil drench of a suitable registered chemical.

Leaf webbing caterpillars can also attack waxflower, causing distorted leaves and stems. Control is through regular applications of a synthetic pyrethroid.

Soil borne diseases
While soil borne diseases can be a significant problem in waxflower, probably the most common cause of plant death is from root binding. The symptoms of root binding are very similar to those caused by soil borne diseases.

The most significant disease of waxflower is Phytophthora spp. Species include P. nicotianae and P. cinamomi. Symptoms of infection are leaf yellowing, leaf drop and tip death followed by the whole plant dying. Control is difficult once a plantation is infected with this disease. Therefore it is best to avoid contamination. This begins with site selection, and testing for the presence of the disease before purchasing the property or planting a new...
Other avoidance methods include ensuring all planting stock and machinery are free of the disease and the use of chemical baths when entering the site. Chlorinating irrigation water may also be necessary.

Elimination of the disease once present is difficult but can be achieved through sterilisation. Suppressing the disease is probably the most effective treatment once it is present. The most widely used technique is a foliar spray with phosphonic acid at regular intervals. This does not kill the disease but prevents infection while the chemical is active.

Other soil borne problems include collar rot caused by *Rhizoctonia* spp. and *Cylindrocladium* spp. *Cylindrocladium* spp. can also cause root rots, as can *Pythium* spp. particularly on young plants. These diseases can be controlled through the use of fungicides. For the most up to date registered products contact your local Department of Agriculture.

The other major soil borne pathogen on waxflower is nematodes. Infected plants generally are less vigorous and unhealthy. Root symptoms can be increased branching or galls. However, these symptoms are not always present. Control is normally through soil sterilisation prior to planting or through the application of Nemacur® in plantations. However the effectiveness of Nemacur® can decline with repeated applications due to enhanced biodegradation.

Recently some growers have been growing waxflower grafted onto rootstocks tolerant to soil borne diseases. While grafted plants will have a higher initial cost, this is likely to be far less than the ongoing management and replanting costs and the costs of lost production.

**Foliar diseases**

Fungal foliar diseases can be a major problem for waxflower growers. The general principles of good hygiene and planting and pruning to maintain a good airflow around plants will aid in controlling fungal infections. Chemical control of foliar diseases can be achieved through the application of fungicides. These chemicals should be rotated to prevent the build up of resistant fungal strains, with no more than three consecutive applications from the one chemical group. Consult your local Department of Agriculture or chemical supplier for the most up to date registered products.

*Botrytis cinerea* is the most significant fungal disease and needs to be controlled from bud emergence through to post harvest, particularly during or immediately after cool wet weather. Flowers are the most susceptible part of the plant. *Botrytis* can cause discolouration and flower deformity and flower drop after harvest. The fresh new shoots on plants can die off following infection from this disease.

*Alternaria alternata* is a fungal disease that also affects flowers and causes stem and leaf discolouration and death. Symptoms include small dead spots with a reddish border on leaves and stems, and brown lesions on the outer edges of the petals.

Powdery mildew is the third major fungal disease of waxflower. Varieties vary significantly in susceptibility to this disease, with some hybrids between *C. uncinatum* and *C. megalopetalum* and intergeneric hybrids between *C. uncinatum* and *Verticordia plumosa* being more susceptible than most *C. uncinatum* selections. This fungus can thrive in warm dry conditions. Infection with powdery mildew can cause severe leaf drop under some conditions. Other symptoms include a white powdery substance on the leaves and stems or banded chlorosis on the leaves.

**Disclaimer**

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**Harvest/handling/storage/post harvest treatments/processing requirements**

The highest costs of waxflower production are from harvest onwards, and therefore efficiencies in this area are critical for good economic outcomes. Harvest and handling practices are likely to differ depending on the production scale. However, the principles are the same.

Stems are normally hand cut when the number of flowers open is between 30 and 70%. The level of flowers open is dependent on variety time of season and market requirements. Stems can be
graded either as they are cut or once they are in the packing shed. The better-synchronised flowering of some of the new hybrids may allow greater use of mechanical harvesting and therefore reducing labour costs.

Stems are normally graded depending on the market to which they are being sent. Traditionally stems for the Japanese and European markets are bunched according to length and stem number for example – ten 60 or 70cm stems, or five 80 cm stems. Product for the USA is normally bunched by weight and stem length. Bunches are normally 400 or 600g bunches either 60 or 70 cm long.

