Growing Christmas Bush for Cut Flowers

A guide for commercial growers
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Foreword

NSW Christmas bush has a long history of use in floristry. The aim of this project was to produce a book that would provide growers, wholesalers, exporters and retailers with practical information about growing, harvesting, postharvest handling and treatment of Christmas bush. This is a practical ‘how to’ guide and covers all aspects from selecting the site to preparing the flowers for market. Particular attention is paid to ‘critical points’—areas that growers have found problematic in the past. The guide is aimed at both existing growers and potential entrants into the industry.

The guide also has appendices that explore some production aspects in more detail. These include pest control, postharvest handling and cool room design and layout. The postharvest handling section was produced as part of a project funded by RIRDC Core Funds, which are provided by the Federal Government and supported by the NSW Department of Primary Industries, with industry funding generously contributed by East Coast Wildflowers and Crooby Cottage Wildflowers.

This guide adds to RIRDC’s diverse range of over 2000 research publications, and forms part of RIRDC’s Wildflowers and Native Plants R&D program, which aims to improve the profitability, productivity and sustainability of the Australian industry.

Most of RIRDC’s publications are available for viewing, free downloading or purchasing online at http://www.rirdc.gov.au/. Purchases can also be made by phoning 1300 634 313.

Craig Burns
Managing Director
Rural Industries Research and Development Corporation
About the authors

Dr Ross Worrall recently retired as a Special Research Horticulturist, NSW DPI. Ross was based at the Gosford Horticultural Research Institute, Narara. He has worked on the commercial development of Australian native plants for most of his career. He has also conducted research in the areas of plant physiology, potting mixes, breeding systems, postharvest management and plant propagation.

Paul Dalley operates Mountain Nursery, a flower farm and propagation nursery at Kempsey, NSW. He has been involved in the development of several eastern Australian cut-flower plants as export crops, including Christmas bush, Christmas bells and flannel flowers. He started GrandiFlora Growers, which functions as a grower cooperative and is well known for the quality of its Christmas bush brand.

Acknowledgements

In particular I wish to thank Bettina Gollnow for her input into editing and reviewing this publication.

Photographic credits: Ross Worrall and Lowan Turton.
Abbreviations

Units

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Chemical symbols

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Other abbreviations

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<td>DEEDI</td>
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Executive summary

What the guide is about
This guide provides advice and information on all aspects of growing, harvesting, postharvest handling and quality management of Christmas bush flowers.

Who is the guide targeted at?
This ‘how to’ guide has been produced for members of the Australian wildflower industry who grow and market Christmas bush, including growers, wholesalers, retailers, florists, exporters, importers, research, development and extension workers, and students.

Where are the relevant industries located in Australia?
Christmas bush is grown mainly in eastern NSW and south-east Queensland. Flowers are sold on domestic markets and are an important export crop.

Background
NSW Christmas bush has a long history of use in floristry. By the 1880s it was well established as a symbol of Christmas in the colonies, with flowering branches harvested from the bush. It has also been grown as a garden plant for many years.

Christmas bush has remained a traditional seasonal favourite in Sydney, where for many years high prices were achieved during the 2 weeks before Christmas, and even poor-quality stems could be sold. Historically this led to marginal returns for domestic producers who could not manage to harvest all of their crop in this 2-week period. Since the 1990s, the availability of high-quality cultivated product has extended domestic acceptance to the whole month of December, and even longer in export markets, particularly Japan. Christmas bush is a major crop, mainly for growers in coastal NSW and Queensland. Growers need to focus on marketing high-quality product in order to retain market share and develop new market opportunities.

Aims
The aim of this work was to produce a guide that includes all the up-to-date literature and all grower and researcher data available so as to provide the industry with practical information and advice about all aspects of growing and preparing Christmas bush for market.

Methods used
This work was done in association with the broader project ‘Quality Specifications for Australian Wildflowers’. This project was conducted by the then Industry & Investment NSW – Primary Industries (now NSW DPI) (RIRDC project PRJ 000331). Guides for the production of waratahs and flannel flowers have also been prepared. Information was gathered from industry members, including growers, researchers, wholesalers, exporters and importers, and from a review of the research literature, both published and, where available, unpublished. Particular attention was paid to plantations that were successful.

Results
This project produced a guide that provides growers, wholesalers, exporters and retailers with practical information about growing, harvesting, and postharvest handling and treatment of Christmas bush flowers. This is a practical ‘how to’ guide and covers all aspects from selecting the site to marketing
the flowers. Particular attention is paid to ‘critical points’—areas that growers have found problemat-
ic in the past. A summary of the critical points is provided. The guide also relies on the personal expe-
rience of the authors in their research and development of Christmas bush as a high-quality
commercial cut flower and in advising growers.

The guide covers all aspects of commercial Christmas bush growing, from site selection to marketing
the flowers. It includes appendices that explore some production aspects in more detail, namely pest
control, postharvest handling, and cool room design and layout.

Implications for relevant stakeholders

This information is now available for people in the industry to use to improve the production and
postharvest quality management of Christmas bush. The information should lead to the benefits of
lower costs, improved sales and returns, and more efficient production practices.

There is a need for ongoing extension of this information and for ongoing R&D in this area (see Rec-
ommendations below).

For students, this can be an extremely valuable resource.

Recommendations

The availability of this guide needs to be made widely known, by RIRDC, the authors, industry lead-
ers and bodies, and government bodies.

We recommend that industry members adopt production, postharvest and quality management prac-
tices outlined in the guide. Individual users can add new information to this guide.

The guide can be updated in the future if there is enough new information, demand, funding and ex-
pertise. It is clear, however, that more research is needed on:

• nutrient requirements and timing of nutrient applications
• canopy management for high yield and stem length
• causes and treatments for grow-through
• long-term sustainable pest management
• selection of alternative varieties with market appeal
• the effect of postharvest solutions on vase life.

R&D and extension workers need to discover and ensure that new information is made available to
the industry in a way that maximises the uptake of those new learnings.
Summary: Producing quality Christmas bush—a critical-point analysis

General points

✓ A large proportion (60%+) of Christmas bush’s potential vase life is determined by growing conditions before harvest.

✗ Don’t allow the flowers to dry out at any stage after harvest. Loss of fresh weight means a shortened vase life.

✓ Christmas bush absorbs water well through the leaves and flowers.

✗ Cool flowers (<20 °C), and keep them cool, as soon as possible after harvest.

✓ Store at 6 °C. Christmas bush can be dry-stored for about a month. Don’t store for too long at low temperatures (below 4 °C), and don’t allow to freeze.

✓ Store only good-quality flowers for extended periods.

✓ If stored with other flowers, try to keep at 8 °C or below.

✓ Use the correct hydrating and vase solutions.

✓ Always use clean containers and clean, low-salt water.

✗ Don’t store with fruit and vegetables or old flowers.

✓ Keep coolrooms and work areas clean and free of old plant material.

✓ Always use sharp blades to harvest and trim flowers.

✗ Christmas bush is susceptible to ethylene at very high concentrations, so avoid sources such as ripening fruit or over-mature flowers.

✓ Rotate stock. Coloured containers indicating date of picking or purchase are helpful.

Tips for growers

✓ Ensure good growing conditions, including correct light, temperature, fertilisers and irrigation.

✓ Choose your varieties carefully for yield, quality, type and vase life.

✓ Control pests and diseases.

✓ Harvest at the correct stage for the variety.

✓ Cool to 10 °C as soon as possible and to 6–8 °C later.

✓ Keep product damp to avoid drying out.

✓ Pack product damp.

✓ Pack evenly graded bunches together.

✓ Pack firmly but ‘springy’ so that the product will not move and be damaged.

✓ Sleeve bunches or use paper to separate layers of product in the box.

✓ Line the box with plastic to prevent drying out (but don’t block ends).

✓ Use boxes with holes in the ends to allow forced-air cooling and to facilitate fumigation.

✓ Use the correct hydrating or pulse solutions.

✓ Use clean, low-salt water to make up solutions.

✓ Cool and hydrate as soon as possible, and precool packed containers.

✓ Pack to the appropriate standard for the market.
Tips for wholesalers

☑ Rehydrate by placing leaves and flowers in water.
☑ Stand flowers in a preservative solution made up with clean, low-salt water.
☑ Maintain good hygiene, and keep containers clean.
☑ Store at the correct temperature.
☑ Don’t sell old stock. Throw it out!

Tips for retailers

☑ Do not display flowers in areas that are exposed to full sun, draughts, high temperatures or vehicle exhausts, and preferably not near fruit and vegetables. Use refrigerated displays if possible.
☑ Use clean buckets for displays.
☑ Use preservative vase solutions made up with clean, low-salt water. Also use in arrangements.
☑ Insert the stems properly into floral foams when making up arrangements, and use enough solution.
☑ If flowers show any signs of wilting or have been stored or transported dry for any length of time, recut stem ends and immerse them in water until they recover.
☑ Tell the customer how to care for the flowers (for example, give them a care sheet) and emphasise the need for preservative vase solutions. Give the customer a sachet of cut flower food to take home.

Tips for consumers

☑ Keep the vase filled with the correct preservative solution. Check daily, as flowers can use a lot of water. Change the water at least every second day if preservative solution is not used. Always use clean vases and clean, low-salt water.
☑ Remove any leaves that will be below the water line.
☑ Do not display in areas that are exposed to full sun, draughts or high temperatures. Keep as cool as possible without freezing.
☑ If flowers show any sign of wilting, immerse them in water until they recover.
☑ Discard other flower types that may be in the same vase when they reach the end of their vase life.
Introduction

This guide concentrates largely on the physical requirements for the commercial production of Christmas bush. Market preparation, financial and other factors are also discussed. Growing Christmas bush should be considered as a business, similar to growing any other cut flower.