Waxflower can suffer severe flower drop from the effects of ethylene, rendering the product unsaleable. Ethylene is a gas produced naturally from ripening fruit and from artificial sources such as engine emissions. Ethylene can also be produced as a wound response from infection by Botrytis.

It is critical for the production of quality waxflower that stems are treated to prevent flower drop. The compound normally used for this is silver thiosulphate (STS). STS works by binding to the flower abscission layer, preventing flower drop. Stems are normally treated by placing the lower part of the stems in an STS solution and allowing the solution to be taken up to the flowering region.

Uptake of STS solution for sufficient protection takes about 20 minutes at 20°C and 50% relative humidity. However in cooler conditions or if foliage is wet or humidity is high, uptake can be far longer. Uptake should therefore be checked using a transparent cylinder with STS solution in which a standard bunch has been placed.

Silver is regarded as a dangerous heavy metal and its use is banned in some countries. Alternatives to treating with STS including 1-MCP, are currently being researched.

Postharvest disinestation treatments include dipping in a solution containing an insecticide, fungicide and a wetting agent. It is important that field heat is removed from the stems as quickly as possible. Once flowers have been suitably treated with STS and disinfested they need to be cooled to about 2°C for optimal quality. The type of packing may insulate the stems against fast cooling and growers need to monitor their system’s ability to quickly cool their product. Low cost temperature monitors are now available and can be placed in cartons to help growers and exporters better understand the temperature fluctuations during cooling and transport.

Financial information

Production economics varies greatly amongst the different waxflower growing enterprises. This is due to the varying size of establishments which influence economies of scale, the range and age of varieties, location and costs of market access.

As waxflower is normally only harvested over a maximum of a 5 month period, those wishing to manage a full time commercially viable flower growing operation need to consider growing a range of other crops that flower outside the harvest period for wax. If used, this will maintain a labour force and a cash flow. A family sized operation may have a different crop structure than a large commercial enterprise, particularly if they don’t access outside labour. The volume of production for each variety needs to be carefully managed so it is as even as possible over the year. This is not always easy to predict as different varieties flower in response to different environmental cues such as temperature and daylength.

Western Australian growers wishing to access the US market pay more for freight than their eastern States’ counterparts to...
Waxflower growing and harvesting is very labour intensive. Mechanisation of some of the production and harvesting chain could significantly reduce production costs leading to greater profitability.

An example gross margin budget for a 10 hectare operation is shown in table 4. This does not include development or environmental costs, depreciation or taxation. However it allows a quick comparison with other intensive agricultural enterprises.

**Table 4: Waxflower gross margin estimate**

<table>
<thead>
<tr>
<th>Waxflower</th>
<th>Gross margin</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Income</strong></td>
<td></td>
</tr>
<tr>
<td>Total area (hectare)</td>
<td>10</td>
</tr>
<tr>
<td>Average bunch per hectare</td>
<td>20,000</td>
</tr>
<tr>
<td>Total production</td>
<td>200,000</td>
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<tr>
<td>Average price per bunch</td>
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</tr>
<tr>
<td>Grade 1</td>
<td>$2.80</td>
</tr>
<tr>
<td>Grade 2</td>
<td>$2.00</td>
</tr>
<tr>
<td>Grade 3</td>
<td>$1.50</td>
</tr>
<tr>
<td><strong>Total income</strong></td>
<td>$422,000</td>
</tr>
<tr>
<td><strong>Costs of production</strong></td>
<td></td>
</tr>
<tr>
<td>Land preparation</td>
<td>$200</td>
</tr>
<tr>
<td>Replacement plants 10%</td>
<td>$3,000</td>
</tr>
<tr>
<td>Pruning</td>
<td>$600</td>
</tr>
<tr>
<td>Weed control</td>
<td>$4,500</td>
</tr>
<tr>
<td>Disease control</td>
<td>$5,620</td>
</tr>
<tr>
<td>Insect control</td>
<td>$1,240</td>
</tr>
<tr>
<td>Tissue/soil test</td>
<td>$600</td>
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<tr>
<td>Fertiliser</td>
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</tr>
<tr>
<td>Irrigation</td>
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</tr>
<tr>
<td>Fuel</td>
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</tr>
<tr>
<td>Harvest/post harvest</td>
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</tr>
<tr>
<td>Miscellaneous</td>
<td>$2,000</td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
<td>$162,530</td>
</tr>
<tr>
<td><strong>Gross margin</strong></td>
<td>$259,470</td>
</tr>
<tr>
<td><strong>Gross margin per hectare</strong></td>
<td>$25,947</td>
</tr>
</tbody>
</table>

Note: This is an example only, and is to be used as a guide. Individual growers will need to consult with their financial advisers as costs of production vary widely.

**Acknowledgements**

The author thanks the many people who contributed to this article, especially Gerry Parlevliet, Kevin Seaton and Aileen Reid.

**Key references**


Mr. D. Growns. (B. Hort Sc (Hons.)), is the Floriculture Project Manager at the Western Australian Department of Agriculture, where he has worked since 1993. Mr Growns oversees and participates in research to develop the Australian native flora for commercial use in the cutflower and nursery industries, with a focus on the export chain.

Mr Growns has a particular expertise with waxflowers (Chamelaucium spp.) and Verticordia spp.. He has been researching waxflowers since 1991, and has been involved in intraspecific, interspecific and intergeneric (with Verticordia spp.) hybridisation since 1995. Since this time, 20 selections and hybrids from the Floriculture project have been commercially released to industry in Australia, and internationally.
Financial models

Industry examples

Introduction

This chapter builds on previous work that was carried out by Hassall & Associates to develop financial indicators for new rural industries (Hassall, 1999 and Hassall, 2000). This work, which was carried out for RIRDC, developed a three-staged approach for assessing industry opportunities, developed two financial model templates (gross margin and cashflow), and also provided examples (using the models) of new industry information gained from consultation with industry stakeholders. Three stages were recommended in the approach. These were:

Stage One:
Preliminary Concept Screening - to ensure fundamental components are in place and to identify and data gaps;

Stage Two:
Financial feasibility - to ensure commercial worth of the prospect; and

Stage Three:
Is the establishment of site and scale, and the incorporation of confirmed data. This may also include the proposed enterprise within the whole farm plan.

Complete details on the suggested methodology, ideas and concepts behind the evaluation of individual crops, and the models behind the assessment, can be viewed in Hassall 2000, available from RIRDC.

This chapter updates some of the industry examples that were previously generated, and includes new industry examples from this report. There are nine key industry categories included in this report, correspondingly nine examples have been chosen, each one selected as indicative of the specific category. A list of the categories and the industries modelled for each is provided in Table 1.

At the end of this chapter, a gross margin and cashflow model is presented for each of these industries. All of the models contain estimated costs (investment and recurrent) and revenues, sourced from industry practitioners, and calculated results such as estimated costs and revenues, returns on investment and recurrent inputs, internal rates of return and benefit cost ratios.

A MS Excel financial model template was used that had been developed previously for the RIRDC evaluations (Hassall 2000). All original financial calculations were revised with the assistance of industry experts. All new examples were developed in consultation with the authors of the associated chapter in this document, seeking additional specific advice from public and private enterprises where necessary.

Source of information and methodology

The selection of specific industry examples was made in consultation with RIRDC. In deciding upon

<table>
<thead>
<tr>
<th>Category</th>
<th>Industry modelled</th>
<th>New / Updated*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native food</td>
<td>Lemon myrtle</td>
<td>New</td>
</tr>
<tr>
<td>Fruits and berries</td>
<td>Rambutans</td>
<td>New</td>
</tr>
<tr>
<td>Grain legumes</td>
<td>Azuki Beans</td>
<td>New</td>
</tr>
<tr>
<td>Nuts</td>
<td>Hazelnuts</td>
<td>New</td>
</tr>
<tr>
<td>Herbs and spices</td>
<td>Medicinal herbs</td>
<td>Updated</td>
</tr>
<tr>
<td>Misc crops</td>
<td>Coffee</td>
<td>Updated</td>
</tr>
<tr>
<td>Wildflowers</td>
<td>Geraldton wax flower</td>
<td>Updated</td>
</tr>
<tr>
<td>Asian vegetables</td>
<td>Bok Choy</td>
<td>New</td>
</tr>
</tbody>
</table>

* According to work carried out previously - Hassall (2000)
the source of information, the first contact was always the author of the chapter about the specific industry. Where further detail was required, guidance was taken from the author for contacts that included both public and private industry practitioners.