The key aim of any cut-flower business should be to make a profit rather than to produce flowers. Failure to make a (real) profit means that either you go out of business or the business becomes an expensive lifestyle option.

It is important also to consider risks. If you are thinking of growing Christmas bush, you should develop a business plan to control risks, whether they be physical, marketing, legal or business-related. These risks are discussed in greater detail in the later sections of this manual (from ‘Selecting a site’ onwards) and more broadly in Gollnow (2012).

The following references are recommended for those getting starting in the business, as well as for established growers:

- Postharvest Handling of Australian Flowers and Quality Specifications for Australian Wildflowers—Christmas bush (see References), which include a great deal of general information as well as some information specific to Christmas bush.
Natural environment

The NSW Christmas bush is widespread and common in the Central Coast botanical subdivision. This is centred on Sydney, but ranges from Lake Macquarie (near Newcastle) in the north to Nowra in the south. It is bounded by the Blue Mountains in the west and by the Pacific Ocean in the east. Christmas bush also occurs to about 180 km south of Sydney (to Ulladulla) in the South Coast botanical division. To the north there are scattered populations in the North Coast botanical division to about the Richmond River, 600 km north of Sydney.

The plant is associated with a number of vegetation types, but contrary to what is stated in some publications it does not occur in true subtropical rainforest. It is found only on well-drained sites that are naturally drier and of lower fertility than those in rainforests. It is usually found in association with tall eucalypt forests of *Eucalyptus pilularis* and *E. piperita*, species that occur on low-fertility soils derived from Sydney sandstones, found mainly in valleys. It is also found in association with *Angophora costata* and *Eucalyptus punctata*, with an understorey of *Dodonaea triquetra* and *Pultenaea flexilis* often abundant. Another association in which it is found is *Syncarpia glomulifera* and *Pittosporum undulatum*. In open forests, on soils of slightly higher fertility derived from Narrabeen group sandstones with some shale inclusions, it may be a dominant tree in association with *Allocasuarina torulosa*.

In summary, Christmas bush occurs:

- on well-drained sites on soils derived mainly from sandstones; the good drainage may be due to the depth of the soil or the slope of the land on the sides of hills and in gullies
• on sites that are drier than rainforest and towards the margins of tall eucalypt forest (especially on southern or eastern slopes)
• on sites that are usually well protected and have 30% to 70% tree cover
• on soils that range from extremely deficient in nitrogen and phosphorus (derived from Hawkesbury sandstone) to low to moderate fertility because of washing of nutrients on to the site from weathered shale seams or the accumulation of organic matter
• in a subtropical humid climate (Cfa in the Köppen climate classification) bordering on temperate—that is, at least 1000 mm rainfall relatively evenly distributed throughout the year, a relative humidity of over 60%, hot and humid during the long summers, and cool and humid during the short winter season.

Most of the sites where Christmas bush is found are in open forest with 30% to 70% tree cover, although it has been recorded in heath associations and in open forest developed on old sand dunes.

Christmas bush growing in the wild is often much less vigorous and produces far fewer flowers than those grown in commercial plantations. Because psyllids (serious insect pests affecting Christmas bush) require young, nitrogen-rich growth for successful infestation, the lower and often intermittent growth of natural stands make those stands much less susceptible. Natural stands of Christmas bush close to infested cultivated plants often have few, if any, psyllids.

*Ceratopetalum apetalum* (coachwood), which often occurs close to Christmas bush, may be the primary host of the Christmas bush psyllid.

**Historical perspective**

The green foliage contrasting with the bright red sepals, which are produced around December in its natural habitat, gives the bush its ‘Christmas’ name. Christmas bush has been enjoyed as a garden plant and sold as a cut flower in Sydney for over a century. Christmas bush was originally picked from natural stands in the bush or from garden-grown plants. Plantation production for cut flowers began only in the 1950s, when natural populations started coming under pressure from unrestrained picking from the bush. It was not until the 1990s that large plantations were set up to supply not only the local market, but also an export trade.

**Commercial uses**

There is a strong demand on the local market for the cut flowers immediately before Christmas, especially in Sydney, but prices drop dramatically just afterwards. Flowering occurs from mid October in southern Queensland through to January and March in Victoria. Harvest times can be quite variable from year to year at any one site. Often the red sepals develop when the prices are low. Changing the name to ‘festival bush’ has been suggested as a way to extend the profitable period of sales by removing the exclusive association of the plant with Christmas. This name is now being used a number of catalogues. High-quality flowers are now in demand in Japan before Japanese New Year and in the USA after Thanksgiving (the fourth Thursday in November) up to Christmas. Chinese New Year and Valentine’s Day are also suitable targets for late product in Asia and the USA. The foliage alone—especially the variegated and other colour forms—also has a use as a foliage filler in bunches.

The Australian Cut Flower Best Bets Program (Slater and Carson 2003) identified Christmas bush as a clear winner (second only to flannel flower) from 117 crops surveyed, in terms of current price, postharvest efficiency, profitability, ease of handling, current and future demand and profitability. Particular opportunities identified were extension of the harvest season, high-quality product and new varieties.

**Plant characteristics**

Christmas bush belongs to the family Cunoniaceae, which is found mainly in the Southern Hemisphere. Australia has more than half of the genera (14 out of 26), but only 23 species out of the world total of approximately 300. Most of the Australian genera are small and often monotypic or endemic.

The family is identified by a number of features, namely:
• simple or compound leaves with serrated margins
• interpetiolar stipules, which are small, triangular leafy appendages on the stem between the bases of the leaf stalks; these fall early, leaving distinctive scars at the lower nodes
• 8 to 10 stamens, which are attached to the edge of a nectar-secreting disc surrounding the ovary.

Of the 26 genera within the family Cunoniaceae, the two most valuable species belong to the genus *Ceratopetalum*: *C. apetalum*, commonly known as coachwood, is used as a timber for plywood, furniture and joinery; the other is *C. gummiferum*, or Christmas bush.

*Ceratopetalum* is distinguished as a genus by the following features:
• tall shrubs or trees with opposite leaves
• petals that are small in Christmas bush and absent in coachwood, but sepals that enlarge as they mature
• a fruit that is a one-seeded nut surrounded by the sepals, giving the appearance of a flower; this finally becomes dry.

Apart from the presence or absence of petals, Christmas bush is distinguished from coachwood by having trifoliate, lanceolate leaves that are 3 to 7 cm long and have toothed margins. In contrast, coachwood has unifoliate, simple elliptical leaves, 8 to 16 cm long, which are articulated on the petiole. Coachwood is also a medium-sized tree that has smooth, whitish bark blotched with grey and white lichens and distinctive horizontal lines encircling the trunk. It occurs only in subtropical rainforest, whereas Christmas bush is found only in other types of forest, although these may be nearby.

There are other species of tropical *Ceratopetalum* in Australia. However, their potential as cut flowers is yet to be fully assessed. *Ceratopetalum hylandii* ‘Summer Stars’ has comparable cutflower qualities and vase life to ‘Albery’s Red’. Calyces are blue-purple and foliage is glossy bright green. *Ceratopetalum apetalum* at least is known to be affected by psyllids.

*Ceratopetalum gummiferum* sepals can vary widely in number, shape, size and colour. Growers should learn to recognise the small white flower that is necessary for development of the coloured calyx—no flower or abscission of flower means no development of the calyx.
Other colours of *Ceratopetalum* are available, but the vibrant ‘Albery’s Red’ remains the most popular.

**Flower and fruit development**

*Ceratopetalum gummiferum* flowers in spring and fruits in summer, whereas *C. apetalum* flowers in spring to summer. The small, white Christmas bush flowers are formed in loose cymes or panicles that are borne on an inflorescence up to 10 cm long. The flowers have four or five petals approximately 3 mm long, which are cut into narrow teeth or lobes. Each flower has 10 stamens. The sepals (4 or 5) are valvate (their edges touch but do not overlap) and are persistent, enlarging from 2 mm to 12 mm when in fruit. The sepals also generally change colour to various shades of pink or red after flowering. It is only when the flowerlike sepals are fully coloured that the stems are marketable as cut flowers.
Selecting a site

Current growing areas

Christmas bush grows well naturally in areas around Sydney and the North Coast of NSW. In Queensland, the former Department of Primary Industries (now part of DEEDI, the Department of Employment, Economic Development and Innovation) tested Christmas bush in different climatic and soil areas within the State. It grew successfully near Toowoomba, on the coast near Rockhampton, Gympie, Maleny and Childers, and as far north as Emerald, which is subtropical but has a dry winter. However, successful production in Toowoomba and Emerald was patchy, and that at Rockhampton and Childers was only slightly better. Reliability of flowering may be a problem in the more northerly locations.

Christmas bush has also been grown in the coastal areas of Victoria and in the ACT. It grows well in the cool summer and mild autumn conditions found in these areas, as long as it receives sufficient irrigation. The main advantage of these areas is that they have fewer late heat waves than more northerly areas, which can cause the flowers and sepals to drop, ruining the crop. The plant is relatively frost hardy once established, although heavy frosts in Canberra have caused some damage to foliage. Damage to flower-bearing stems and death of young plants can be expected below –4 °C. A major disadvantage of growing in these areas is that the plants are generally not as vigorous as those grown in the warmer climates further north. Some plants can be harvested only every second year. Product is harvested in February to March, with shorter stems than in NSW and Qld, and much too late for the Christmas market. Possible markets for late product are Chinese New Year and Valentine’s Day, with prices likely to be variable (note that the price falls by as much as 50% just after Christmas).

Christmas bush will grow on the east coast in almost any soil or situation except where open to strong winds. Good drainage is essential, as plants are susceptible to die-back during wet years.