Where possible two or more contacts were used to source and/or review the modelled information. A list of all the contacts used is presented at the end of this chapter.

Most information was sourced and estimated in discussion with the key contacts and those that provided the model reviews. In some instances guidance was also taken from:

- Australian Bureau of Agricultural Economics – AgSurf - Exploring ABARE’s Farm Survey Data. See website - http://agsurf.abareconomics.com

### Indicative industry results

Results summaries were calculated for both the gross margin analysis (Stage 1) and the cashflow analysis (Stage 2). The results of the cashflow analysis are shown in Table 2.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Location (enterprise scale)</th>
<th>NPV</th>
<th>BCR @ 7%</th>
<th>Breakeven (Year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lemon myrtle</td>
<td>Lismore, NSW (5ha)</td>
<td>$37,000</td>
<td>1.03</td>
<td>20</td>
</tr>
<tr>
<td>Rambutans</td>
<td>Northern QLD (5ha)</td>
<td>$510,000</td>
<td>1.45</td>
<td>9</td>
</tr>
<tr>
<td>Azuki Beans</td>
<td>Central-Southern NSW (50ha)</td>
<td>$264,000</td>
<td>1.73</td>
<td>na*</td>
</tr>
<tr>
<td>Hazelnuts</td>
<td>Victorian Highlands (10ha)</td>
<td>$22,000</td>
<td>1.06</td>
<td>20</td>
</tr>
<tr>
<td>Medicinal herbs – Echinacea</td>
<td>North-East NSW (1 ha)</td>
<td>$15,000</td>
<td>1.06</td>
<td>17</td>
</tr>
<tr>
<td>Coffee</td>
<td>Northern QLD (20ha)</td>
<td>$282,000</td>
<td>1.23</td>
<td>13</td>
</tr>
<tr>
<td>Geraldton wax flower</td>
<td>Western Australia (10ha)</td>
<td>$372,000</td>
<td>1.13</td>
<td>8</td>
</tr>
<tr>
<td>Bok Choy</td>
<td>Sydney Region</td>
<td>$27,500 (negative)*</td>
<td>1.12 (0.81)</td>
<td>10 (+ 20)</td>
</tr>
</tbody>
</table>

**Notes:**

a. Shows positive return from first year.

b. The initial model was based on a larger farm, mechanised model. Model review led to the suggestion that there should be increased labour in the model, representative of the Vietnamese/Chinese market garden model (ie. including the producer time). Both have been included in the results.

c. Crops are grown in rotation. Further analysis required to account for total land productivity and returns.

### Precautions

In selecting the information to be used for this report, an attempt was made to provide a representative example of the chosen industry. This took into account factors such as:

- Geographic location and conditions;
- Stage of development of the industry; and
- Size of enterprise.

There were a couple of issues that arose in developing the models that require attention when interpreting the results, namely crop rotations and interpretation of key risks.

To allow for crop rotations, the cashflow analysis was included for only those years (or part thereof) that the crop was grown (eg. Azuki beans for four years every four years; Bok Choy for two months in a year). Costs and revenues were not included for those periods in-between, thus the calculated figures do not reflect the productive capacity of the land for the entire 20 year evaluation period.

Crop rotations also proved difficult as shared machinery meant that investment costs were difficult to establish and attribute accordingly. As a result, basic gross margin input costs were taken from the NSW Agriculture farm budget sites and adjustments made accordingly. It is recommended in these instances that a third stage of analysis should be carried out to include a whole of farm (budget) approach. In this way, decisions can be made to compare substitutes at a more detailed level (eg. Azuki vs Soya beans).

One of the key aspects focused on in the revised models was the key
risk associated with the production of each crop/product. In summary these risks included:

- oversupply in the market;
- selection of appropriate stock for planting given climatic and soil condition variability;
- effect of imports; and
- effect of imported diseases.

More specific risks were associated with individual crops. For example, it became obvious during discussions over lemon myrtle that significant effort was required to develop the business, also including marketing, quality assurance and equipment research and development (in-house). Thus, these costs may be underestimated in the model, and considerable care would need to be taken during any follow up analysis to ensure that all the costs are appropriately addressed for the individual situation.