Potential cultivation areas

Predicted distribution

The environmental range for successful, commercial growth of Christmas bush is yet to be determined. Areas around the world with climates similar to that of the natural distribution area (humid subtropical) are the east coast of South Africa, Uruguay, the south-eastern states of the USA, China and southern Japan. The potential for successful Christmas bush growth within these areas is unknown.

Apart from the current growing areas within the eastern states, the rest of Australia appears to be unsuitable for the commercial growing of Christmas bush, except for possible small niches with suitable microclimates. It remains essentially untrialled in the south-west of Western Australia, with as few as 50 plants being recorded in one survey. There have been some successful harvests in March there.

Factors limiting distribution

Harvest time may also be a limiting factor. Along the east coast of NSW and Queensland, flowering is affected by temperature and day-length, occurring progressively from north to south. To take advantage of pre-Christmas demand, areas between Gympie in the north to the Sydney Basin in the south appear most suitable. If the popularity of the plant can be increased outside of the pre- and peak Christmas period, then we will be able to look to areas of the NSW South Coast, Canberra and central Victoria for harvest in January to March.

Care should be taken in predicting where Christmas bush can be grown successfully. In other crops (for example, waratahs), detailed extrapolations made from a plant’s existing range did not include areas where it is now grown successfully.

Known constraints on areas suitable for commercial Christmas bush production are listed on the next page.
Climate
- Minimum temperature (frost and survival)
- Maximum temperature, low humidity, hot winds (flower drop)
- Average temperature and day–night difference (growth rate too slow or too fast, resulting in lodging or overgrowth)
- Daylength (may not flower at all, may affect harvesting time)
- Variation in microclimate
- Light levels (growth, colour development)
- Rain (lodging)
- Wind
- Hail

Soil
- Fertility
- Drainage
- Structure
- pH

Water
- Availability
- Salinity

Other local problems
- For example, the quality of bore water can vary considerably over small areas.

A well managed plantation at harvest stage.

Site selection criteria and their importance

Many people have come into the cut-flower industry from an urban environment by purchasing a ‘lifestyle’ block close to where they work or by moving to a new desirable area such as the NSW North Coast or south-east Queensland. The block is often purchased primarily for lifestyle reasons, after which the owner seeks to make it more productive. Few farms are selected because growers have sought out the land best suited to the crops they wish to grow.
Many factors are very important when considering where to buy your flower farm, and any one of them could make the land unsuitable. Just a few examples are remoteness from markets or labour supply, adverse climatic conditions (causing plants to grow under stress and making them more susceptible to pests and diseases), and availability of sufficient suitable water. Technology and investment (in money and labour) can be used to overcome many of these impediments, but all of these factors will have a dramatic effect on the profitability of the crop. It must be remembered that the **key aim of any cut-flower business should be to make a profit rather than simply to grow flowers**—all other factors are secondary. Experience has shown that if you take this approach, the chances of success are greatly improved.

When you are considering where to buy a farm, remember that other crops will probably be grown in association with the Christmas bush to maximise returns. Other potential crops must therefore be taken into account. Perhaps a compromise will have to be reached. Similarly, if you already own a block and find it not quite suitable for the optimum growth of Christmas bush and other flower crops, it may be cheaper to sell and buy again in a better location.

**Climate**

Adverse climate will severely affect the development of the plantation. Temperature extremes, unsuitable rainfall patterns, frost, hail and strong wind can cause major problems. You can minimise some of these risks to development by good site selection, good design and layout, adequate water resources and shelter, and the implementation of technology such as frost control and hail netting.

Expansion of the growing area further north within NSW and into Queensland is limited by temperature and rainfall. Increased problems associated with higher temperatures, particularly when accompanied by strong winds, are found during flower set and fruit formation. This can be partly offset by the use of shelter belts or windbreaks. Greater vegetative growth in hotter areas can also contribute to management problems (for example, difficulty in providing the correct level of nutrition and irrigation to maximise harvest or in avoiding ‘grow-through’, also known as ‘growpast’—see below) and logistical problems in handling the harvested stems.

The majority of establishment problems experienced in Queensland relate to plants transplanted into the field during late spring and summer, when harsh conditions and high soil temperatures cause losses of plants with small root systems. This could be offset by better acclimatisation of the new plants or by planting when conditions are less harsh.

An extreme example of shoot grow-through. Such stems tend to wilt at the tips after harvest and should not be marketed.

Unseasonably heavy rain during the flowering season can adversely affect production, causing stem bending and breakage due to the weight of water, or excessive growth leading to ‘grow-through’, when shoots at the stem tip grow through the flowers. This growth is unsightly and undesirable and often wilts after harvest.
Heavy rain and overcast conditions before and during harvest can also reduce both yield and colour intensity.

Established plants can tolerate moderate frosts down to about –4 °C. An air temperature of –6 °C has been recorded as causing severe burn of branches for about 1 metre from the tip. Even –5 °C has been found to cause tip burn after budding had occurred. Death of small plants has occurred at –4 °C.

**Flowering time variability**

Flowering times can vary considerably, even in plantations close to each other. For example, in the Gosford area, plantations less than 1 km apart have had flowering times that have differed by 2 weeks. Close to the coast near Gosford, flowers developed a deep red colour in late November. To the west on the Somersby plateau, flowers did not mature until late December, and even early January further west. At Kempsey, blocks within 300 m have harvest start dates ranging from 3 to 10 days apart. Within a 10-km radius, flowering has been found to vary by up to a month.

There can also be a considerable difference in the quality of the flowers, even between plantations that are close together.

**Soil**

Soil type does not seem to be important in the growth of Christmas bush, provided the drainage is good and the pH is not too high. Good drainage allows for water to infiltrate the soil, for gas exchange and for root penetration. Good drainage is also essential to allow leaching of unwanted salts and removal of nutrients from the root zone. A good horticultural soil should appear granular and porous, enabling water to enter rapidly and easily after rain or irrigation. Very sandy soils have no structure, and their porosity is maintained only by the space between the grains. It is difficult to have drainage problems in coarse sandy soils, but fine sand with very small pores can compact down and suffocate the roots.

An analysis of the soil will indicate its suitability for growing Christmas bush. Old farming land may have high residual levels of some elements (especially P), and the soil may have an extremely high or low pH or be saline. The ability of Christmas bush to tolerate saline soils has yet to be experimentally determined but it is thought not to be tolerant of salty conditions. A previous history of the site may indicate the presence of residual herbicides, which may compromise the growth of the crop.

**Water**

**Quantity**

Growing any cut-flower crop requires a reliable supply of good-quality water. Irrigation is essential to good plant growth and high yields of good-quality flowers, to good stem length, and to minimising defects such as grow-through and flower burn. The water for the plantation can come from a dam, river, bore, town water or recycled supply. Whatever the source, it must be sufficient to deliver the required amount when it is needed. Future expansion and increased water needs must be taken into account when estimating needs.

The exact water requirements of Christmas bush are unknown, but commercial experience shows that it requires relatively large amounts, particularly in summer, when moisture levels must be consistent from budding to harvest. Plants may also require regular irrigation during winter in areas where growth continues during winter. Typically, 2- or 3-year-old plants may require 4 L/day during early summer through to harvest and about 2 L/day or less during winter (Dalley 1997). This may be higher in windier areas or on lighter soils. Irrigation requirements are discussed in more detail on page 18.

**Quality**

It is important to have your water tested for salinity, pH and all ions likely to be toxic. In particular, phosphates, iron, sodium, chloride, boron, bicarbonate and calcium should be tested for before you establish any crop. The quality of bore or river water, even in high-rainfall areas, can be very variable. Some water may not be suitable for irrigation. The quality of water tested at the end of summer will generally indicate the quality of your water at its poorest. Guidelines are available from most testers.
Crop failure is much more expensive than the cost of testing your water.

Salinity, in particular, can have a wide range of deleterious effects on the growth of plants. By the time visible symptoms occur it is generally too late—growth will have already been greatly reduced. Other effects that may not be immediately apparent are a reduction in flower quality (especially vase life) and increased susceptibility to disease and insect attack. Christmas bush is intolerant of salty water (Worrall and Dalley 2004). The precise level that can be tolerated has not been determined, but will depend on climate, soil type and management practices. It is safest to assume that Christmas bush is relatively sensitive to salt. In pot trials, as little as 60 ppm Na has reduced growth. The lower the level of salt in the water the easier the situation will be to manage. On the other hand, Christmas bush is more tolerant of high P levels in soils than are many other natives or proteas.

Irrigation water taken from creeks or dams that drain farming areas may be a potential source of serious diseases, such as Phytophthora. This water may need to be treated to minimise the spread of disease. Bore water is generally considered to be free of plant pathogens but may have a high salt content. Chlorinated town water is generally suitable without any further treatment but may be expensive and may have restrictions placed on its use.

Aspect

Aim for a north to north-east aspect, giving maximum light and warmth, especially in winter. Christmas bush needs high levels of light to develop full (and commercially desirable) colour intensity. Heavy shading from trees and windbreaks, mutual shading and self-shading reduce colour intensity greatly. Plants are ready to harvest earlier on sites with more sun (Dalley 1997). Protection, particularly from hot, dry winds, is important for avoiding flower and fruit drop. Windbreaks are advisable on exposed sites.

Generally, a windbreak will protect an area downwind that is 8 times its height. The most efficient windbreaks are not solid but have a porosity of about 40%. Solid windbreaks can actually accelerate the wind. Trees are easy to establish as windbreaks. Their biggest disadvantages are that they:

- may reduce the growth of plants close to them (that is, within about 10 m)
- take up water freely
- take time to establish
- may grow too large
- leave holes when they die.

Artificial windbreaks are a viable alternative.