Examples are indicative only and care should be taken to adjust the inputs for the local conditions. Where special care should be taken, the individual conditions under which the information was modelled have been outlined in the text associated with each model.

**Summary of findings**

Following are the results tables from each of the stage two – Model Cashflow summaries. Further details for stage one and stage two evaluations are represented in the following section.

---

**Rambutans (Hassall & Associates) March 2004**

**Key Assumptions:**
- Enterprise scale: 5 hectares
- Geographic location: Northern QLD
- Initial investment: $222,250
- Typical recurrent input costs: $137,750
- Key yield factors: Pruning
- Farm gate (or other) prices: $9,000 per kg
- Discount rate: 7%
- Inflation rate (if any): n/a
- Analysis period: 20 years

**Present Value @ 7% over 20 years:**
- Investment inputs: $232,097
- Recurrent inputs: $908,866
- Revenues: $1,638,541
- Residual values: $8,054

**Net Present Value of Enterprise @ 7% over 20 years:** $507,628

**Financial Analysis Results:**
- Return on recurrent inputs: 31% static state
- Return on investment and recurrent inputs: 7% static state
- Internal Rate of Return: 20%
- Benefit Cost Ratio @ 7%: 1.45

**Breakeven on cumulative discounted basis after:** 9 years

**Threshold Analysis Results:**
- Net Present Value of Enterprise equals ZERO when:
  - Yield / Prices decreases by (%): 31%
  - Investment Expenditure increases by (%): 219%
  - Recurrent Inputs increases by (%): 56%

**Major Risks to Financial Viability:**
- Picking and packing costs
- Oversupply on the domestic market

A Rambutan enterprise in North Queensland was found to break even in year 9. The financial analysis indicates a marginal NPV of $510,000, an IRR of 20% and a BCR of 1.45 (20 year analysis period @ 7% discount rate).

The development of the model was assisted, and reviewed by, Yan Diczbalis (QLD Department of Primary Industries), and review carried out by a local producer and found to be representative.
Lemon myrtle (Hassall & Associates) March 2004

Key Assumptions:
- Enterprise scale: 5 hectares
- Geographic location: Lismore, NSW
- Initial investment: $530,989
- Typical recurrent input costs: $72,410

Key yield factors
- Farm gate (or other) prices: $154 per kg
- Discount rate: 7%
- Inflation rate (if any): n/a
- Analysis period: 20 years

Present Value @ 7% over 20 years:
- Investment inputs: $542,676
- Recurrent inputs: $706,043
- Revenues: $1,269,825
- Residual values: $12,921
- Net Present Value of Enterprise @ 7% over 20 years: $36,572

Financial Analysis Results:
- Return on recurrent inputs: 86% static state
- Internal Rate of Return: 8%
- Benefit Cost Ratio @ 7%: 1.03

Breakeven on cumulative discounted basis after 20 years

Threshold Analysis Results:
Net Present Value of Enterprise equals ZERO when:
- Yield / Prices decreases by (%): 3%
- Investment Expenditure increases by (%): 7%
- Recurrent Inputs increases by (%): 5%

Major Risks to Financial Viability:
- Current oversupply of product in the market
- Establishing and maintaining markets for new products is very high
- High chance of failure with limited market, and high costs
- Outcome sensitive to yield / price assumptions

A lemon myrtle oil enterprise in Lismore, NSW was found to breakeven in year 20. The financial analysis indicates a small NPV surplus of $37,000, an IRR of 7.63% and a BCR of 1.02 (20 year analysis period @ 7% discount rate). This is considered to be a maximum value (with one product only), and negative return would otherwise result. The spreadsheet has been set up to emphasise the key aspects of lemon myrtle oil production. It is important to note the following when interpreting this model:

- The results have been obtained from a commercial orchard but are not necessarily representative of all orchards;
- The time and effort required for product and market development has not been fully costed, an initial estimate of $100,000 has been made; and
- There is currently an oversupply of lemon myrtle oil in the market;

The development of the model was assisted by Sibylla Hess-Bushman (Australian Rainforest Products) and found to be representative.
Azuki beans (Hassall & Associates)  March 2004