Slope

A gentle slope (less than 15%) is desirable, allowing for rapid runoff of surface water, thus reducing the risk of soilborne diseases. Design the farm to minimise erosion by forming beds that run slightly below the contour of the land, but beware: a sloping site may not necessarily have good drainage. In high-rainfall areas it is better to run furrows down the hill, provided that good erosion control, such as grassed interrows, is used. This system is generally used for macadamias. It prevents ponding of water on the high side of the bed and stops breakthrough.

In areas with recurring frosts, a slope may provide both cold air drainage and an elevated production area that can be used to avoid frost problems.

Steep slopes are impractical and dangerous for the movement of farm equipment, and make day-to-day operations such as planting and harvesting difficult. Apart from presenting an erosion risk, a steep slope can also cause problems with irrigation flow. The design of the irrigation system should take into account the slope. Depending on aspect, plants on a steep slope may also be more exposed to wind and the potential damage that it can cause.

Care with using herbicides

Damage to Christmas bush has been observed after the application of glyphosate. Symptoms include yellowing of the crop and slow growth. These symptoms have also been observed on other crops. Contrary to popular belief, glyphosate does not readily break down in the soil. Adding fulvic acid to it may increase its break-
down rate. The effect on Christmas bush may be due to the ability of glyphosate to tie up metal ions in the soil and to its effect on nitrogen-fixing soil micro-organisms. Glyphosate has resulted in the long-term decline of plant growth in some trials (SESL 2010).

Take particular care to apply only recommended rates, and infrequently. Avoid spraying the plant, or weeds that have roots within the root zone of the Christmas bush, as the glyphosate is translocated through the plant. Effects are exacerbated by light sandy soils. Another problem with the repeated use of glyphosate is the build-up of resistant weeds to the extent that one set of problem weeds may be replaced by another. Rotation with other herbicides is recommended for this reason.
Sourcing plant stock

Vegetative propagation (cuttings)

Christmas bush can be propagated by seed (fresh seed germinates readily) or by cuttings. Christmas bush grown from seed is very variable in growth, timing of flowering and, in particular, number of flowers, and size and colour of sepals. Although this provides a good source of variability for the development of new varieties, seed does not make a good uniform source for production plants. Therefore, while cuttings may be difficult and slow to root, they are preferred. With cuttings you can grow selected forms, provided the variety is not protected by Plant Breeders’ Rights (PBR). Currently (February 2012) there are no Christmas bush varieties protected by PBR. However, this may change in the future, and it is the grower’s responsibility to check the status of any varieties grown. Protected varieties must be acquired from a grower who has purchased the rights to propagate and sell those plants.

Grafting can provide plants with selected qualities on stronger clonal rootstocks, giving greater productivity. Seedlings have been successfully budded and grafted with clones of Christmas bush. The budded plants are vigorous: those done by Perce Parry at Floralands at Gosford lasted for over 40 years before being cleared for a housing development. When plants are actively growing, grafts usually establish within a month. One advantage of this method is that seedlings appear to have a more vigorous and perhaps a more stable root system.

Grafting can quickly replace poorly performing seedlings or clones with better clonal material. Its major disadvantages are cost and the skills needed by the budder or grafter. Trees will also have to be severely cut back, and all the shoots will have to be removed from the stock, perhaps many times. Detailed instructions are given in many texts: Hartman et al. (2002) is one example. As with cuttings, upright-growing scion material is preferred.

The closely related coachwood, a true rainforest species, has also been used (at least with initial success) as a rootstock. Long-term compatibility, however, has yet to be shown. Possible benefits are greater vigour of the roots and greater tolerance of wet conditions. Grafted plants are not yet available commercially.

Varieties (cultivars)

It is strongly recommended that you use selected clones, because seedlings can be highly variable. The most commonly grown variety at present is ‘Albery’s Red’. This is compact, dark red, and early and free flowering. Almost all new 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 develop and introduce more varieties so as to extend the flowering season and to introduce better and more uniform colour, a greater range of colours, large flowers and a better vase life.

Albery’s red has a number of ‘faults’:

- The reverse of the sepals is a much lighter colour, so the plant loses some of the overall bright red effect.
- The habit is very upright. Some markets may prefer more weeping forms offered by other selections.
- The main harvesting season is short, only 2 to 3 weeks. There is a need to spread the harvesting time and therefore reduce the risk posed by poor weather at flowering and harvest times. In particular, there is a need for earlier varieties, especially in the south, and for later varieties in the north.
- It is not as vigorous as seedlings or some other varieties and is prone to falling over, especially in wind and with overloading by rain. (This may also be a feature of cuttings.)

In these circumstances, there is a need for:

- better flower set under adverse conditions
- less grow-through
- bigger flowers
- greater resistance to psyllids (see page 24).
One variety that shows particular promise is ‘Shiraz’ (syn. ‘Christmas Belle’). It flowers 2 to 4 weeks later than ‘Albery’s Red’, depending on location, and is a darker red. Initial shipments have been well accepted by the Japanese market. Another red variety is ‘Festival’. It flowers a little later than ‘Albery’s Red’ and appears to be well accepted by the market. It has an acceptable yield and a more pendulous and open habit than ‘Albery’s Red’. ‘Albery’s Millennium Red’ also has good reports from some growers, being redder than ‘Albery’s Red’, especially on the back of the sepals. Two white varieties are ‘Silent Night’ and ‘White Christmas’, the second of which is less vigorous and more compact. 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. A range of other colours are also available, especially pinks (some of which show particular promise in terms of plant form and vase life). Some varieties are more orange than red, but the North American market prefers dark reds. Some buyers may consider pink varieties to be a poorly coloured red and may not like them. (Conversely, some poorly coloured ‘Albery’s Red’ has been sold as a pink.) The variegated foliage variety has not done well in the foliage markets.
Setting up

Equipment required

- A packing shed with concrete floor, grading benches, water, power, lights, toilets and vehicular access.
- A coolroom. Cut stems need to be held at 6 to 8 °C at high humidity. A humidifier may be needed, as well as forced-air cooling. Coolrooms can be hired for the season.
- An implement shed for storing machinery and equipment.
- A chemical shed (lockable and with satisfactory ventilation).
- A fertiliser storage area.
- An area for maintenance of new planting stock. It should have shade and wind protection, with benches and a well drained, sealed floor and access to water.

The use of contractors for large jobs, such as the initial land preparation, avoids the need to buy large tractors and heavy cultivation equipment. The machinery and equipment required will depend on the size of the farm. The following machinery and equipment may be required for a small-scale flower production enterprise:

- Tractor (30–45 kW, or 40–60 hp).
- Cultivation equipment (scarifier, bedformer or scarifier blade, rotary hoe).
- Slasher (mower).
- Fertiliser applicator or fertigation equipment.
- Sprayer (separate tanks for herbicide and pesticide).
- Vehicle to transport product, supplies and labour.
- Trailer (preferably with cover) for harvesting.
- Delivery vehicle, preferably refrigerated if no pick-up service is available to transport product to market.
- Four-wheel-drive buggy (for inspection and management of plantings).
- Second tractor (for flexibility in managing the crop).
- Irrigation equipment, including trickle irrigation hardware, pump, head works and piping.
- Filters for water supply; pumps.
- Chlorinators.
- Fencing.
- Frost alarm or solenoid-controlled automatic watering system in high frost areas.
- Strong secateurs (pressure-pump-operated or electrical for woody species) or pruners (ratchet preferable), pruning saws, bunch cutters and gloves.
- Dipping tanks.
- Bunching and grading benches.
- Packing and boxing benches.
- Scales for weighing bunches.
- Scales for weighing chemicals.
- Safety equipment for handling chemicals.
- Large buckets for storing and pulsing.

Other useful equipment:

- Tying machines.
- Strapping machines for cartons.
- Rollers, pallet jack or trolley for moving packed boxes around, especially when assembled in pallet loads.
- Sleeves for packing individual bunches, to provide protection and to slow drying out.
- Conveyor systems.

A circular packing table can manage variable loads and takes up less space; if something goes wrong the product just goes around again.
Planting material

Faults in root systems (from Wilk 2002).

Many problems can occur at planting, resulting in great variability in early plant performance. Christmas bush has suffered in the past from problems associated with the quality of the material supplied from some growers for planting out. These problems have included poor root development of cuttings and plants and infestation with insect pests, mainly psyllids. Poor root development in Christmas bush, particularly ‘Albery’s Red’, can result in poor performance or failure to survive. In some cases, the proportion of plants affected has been as high as 40%. Problems can also be related to the type, size and strength of cuttings supplied (Dalley 1997). Plants that are too small at planting can take a year or more to recover; some may never catch up. Dalley (1997) recommends that small plants be potted on into 100–125-mm pots and grown on for 4 to 6 months before planting out. While in the nursery, young plants are tip-pruned to form a multi-trunk bush.

It is preferable to buy well grown plants that are ready for planting out on delivery. They should have a good, healthy root system without being root bound, and there should be no sign of insect infestation. Look for signs of disease, removing any plants that appear unhealthy. If any part of a delivery is sick or dying, do not plant the remainder until the possibility of disease has been eliminated. Do not accept poor-quality plants. Losses or poor performance will have a considerable impact on production and therefore income.

On the other hand, nursery suppliers can deliver plants in good condition that, owing to lack of planning, are held over for planting and not looked after satisfactorily, drying out or becoming overgrown and root bound. Ignorance of planting procedures has seen plants put in the ground still in their tubes, planted too deep, planted with a cup of fertiliser dumped on top, covered in mulch, or buried under the plastic weed matting. Nurseries sometimes receive unfair blame for such problems.

Planting times

Autumn and spring to early summer are the best times of year to plant, avoiding the need to care for young plants through the extremes of summer and winter. In frost areas, avoid planting during autumn; planting during spring will...
give plants more time for growth and establishment before adverse weather. Frost can kill newly established plants (at −5 °C). Larger plants are less susceptible.

**Bed layout**

After the site has been selected and any drainage has been installed, incorporate a basal dressing of fertiliser or chicken manure into the beds, as Christmas bush requires a moderate to high level of nutrition for good results. A soil test will determine what’s needed, but laboratory test interpretations vary.

**Hilling**

A well drained soil is essential for good root growth and to minimise the potential for development of root diseases. Hilling or mounding may not be necessary in deep, porous soils where the drainage of the topsoil is rapid, but generally beds are raised to help with drainage and to give relief from periods of extended heavy rain or high water tables. Hilling is not recommended in very light soils unless the sides are constrained, for example by weed matting. Higher mounds often give better growth because of improved aeration in the root zone, but these tend to dry out more in dry times. For Christmas bush, beds are usually raised 1 m wide at the base and 20 to 70 cm high at the centre.

**Row spacing**

The space between rows should allow for vehicle access for pruning, spraying, mowing and harvesting, keeping the final size of the plants in mind. This is generally 3.5 to 4 m between rows, with 2 m between plants within the row. It may be preferable to set the space between rows to suit the size of any pre-existing equipment, rather than purchasing new, expensive machinery to fit a particular layout.

Double spacing (every 1 m) may give higher returns, at least initially, but introduces problems such as:

- shading, which reduces flower quality, especially colour, and overall yield per plant
- practical difficulties with maintenance (spray penetration, pruning, weed control)
- difficulty at harvesting: workers have problems reaching more than 60 cm into a crop to cut and remove the stems without causing damage; the greater the distance that workers must stretch, the less efficient their efforts and the more costly their labour
- increased root contact between adjoining bushes, giving greater competition for water and nutrients as well as increased risk of disease transfer.

Double planting can be used to maximise returns in the first 5 or 6 years while plants are still small. Every second plant can then be removed or transplanted when shading becomes a problem. Initial double spacing will require allowance the extra irrigation outlets.

Row layout is affected by the shape of the land, the slope, boundaries and access. Often rows are best oriented somewhere between a true contour and directly downhill. Running rows lower than the contour prevents water being trapped on the high side, but they should not be so low as to cause erosion. Rows are best broken by crossroads at about 50 m to allow better access, even if the row continues. This results in a plant density of approximately 2250 plants/ha.

In high-rainfall areas, positioning rows directly up and down the slope stops ‘breakthrough’ of beds as a result of intense rainfall. This has been very successful in practice and also allows for safer operation of machinery. However, there must be sufficient erosion control.

**Weed control**

Weed matting or mulch is useful for avoiding weed problems within the rows and therefore significantly reduces the labour needed for controlling weeds. Weed matting can repay its cost in as little as 2 years. It also:

- helps reduce the amount of water lost by evaporation
- helps shed water away from the root zone during periods of excessive rainfall and therefore reduces leaching of fertilizer, but can keep soil dryer during light rain, especially when the mat is new
• helps prevents cultivation equipment from damaging the crop roots.

The main problem with weed matting is that it restricts the application of fertilisers, unless fertigation is used. And over time, it appears to reduce microbial activity, and the soil underneath becomes very hard. A hybrid system using weed matting along the edges (to hold the soil) and a strip of mulch down the centre gives the best of both worlds.

A combination of mulch around the root zone and weed matting to secure the soil can work well.

There are two main types of plastic matting available. Woven plastic generally lasts for 4 to 5 years, by which time plants are mature and self-shading, so that some other method of weed control can be used. Non-woven plastic generally needs an organic mulch on top to be effective. Weed matting alone is not recommended by some growers, as it is thought to raise the temperature within the root zone, making it too hot for good root development. This is more important when plantings are young and more susceptible to damage. It also makes application of solid fertiliser difficult.

Mulch used in association with matting is preferred, as it discourages weeds and, by insulating the soil, provides a cool root run for good plant development. Organic mulches such as straw, compost and hay, crop residues such as tea tree mulch, cotton trash and bagasse, softwood chips and sawdust also aid soil health in the long term, as they break down slowly and increase the organic matter in the soil. They should be properly aged and free of excessive amounts of fertiliser and weed seed, and they should have a large particle size. The particle size affects both the soil aeration and microbial breakdown action. If the particle size is too small the mulch will break down quickly and may cause nitrogen depletion. Organic mulches can contribute to the control of Phytophthora, but they must be kept back from the trunks to avoid collar rot or termite attack. Such mulches also have some disadvantages; they:

• can introduce weed seeds
• must be regularly reapplied
• are difficult to apply to a growing crop
• require considerable labour input.

Hardwood chips are dense and so do not break down quickly. Phenols that leach from the tim-
ber may cause a problem in some crops. Because different timbers contain different types and quantities of phenols, it is a good idea to trial a particular hardwood first for suitability.

The space between the rows is generally grassed. Weed growth can be controlled by mowing or the use of chemicals. Herbicide strips can be used to prevent damage by the slasher: to be an effective barrier, they need to be about 1 m wide, or weeds (especially grasses like couch and kikuyu) can quickly grow across the strip and into the bed.

Preparing the beds

Mulching is not a substitute for soil preparation. The soil for bedding should be free of rocks, sticks and hard clods. The beds can then be formed with a bed former and firmed down. The irrigation lines should be applied to the soil surface or buried 5 to 8 cm down. Rodents and birds can damage exposed tubes, but burial makes maintenance more difficult.

Equipment is available that will lay the irrigation lines and plastic matting in a single pass of the tractor. The matting must be applied properly to get the maximum benefit. Never apply it when the soil is excessively dry or wet: dry soil can settle and allow the plastic to become loose, and wet soil does not seal the plastic well, increasing the possibility that it will blow off the bed. It is important to have the plastic in continuous contact with the soil, because:

- space between the soil and the plastic interferes with heat transfer, preventing the soil from warming quickly and thoroughly
- if the plastic can move in the wind, tears can start
- movement against the stems of young plants can cause abrasion and thus increase the risk of disease entry.

Secure the edges of the matting with soil. Mulch applied correctly will not blow off the beds, but at the same time will not be too difficult to remove as required.

Irrigation

Water needs during planting out

Plant out into a moist bed, and water plants immediately after transplanting. They are especially susceptible to both drying out and overwatering at this stage, because the root system is limited in size, especially when small tubes are used. This situation will be exacerbated if the plants are relatively large in comparison with the tube size.

Because water will drain from the root ball into the surrounding soil, where it is unavailable, young plants can require much more frequent irrigation than when they were in their original containers. When a soil has drained after irrigation, water movement within it is usually very slight. This situation can mean that the surrounding soil can appear moist while the root ball is actually very dry and the plant is therefore stressed. Stressed plants fail to establish and to grow well.

The establishment stage generally lasts for about 6 weeks while plants are actively growing. It is particularly important in this phase for the soil to be freely draining to maintain a high air space ratio between waterings. Take care, however, not to overwater.

If the ground is irrigated during planting, new plants can be placed directly into the wetted soil. However, losses can occur when the young plants dry out if they are too far from the dripper to receive the water, because their root systems are small.

Water requirements

The exact water requirements of Christmas bush are unknown. However, from commercial experience we know that it requires relatively large amounts, particularly in summer, when moisture levels must be consistent from budding to harvest. Plants may also require regular irrigation in areas where growth continues during winter. Typically, 2- to 3-year-old plants need 4 L/day during summer and about 2 L/day or less during winter; 6-year-old plants require roughly double these rates. Rates may be higher in windier locations or on lighter soils.
Actual water requirements can be estimated from evaporation pan data. Average values for Gosford (NSW), Kempsey (NSW) and Esk (southern Queensland) are shown in Table 1. However, note how the minimum and maximum values can vary greatly. For precision, and to relate to the actual crop site, a local evaporation pan is essential. Evapotranspiration is calculated from evaporation to take into account the actual water lost from both the crop and the surface of the soil.

Table 1. Average evaporation at three sites over the past 15 years.

<table>
<thead>
<tr>
<th>Site</th>
<th>Average (L/m²/day)</th>
<th>Minimum–maximum (L/m²/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gosford (NSW)</td>
<td>2.9</td>
<td>0.0–8.0</td>
</tr>
<tr>
<td>Kempsey (NSW)</td>
<td>3.4</td>
<td>0.2–10.8</td>
</tr>
<tr>
<td>Esk (Qld)</td>
<td>4.5</td>
<td>0.6–11.4</td>
</tr>
</tbody>
</table>

Source: Data Drill, Queensland Department of Natural Resources and Mines.

Irrigation rate and frequency required depend on several factors:

- Actual weather conditions. As can be seen from Table 1, evaporation varies widely with time. However, as a general rule, allow 2 to 3 times the rate in summer as in winter.

- Differences between the pan site and the crop site. Mulching of the soil surface and even the siting of windbreaks can have a large effect on evapotranspiration. Also, the outer rows of plants to windward can require considerably more water, especially if exposed to hot, dry winds.

- The stage of crop growth and the crop factor. Assume a crop factor the same as that for a mature crop if the crop is over one-quarter grown. For transplants, irrigation will be required 2 or 3 times a day without additional rain for the first 3 or 4 weeks. The crop factor for Christmas bush is not known, but similar crops require about 80% of the actual evapotranspiration rate. After harvesting, when the foliage area has been greatly reduced, plants will also require much less water until regrowth occurs.

- Losses in application systems. Assume 10% loss for night sprinkler irrigation, 20% for day application and up to 40% on hot, windy days. There are few losses in drip systems, unless excessive water is applied and it runs to waste.

- The water-holding capacity of the soil. For sandy soils with a low water-holding capacity, up to 140% of the calculated irrigation rate may be required, because much of the water may run to waste.