Key Assumptions:
Enterprise scale 50 hectares
Geographic location Central-Southern NSW
Initial investment $67,750
Typical recurrent input costs $55,250
Key yield factors Management of crops (eg. timing)
Farm gate (or other) prices $1,020 tonne
Discount rate 7%
Inflation rate (if any) n/a
Analysis period 20 years

Present Value @ 7% over 20 years:
Investment inputs $13,834
Recurrent inputs $359,455
Revenues $627,338
Residual values $10,337
Net Present Value of Enterprise @ 7% over 20 years $264,386

Financial Analysis Results:
Return on recurrent inputs 90% static state
Return on investment and recurrent inputs 69% static state
Internal Rate of Return na
Benefit Cost Ratio @ 7% 1.73

Breakeven on cumulative discounted basis after na years (positive net cashflow from beginning)

Threshold Analysis Results:
Net Present Value of Enterprise equals ZERO when.....
Yield / Prices decreases by (%) 42%
Investment Expenditure increases by (%) 191%
Recurrent Inputs increases by (%) 74%

Major Risks to Financial Viability:
- Quota allocation from Japan (main market)
- Over production - leading to severe price reduction
- Establishing the contract price (every year)
- Competition from US and China

An azuki beans enterprise in central-southern NSW was found to show a positive return from the first year. The financial analysis indicates a significant NPV of $264,386 and a BCR of 1.73 (20 year analysis period @ 7% discount rate).

Azuki beans are farmed as part of a double cropping system and complement other crops such as irrigated wheat, in rotation with lucerne hay. Initial investment costs for machinery and harvesting equipment that are common across crops were not included in the analysis. Installation of a central pivot has been included. Figures can be taken as an indicative maximum. In discussions with NSW Agriculture, it was suggested that after an initial evaluation, a systems approach (including figures for the double and rotation crops) when carrying out further analysis should be used.

The spreadsheet and results used for the Azuki bean have been reviewed by Tony Hamilton (NSW Producer) and Ken Motley (NSW Agriculture) and found to be representative.
A hazelnut enterprise in the Victorian highlands was found to break even in year 20. The financial analysis indicates a low NPV of $22,600, an IRR of 8% and a BCR of 1.06 (20 year analysis period @ 7% discount rate). Both the gross margin calculations, and cashflow estimates show a small positive result based on a conservative yield and medium size hazelnut. Improved yields and nut sizes would be expected to offer higher returns.

The spreadsheet and results from the hazelnut analysis have been reviewed by Peter Wheelwright (Victorian Producer and President of the Hazelnut Growers of Australia ‘HGA’) and the results were found to be representative. Further valuable comments were provided by other members of the HGA and incorporated into the analysis.
Echinacea – medicinal herbs (Hassall & Associates)
March 2004

Key Assumptions:
Enterprise scale 1 hectare
Geographic location North East NSW
Initial investment $ 96,000
Typical recurrent input costs $ 27,632
Yield roots at 2000 kg/ha
Discount rate 7%
Inflation rate (if any) n/a
Analysis period 20 years

Typical recurrent input costs $ 27,632

Key yield factors:
Yield roots at 2000 kg/ha

Farm gate (or other) prices $ 25.00 per kg

Net Present Value of Enterprise @ 7% over 20 years:
Investment inputs $ 112,201
Recurrent inputs $ 151,317
Revenues $ 273,807
Residual values $ 4,496
Net Present Value of Enterprise @ 7% over 20 years $ 15,119

Financial Analysis Results:
Return on recurrent inputs - Stage One 65% static state
Return on investment and recurrent inputs - Stage One 9% static state
Internal Rate of Return 10%
Benefit Cost Ratio @ 7% 1.06

Breakeven on cumulative discounted basis after 17 years

Threshold Analysis Results:
Net Present Value of Enterprise equals ZERO when:
Yield / Prices decreased by 6%
Investment Expenditure increased by 13%
Recurrent Inputs increased by 10%

Major Risks to financial viability:
There is currently a large oversupply of Echinacea in the market, with associated reduction in market price. This combined with a severe decline in the demand for Echinacea Aerial parts (that used to provide an additional revenue stream) provides a major risk to its ongoing financial viability. Outcome very sensitive to yield / price assumptions and investment expenditure assumptions.

A medicinal herb enterprise in North Eastern NSW was found to breakeven in year 17. The financial analysis indicates a modest NPV of $15,119, an IRR of 10% and a BCR of 1.06 (20 year analysis period @ 7% discount rate).