- Rainfall. Its effect will be determined by its frequency and amount and the water-holding capacity of the soil. As it is critical that drainage be good so that excess moisture can be removed quickly, little of the natural rainfall may be usable. Even after heavy rain, irrigation may have to recommence after a day or two in summer.

Water quality

Growing any cut-flower crop requires a reliable supply of good-quality water. Irrigation is essential to obtaining good plant growth and high yields of good-quality flowers, ensuring good stem length, and minimising defects such as grow-through and flower burn.

Test irrigation water regularly to monitor its suitability. Water used for irrigation from creeks or dams that collect from farming areas may be a potential source of diseases such as Phytophthora. This water may need to be treated to minimise spread of the disease. Bore water is generally considered to be free of plant pathogens but may have a high salt content. Chlorinated town water is generally suitable without any further treatment.

Christmas bush is very sensitive to salts in the irrigation water. A pot experiment has demonstrated that it is sensitive to even low levels of sodium (60 ppm) and chloride (90 ppm), concentrations considered safe for many other crops. This observation is supported by anecdotal evidence from growers. Sodium chloride at about 150 ppm concentration in the irrigation water results in slower growth rates, reduced uptake of calcium and magnesium, and reduced leaf chlorophyll levels. Higher concentrations would result in typical toxicity effects. Irrigation water should be below an EC (electrical conductivity) of 0.75 dS/m. Saline water is difficult to deal with, but its effects can be minimised by using micro-irrigation systems that
minimise evaporation. Overhead sprinklers exacerbate salinity problems through increased evaporation, especially if used during the day and during hot, dry weather. Do not let the soil dry out. Salt can be removed from water by reverse osmosis, but this is expensive and yields only low volumes of usable water.

Soluble iron and manganese can be present naturally in many water sources, particularly ground water and farm dams. High levels of iron can stain spray-irrigated crops or block pipes and sprinklers. In addition, manganese can cause toxicity in crops. The water can be treated by aeration and settling before application. Similarly, algae can block micro-irrigation systems and filters. Algae are stimulated to grow by sunlight and high levels of nutrients. The best way to minimise the problem is to stop nutrients from entering the water supply. Nutrient sources include septic tank seepage and runoff from fertilised beds or livestock sheds. Algae can be treated chemically.

As with iron in the water, turbidity or murkiness from fine suspended clay particles can stain plants and block irrigation systems. Chemical treatment can settle out the clay, making the water clear. Farm dam turbidity can be reduced by grassing the catchment areas.

The irrigation system

Design your irrigation system to meet both the present and future requirements of your crop. In your initial planning, allow for future expansion of the plantation or a change of crop. The soil type will affect the irrigation volume and frequency. For example, water soaks through sandy soils faster than through clay, so more frequent, lighter watering is needed on sandy soils. Conversely, if water soaks into the soil more slowly than it’s applied, it will run off the soil surface. This is wasteful and can cause drainage or erosion problems.

The system should be able to deliver enough water under the most extreme conditions. This is especially important when the bushes are flowering. One day of hot dry winds can result in complete flower loss.

Irrigation systems are classified as either pressurised or unpressurised. Unpressurised systems rely on gravity to supply, apply and remove the water. These methods, such as furrow irrigation, are generally not suited to flow-er growing. A pressurised system relies on a pump to supply the water to the irrigated area.

No matter how technically advanced or expensive your irrigation system is, it is important to check on a regular basis that it is working properly. Good maintenance is essential.

Every irrigation system needs the following components:

Water source
Dam, river or bore water, town water or recycled water can be used. Town water may be expensive, but in some areas bore water or dam water may be too salty or unreliable for flower production. Recycled water, either from previous irrigations or from effluent (such as treated sewage), will require some form of chemical treatment before use, for example to kill plant diseases or to control algae and bacteria.

A reliable water supply is vital.

Filtration
This is needed to protect the emitters from becoming blocked. Filters can be screen, disc or gravel types. If irrigation water is to be collected and recycled, it should be pre-filtered before chlorination.

Main line
This is the system of pipes that deliver water to the beds. Pipes can be made of polyethylene, PVC, copper, galvanised steel or other materials. Each material has features and benefits that should be considered before installation.

Control valve
Various types of valves—such as gate, ball, butterfly or solenoid—operate either automatically or manually, allowing the flow of water to the emitters to be turned off and on.

Submain
This is the pipework to which the laterals are connected. It is pressurised only after the control valve is opened. These pipes are usually made of polyethylene or PVC.
Laterals

These are the pipes to which the emitters are connected. They are usually made of polyethylene or PVC.

Emitters

These deliver the water to the plant. They can be drippers, sprinklers or another type of nozzle. Emitters can be pressure regulated or non-pressure regulated. Slopes of 3% or greater are generally not suited to non-pressure-regulated emitters, as the water pressure can be much greater in the low spots of the system.

Micro-irrigation, trickle (drip) irrigation, jet sprays and mini-sprinklers are the most efficient for irrigating native flower plantations and achieve the most economical use of water. They reduce foliage diseases by keeping the leaves dry and reduce weed growth by watering only the crop. Trickle irrigation is popular, as it is relatively inexpensive to install, places the water where it’s needed, and avoids wetting the foliage. For good coverage of the root zone, several outlets per plant may be required. Very little water is wasted, and watering is not affected by wind.

However, as found in many other crops grown in high-rainfall areas and on light soils, microjets may result in a better coverage of the root zone and greater water uptake than trickle irrigation. Microjets have the advantage of not wetting the foliage, but they may increase the humidity in the crop under adverse conditions. In high-rainfall areas there is a need to wet most of the root system, as the root zone tends to be spread out.

Overhead irrigation is used sparingly. It can cause lodging of the flowers (especially as they near maturity) and spotting on the flowers. It can splash soil onto the foliage and generally promote the spread of disease. It is, however, useful in the early stages of crop establishment to ensure that small plants are not missed.

Design your irrigation system to cope with the fully mature business and to allow for the irrigation of fully mature trees, with the flexibility to handle crops of differing water requirements. Trickle or drip irrigation or micro-sprays offering 180° spread are preferred for Christmas bush, mainly to avoid wetting the foliage, but overhead sprinklers may be needed where hot drying winds are a problem between flowering and harvest or to control frost.

Deciding when to water

Deciding when to water is often viewed as a difficult part of flower farm management. Some growers wait until plants start to wilt (which is far too late, because there will already have been adverse effects, including flower damage), whereas others overwater because they fear that the plants will dry out. There are many devices available for monitoring water use, from soil moisture probes, runoff monitors and weather stations to the tried and tested 'fingers in the soil', but they must all be combined with an understanding of what to do with the information and when to do it. The optimum level of water in the soil must be determined and then maintained with frequent, short irrigations.

Shelter

Flower crops need a good flow of air around and within them to dry the leaves and flowers and thus reduce disease problems. Wind, however, can be a major cause of crop damage or downgrading of flower quality. Hot, dry winds can cause complete flower and fruit drop. Wind may also accentuate drought effects, break stems, or just disrupt the application of sprays or irrigation. Windbreaks should reduce wind speed by up to 50%. As a general rule:

Protected area = (shelter height – crop height) × 8

Mature Christmas bush will reach a height of at least 2 m. Ground slope also affects results.

Natural or artificial shelter can be used, but good design is critical. Artificial shelter has a number of advantages in that it:

- is immediate
- can be built without gaps, which can cause wind tunnel effects
- can be incorporated with hail netting or shade cover for further crop protection
- does not compete with the crop for water or fertiliser.
Artificial windbreaks such as shade cloth usually have a 40% porosity.

Natural shelter, if not already in place, can take several years to reach a height that is fully effective. Plants suitable for use as a natural windbreak include the fast growing *Casuarina torulosa*.

**Light**

Christmas bush needs high levels of light to develop full (and commercially desirable) colour intensity. Plants should be grown in full sun where possible. Heavy shading from trees and windbreaks, mutual shading and self-shading reduce colour intensity greatly. Hail netting produces around 11% shade, reducing colour intensity, but the calyces may be larger owing to the higher humidity. Flowers on the upper branches tend to colour before those on lower branches. So harvest the upper branches when they are ready to market, leaving the lower ones (which will now have less shading) a while longer to fully develop their colour.
General maintenance

Pest, disease and weed control

Good growers use pruning, irrigation and fertilisation to reduce pest and disease problems. Plants under stress are more susceptible to attack. Growers should become skilled at looking for problems and working out the cause. Only then can they determine an appropriate course of action and avoid the problem in the future.

Prevention

- Good hygiene in and around the growing areas will help avoid problems. Clean up and remove prunings, and remove old crops when they are finished.
- Know what a healthy crop looks like and investigate changes immediately.
- Check plants regularly—at least every week.
- Monitoring for insect pests using sticky traps enables early recognition of potential problems and avoids wasteful overuse of sprays. Identification of the pests also enables you to choose the correct spray for the job. Some insects may be helpful predators.
- Keep good records of pesticide sprays: when and what was used, and for what pests.
- Check that the irrigation water is free of pathogens, especially if using dam water.

Diagnosing the problem

It is important to be able to identify the cause of a problem when it arises. Many insects are harmless, and the visible symptoms may not be due to a pest or disease at all.

- Define the problem. Is it, for example, death of a plant, leaf drop or leaf spots? Is this the primary problem or a consequence of the primary problem?
- Look for patterns. Non-uniform damage usually indicates a living agent as the cause, whereas uniform damage is generally the result of non-living factors such as spray damage, weather or a nutrient imbalance.
- Learn to distinguish between a symptom (the altered appearance of an affected plant) and a sign (the presence of the causative organism, or evidence of its presence).

If the problem cannot be identified, take samples to send to someone who can diagnose the cause. This involves collecting plant material showing all of the symptoms and signs, together with healthy material for comparison. If sending the material away, make sure it will arrive in a fresh state, and include specific information about the problem. Put insects in unbreakable containers in methylated spirits.

Treating the problem

Because native flower production is fairly new, there may be no registered pesticides for some of the problems encountered. Regulations on the use of pesticides are strict, and a product has to be registered for a particular use, or a permit must be obtained, before it can legally be used or recommended. If you are unsure of whether a product will damage the crop, trial it on a small area of the crop first. Mixing some products together can result in severe damage.

Specific control measures are not given here, as the registered pesticides available can change rapidly. Information is available from a number of sources, including private consultants and your local farm chemical retailer. Information is also available from the Australian Pesticides and Veterinary Medicines Authority (APVMA: www.apvma.gov.au). You can search the APVMA website to find registered pesticides—select PUBCRIS (Public Chemical Registration Information System) on the menu and search by the product name or the active ingredient name. If a product is not listed, it’s probably not registered. A Minor Use Permit system covers off-label uses of pesticides (go to www.apvma.gov.au and search under ‘Permits’ for details).
There are also a number of on-line databases that provide information on pesticide products, such as Pest Genie (www.pestgenie.com.au).

A key reference is NGIQ (2009).

Christmas bush for export often requires disinfection before shipping, as many countries (particularly Japan and the USA) have a zero tolerance for pests and diseases. Non-‘pest’ species such as spiders may also be quarantinable. Pest management during the growing season will make exporting easier, as it reduces the population in the harvested material. You should also ensure that no other material such as weed seeds has contaminated the product.

**Insects**

The main insect pests of Christmas bush are described below.

**Psyllids** are small sap-sucking insects related to aphids. They are by far the most serious insect pests of Christmas bush and can be difficult to control. They cause damage by sucking the plant juices and by causing the juvenile foliage to curl and become distorted. The foliage can also become discoloured and die back. Psyllids also produce a honeydew on which sooty mould can grow. This discolours the plant and lowers its marketability. Ants love the honeydew, so the presence of ants on Christmas bush plants is often an indication of a psyllid infestation, but can also indicate scale infestation. More information can be found in Appendix 1.

Leaf damage caused by psyllids can make product unmarketable.
Close-up of an adult psyllid.

Monolepta beetles have been found in northern NSW swarming in spring and early summer. They are about 3 to 4 mm long and are red and yellow. They eat flower buds and must be treated very quickly, as numbers build up very fast (swarming in from other areas, especially surrounding bushland).

Macadamia twig girdler (Neodrepta luteotactella) is a white moth about 3 cm long. The larvae, about 2.5 cm long, are greenish, with darker heads and stripes. They attack young shoots, boring shallow tunnels in the bark and sapwood. Leaves are often nipped off. Damaged shoots can become swollen and misshapen.

Leaf roller and webbing caterpillars infest growing tips, binding young leaves together.

Fruit tree borer (Oecophoridae, Lepidoptera) caterpillars produce webbing on the leaves and frass at the junctions of twigs or branches.

Longicorn beetle (Cerambycidae, Coleoptera) larvae may tunnel in trees weakened by regular and severe pruning.

Aphids and thrips can attack new shoots. Thrips (plague thrips: Thrips imaginis) suck the sap from the calyces, which turn brown and fall, preventing development of the red bracts.

Scales, including olive brown scale, white palm scale and black scale, are often found on young plants and inside the canopy of older trees that have not been well pruned.

Mealy bugs are also found in dense foliage on older trees.

Diseases

Phytophthora root disease has been found in some plants. The effects often show up during times of active growth, especially in late summer and early autumn (Dalley 1997). Other common root-disease-causing organisms such as Rhizoctonia, Pythium and Fusarium are potentially also a problem. Good soil drainage and control of watering to prevent waterlogging are essential to minimise the risk of root diseases.

Fungicides are available to help control root diseases, but in good conditions they are rarely needed. Spraying with fungicides may be required during extended periods of wet weather to reduce the risk of postharvest botrytis rot of the flowers. There is more information in the ‘Postharvest’ section on page 35.

Weeds

Weed control is a major expense in plantation management, but the problem cannot be ignored, because weeds compete with the crop for nutrients, water and sunlight. They can also harbour many pests and diseases. Weeds can cause total crop loss during the early establishment stages, when plants are small, and severe reduction in yields later.

Most growers need to use all available control methods at some time:

- **Mulching/weed matting.** Good weed control before planting is easier and safer than later.

- **Spraying.** Use systemic herbicides with care. On light sandy soils glyphosate can be transferred to the crop by contact with the roots of weeds (especially perennial grass roots), causing a serious reduction in growth rate. Glyphosate can tie up certain nutrients in the soil if it is used over a period of years, which may result in yield losses. Contact herbicides, although safer for the crop, may not be as effective in controlling the weeds and may need to be applied more frequently, and may be more dangerous to the operator. Spray drift onto the
crop must still be avoided. Only a limited range of herbicides is registered for use in flower crops.

- **Mowing, slashing, brushcutting**
- **Inter-row cultivation.** This can be a problem if it is performed too close to the crop, where shallow roots can be damaged. If the area between the rows is cultivated, serious erosion can occur, especially on sloping land or if the rows run up and down the hill.
- **Hand weeding.** This is very labour intensive and therefore very expensive.

A productive Christmas bush plantation requires ongoing maintenance.

**Pruning**

Normally, vigorously growing bushes will require pruning to maximise financial returns. Pruning to obtain well shaped plants will need to begin in the nursery and continue throughout the life of the plant. To achieve the best prices, flower stems for export are required to be 40–50 cm long for North America, 50–60 cm for Europe, and 50–70 cm plus for Japan (reflecting the high Australian dollar at the time of writing). The aim of pruning is, therefore, to produce stems that will grow to 70 cm or more, with shorter stems and offcuts going to lower grades. Pruning the plant to have an open vase shape will allow for this type of vertical growth while giving good light penetration (Dalley 1997). Normally, vigorously growing bushes in the Kempsey area are pruned to form about 12 main stems.

Over time, the plants will merge to form a hedge, but they should be pruned such that the canopies touch rather than interact. Pruning should remove weak branches and excessive density that will not be harvestable. Where light is limited in the lower foliage, colouring of the calyces may be reduced. Conversely, plants should not be allowed to develop with one or two tall single leaders. Excessive growth of this kind will not necessarily produce good-quality stems. Rapidly growing shoots can be repruned in March, aiming for three or four stems of the desired length.

The severity of the pruning required will depend on the vigour of the bush. Plants from
northern NSW and south-east Queensland will normally be much more vigorous and require more pruning than plants growing in more southerly areas of NSW and Victoria.

When pruning at harvest, cut unharvested branches back by 25% to 50% of their length. Avoid removing too much foliage, and leave a skirt of older foliage from ground level to a height of 1 m above the ground. This allows for quick new growth while giving protection for the roots from summer heat (Dalley 1997). Removing too much foliage will reduce the yield in the following year. In autumn, remove the thin lower branches and prune back the thicker branches. Retention of these lower branches is beneficial to regrowth of the bush. A heavy prune after about 5 years may be necessary to keep the plants manageable. Dalley (1997) often gives older plants (8 to 10 years) a heavy rejuvenation pruning, even removing some of the large branches at the base. It is common for old trees to be cut back to short trunks with no foliage to produce masses of new shoots through the bark; yield will be down in that year but very good the next year.

**Fertilising**

The essential elements (besides the carbon, hydrogen and oxygen that are supplied from the air and water) fall into two groups, according to their concentration in plants:

- **The major nutrients or macronutrients**, which are found in the highest concentrations: nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca) and magnesium (Mg).

- **The micronutrients or trace elements**, which are found in the lowest concentrations, and include iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), boron (Bo), molybdenum (Mo), chlorine (Cl) and silicon (Si).

Lack of any one of these essential elements will impair plant growth. The supply of a nutrient will limit growth when it is either too low (deficient) or too high (toxic or excessive).

Since plants absorb most of their nutrients from the soil through their roots, fertilisers must be soluble in water. This is why proper irrigation scheduling is so important, not only to prevent water stress, but also to maintain nutrient supply. Foliar nutrient application can be important for rapid uptake and for precision application and timing.

**Monitoring fertility levels**

It is important to know the nutrient status of the soil so as to determine what fertiliser is needed. This must be done by either of two methods, and preferably both:

- **Soil testing** to show the nutrient level of the soil. This enables you to plan a fertiliser program to minimise nutrient losses and prevent build-up of individual elements.

- **Plant analysis**, which gives a reliable guide to the condition of the crop and is useful for identifying nutritional disorders.

Leaf standards for Christmas bush have not been established, but Table 2 lists the suggested optimal levels and the ranges that have been found in healthy, actively growing plants of Albery’s Red, both in the field and in pot trials (the youngest recently mature leaf was tested). These values should be taken as a guide only, as values can vary greatly with different management and fertiliser regimes, and with the time of year and environmental conditions.

Research has shown, however, that the ratios of the elements are perhaps of more significance than the absolute levels. The P/N ratio was found to be 0.08 (range 0.05–0.14) in a large number of apparently healthy Christmas bush leaves. The mean is within the range found in most ‘normal’ plants (0.06–0.10; Handreck and Black 1994). If the P/N ratio varies greatly from this range, growth will probably be reduced.

In the same plants the K/N ratio was 0.63 (0.41–1.09). Handreck and Black (1994) suggested that the range in most healthy plants was 0.5 to 1.5, which encompasses the above value.