A major change to previous modelling carried out (RIRDC 00/133) is that this analysis is for a medicinal herb enterprise in north eastern NSW as opposed to Victoria, consequently some of the results may vary from the early analysis. A further point to note is the removal of aerial parts from production in this analysis. This was brought about from a large decline in demand, and anticipated complete decline in demand in years to come.

The update of the model was assisted by Peter Purbrick (MediHerb Pty Ltd) and reviewed by Kym Grant (Austral Herbs & Seeds Pty Ltd) and found to be representative.
A coffee enterprise in northern QLD was found to breakeven in year 13. The financial analysis indicates a significant NPV of $282,136, an IRR of 12.7% and a BCR of 1.23 (20 year analysis period @ 7% discount rate).

The spreadsheet and results used for the coffee model was reviewed by James Drinnan (QLD Department of Primary Industries) and found to be representative.
A Geraldton waxflower enterprise in Western Australia was found to break even in year 8. The financial analysis indicates a high NPV of $372,000, an IRR of 18% and a BCR of 1.13 (20 year analysis period @ 7% discount rate). It must be noted that there is a large variability in price received due to competition (from overseas).

The spreadsheet and results from the waxflower analysis have been reviewed by Gerry Parlevliet (Western Australian - Department of Primary Industries) and the results were found to be representative. Further valuable comments were provided by Gerry’s colleagues at the WA DPI and incorporated into the analysis.
A bok choy enterprise in the Sydney area was found to breakeven in year 10. The financial analysis indicated a low NPV of $27,500, an IRR of 14% and a BCR of 1.12 (20 year analysis period @ 7% discount rate). Estimates were based on a 1 ha crop in a much larger diversified farm (50 ha), and one crop a year (55 day growing cycle).

Further review led to the suggestion that there should be increased labour, representative of the Vietnamese/Chinese market garden model (ie. including the producer’s time). This resulted in a negative NPV and BCR of 0.81. This reaffirmed the view that, consistent with that model, bok choy production was carried out at a loss. The initial model was built up with the assistance of Eddie Galea (Producer) and further review carried out by Vong Nyugen (NSW Dept Agriculture). Both have found the model to be representative.

Results are very sensitive to changes in key variables.
Key contacts

During the modelling of the data, a number of industry practitioners were consulted to assist in developing, and reviewing the model. These individuals are listed in Table 3.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Primary contact</th>
<th>Reviewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lemon myrtle</td>
<td>Sibylla Hess-Bushmann Australian Rainforest Products Pty Ltd</td>
<td>Local Producer (Lismore NSW)</td>
</tr>
<tr>
<td>Rambutans</td>
<td>Yan Diczbalis (QLD Department of Primary Industries)</td>
<td>Local Producer (Northern QLD)</td>
</tr>
<tr>
<td>Azuki beans</td>
<td>Tony Hamilton</td>
<td>Ken Motley NSW Department of Agriculture</td>
</tr>
<tr>
<td>Hazelnuts</td>
<td>Peter Wheelwright (Victorian Producer and President of the Hazelnut Growers of Australia ‘HGA’)</td>
<td>Further comments provided by Peter’s colleagues - HGA Board/Association members</td>
</tr>
<tr>
<td>Medicinal herbs (Echinacea)</td>
<td>Peter Purbrick (MediHerb Pty Ltd)</td>
<td>Kym Grant (Austral Herbs &amp; Seeds Pty Ltd)</td>
</tr>
<tr>
<td>Coffee</td>
<td>James Drinnan (QLD Department of Primary Industries)</td>
<td>-</td>
</tr>
<tr>
<td>Geraldton wax flower</td>
<td>Gerry Parlevliet (Western Austrian - Department of Primary Industries)</td>
<td>Further comments provided by Gerry’s colleagues at WA DPI</td>
</tr>
<tr>
<td>Bok choy</td>
<td>Eddie Galea Producer – Sydney Area</td>
<td>Vong Nyugen NSW Dept Agriculture</td>
</tr>
</tbody>
</table>

Key references


AgSurf - Australian Bureau of Agricultural Economics - Exploring ABARE’s Farm Survey Data. See website - http://agsurf.abareconomics.com

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Table 3: Contacts made during consultation