Leaf tissue nutrients vary widely between species. Compared with the ‘average’ plant, Christmas bush has very low levels of N, P and K but very high levels of Mn. Leaf analysis levels are close to that of *Ficus elastica*. Leaf standards should be developed for each species and perhaps every variety. More important,
Table 2. Suggested optimal levels of nutrients and ranges that have been found in healthy, actively growing plants of Albery’s Red.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Mean (range measured)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>1.5% (1.0%–2.0%)</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>0.12% (0.10%–0.18%)</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>0.9% (0.7%–1.1%)</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>0.9% (0.6%–1.4%)</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>0.22% (0.17%–0.30%)</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>0.14% (0.09%–0.24%)</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>0.03% (0.02%–0.05%)</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>0.28% (0.24%–0.34%)</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>60 ppm (50–100 ppm)</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>930 ppm (119–1490 ppm)</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>8 ppm (5–15 ppm)</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>30 ppm (20–50 ppm)</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>25 ppm (18–33 ppm)</td>
</tr>
<tr>
<td>Aluminium (Al)</td>
<td>85 ppm (75–94 ppm)</td>
</tr>
</tbody>
</table>

**Nutritional disorders**

Visual symptoms on leaves, such as yellowing or browning, may indicate nutritional disorders, that is, an excess or deficiency of one or more nutrients. Remember, however, that by the time visual symptoms are apparent, the growth of the plant has already been greatly reduced.

For general information on plant nutrition see, in particular:

Iron

The most common problem encountered is iron deficiency. The usual symptom is a bright, light yellow colouration of the youngest leaves. The finer veins generally remain green for some time, giving a net-like pattern, but the entire leaf may eventually bleach and begin to die from the tip. Take care, as these symptoms can be confused with phosphorus toxicity and perhaps potassium deficiency. Excessive levels of phosphate can also result in iron deficiency symptoms. One factor contributing to the development of symptoms is high pH (over about 7). This may be caused by the initial soil pH being too high or by over-liming. Also check the pH of the water supply. Even town water can have a high pH. Another major cause of iron deficiency is poor root health, which can be caused by disease, waterlogging or soil compaction. Low root temperatures can also contribute to symptoms.

Symptoms of iron deficiency.

Phosphorus

Christmas bush is not a phosphorus-sensitive plant, as many native plants are reputed to be. It will tolerate relatively high levels of P compared with many other plants. Provided that any iron deficiency is corrected, old citrus and vegetable land can be used even if the P concentration in the soil is as high as 100 ppm (Bray extraction method). This is compared with the upper limit of 15 ppm suggested for protea, a P-sensitive plant. Christmas bush will usually require P fertiliser to be added for full production.

Nitrogen

Mature plants deficient in nitrogen are stunted and slow growing. The tops are pale, and the oldest leaves turn a uniform yellow and fall off. Abnormal reddening of stems and leaves may also occur. Phosphorus deficiency can complicate symptoms. Root damage (for example, disease, waterlogging) can result in similar symptoms to those caused by an inadequate nitrogen supply.
Magnesium

Deficiency of magnesium can cause chlorosis of the leaves. Mg can be lost from the soil during wet conditions.

Boron

Boron deficiency has been noted in Christmas bush. Symptoms are somewhat similar to calcium deficiency, with death of flower buds and growing points and excessive growth of side shoots.

How to fertilise

Common ways of applying fertiliser to a crop:

Solid, mostly soluble form

Chemical fertilisers are generally the lowest-cost form of nutrients. Low-cost methods of application, such as fertiliser spreaders, may be used on well established crops, where the root system has spread into the rows. However, where weed matting or thick mulch is used, getting the fertiliser into the root zone may be difficult, especially with fertilisers that are only partly soluble, such as superphosphate.

The fertilisers will not be available until they are watered in to, or otherwise mixed in to, the root zone. Further, it is not possible to supply all the nutrients needed for a year in one application. Ideally, applications should be made every month or so, or the plants will suffer from both an initial excess and a later deficiency, and much of the fertiliser will be leached from the soil or lost to the air (especially in the case of nitrogen fertilisers, particularly urea).

Controlled-release

Controlled-release fertilisers are relatively efficient: up to 60% of the nitrogen applied is absorbed by the crop. Losses due to leaching are lower because the fertiliser is protected by a membrane. Nutrients are supplied for up to a year. The rate of release of the nutrients is affected by temperature, so the supply may vary when it is extremely hot or cold.

Slow-release fertilisers should be incorporated into the growing medium. This may be difficult with established crops, especially if weed matting is used. The surface of the soil can become very hot (up to 60 °C), causing a very rapid release of nutrients. This can result in fertiliser toxicity in the short term and, if nutrients are leached away, a deficiency in the long term. The main disadvantage of using slow-release fertilisers in field crops is the cost per unit of nutrient added, although for container-grown plants this is often very economical when you consider labour costs and the results achieved.

Liquid feeding (fertigation)

Fertigation is relatively efficient: up to 88% of the nitrogen applied is absorbed by the crop. The rate of leaching is low, because the fertiliser is applied in small amounts over the life of the crop. This also has the advantage of allowing you to tailor the nutrient supply exactly to the crop’s needs. The disadvantages are high capital costs (for fertiliser injection equipment), the need for a high level of technical knowledge, and the difficulty of supply during wet weather.

Foliar feeding

Foliar feeding is inefficient for supplying anything other than trace elements, as you cannot provide all of the crop’s requirements through the leaves without burning the plants. However, it can be used in certain conditions, for example in alkaline soils where iron is a limiting factor.

How much fertiliser?

To estimate the rate of fertiliser to use, first you need to determine the initial fertility of the soil and how much of each nutrient is subsequently removed by the crop. In addition, nutrients can be leached out from, or fixed by, the soil.

Determining the basal level of fertility in the soil

The only real way to determine the initial level of fertility of the soil is by soil analysis. In high-rainfall areas, native soils (especially the lighter ones) are generally deficient in most nutrients (especially N, P and K), and they also have a low pH—that is, they will require liming as well. On land that has previously been used for agriculture—particularly on lighter soils—
N and K are unlikely to accumulate to any significant extent. However, P has been found at high levels in old orchard ground, in pastures, and where vegetables have been grown. Nevertheless, do not assume that previous addition of P means that there will be adequate P available in the soil. Many types of soils can fix large amounts of P and make it unavailable to the plant. Also, P can readily be leached from very light sandy soils with high levels of rainfall or irrigation.

**Determining how much fertiliser is removed by the crop or by leaching**

In the natural habitat of Christmas bush, most nutrients are recycled in the organic matter. In contrast, in a mature planting of Christmas bush, as much as 10 t/ha can be removed in harvested material and prunings. This represents about 150 kg N, 12 kg P and 100 kg K, all of which must be replaced as fertiliser in organic matter. To replace the N component alone you would need approximately 2.5 t of dry poultry manure or 7.5 t of dry sheep manure.

As a starting point, the NPK ratio of solid fertilisers applied to Christmas bush growing in soil should be about 1:0.44:0.83. In practice, this has been found to be satisfactory for a wide range of flower crops. It is not the same ratio that is taken up by the plant; it is assumed that much of the P will be fixed by the soil and thus becomes unavailable to the plant. For soils that do not fix appreciable quantities of P (for example, light sands and most organically based potting mixes), an NPK ratio of 3:0.44:1.66 may be more appropriate, especially if fertilisation is used. This is closer to the nutrient ratio in healthy leaves. In general, P and to a lesser extent K will be retained in the soil and will accumulate over time if fertilisers high in N, P and K are used continuously.

Your calculations of the quantity of fertiliser needed should be based on the quantity of N required. Experience suggests that for mature plantings about 150 kg/ha of N should be applied each year. This represents 3 t/ha of a mixed fertiliser containing 5% N. If the fertiliser is to be applied only to the root zone, the rate for immature crops should be based on the percentage of the area that the root zone of the Christmas bush covers. However, if the fertiliser is to be broadcast over the entire area and there is an inter-row planting of grass or other plants, the full rate should be used. Applying fertilisers at the correct rate can save considerable money.

**Changing nutrient balance through the year**

Paul Dalley, from Kempsey, on the NSW North Coast, uses the following application regime (Dalley 1997).

The first objective is to replace the harvested and pruned stems. As Christmas bush responds well to fertiliser it should be given a boost, with N being the dominant nutrient, to encourage quick growth after harvest and pruning. This comes in the form of a complete NPK fertiliser with trace elements added (a coated controlled-release product) or a slowly soluble product like Nitrophoska® Blue Special, once after harvest (in January), in addition to pelleted chicken manure in January and again in March, when the plant is making the most of its stem growth. These applications won’t do much unless there is sufficient rain to wash them into the soil, so if rain is lacking in January–February, use fertigation instead of the second application.

The next objective is to switch from N to K and Ca as the days shorten into autumn. Complete high-K liquid fertiliser, alternating with Ca nitrate, is fed to the plants through the irrigation system approximately every 2 weeks between January and September. Foliar applications are also made, especially during periods of excessive soil moisture. No fertiliser is used then up to harvest. Lower fertility in November prevents grow-through and produces a slightly hardened product which is good for shipping.

Christmas bush can develop chlorosis from low levels of Mg, which can be lost from the soil during wet conditions. Application of Mg sulfate (Epsom salts) at 20 g/plant/month should alleviate this. Chlorosis can also be caused by low Fe levels due to poor uptake because of Mn accumulation. A Ca chelate, with B, and a K chelate spray before flowering can be beneficial.
Harvest and handling

To optimise the financial return, the crop must be fully harvested when at its best, processed, packed, and then delivered all the way along the marketing chain to the consumer in good condition. If growers are unable to fully harvest the crop, either through poor management (such as underestimation of labour requirements or high cost of labour) or because of circumstances outside their control (such as weather), then returns will suffer. Similarly, a lapse in quality control somewhere along the chain can make the difference between a high-quality product reaching the market and a box of worthless rubbish. Because flowers are a volume product with a low unit value, the grower must be mindful of the cost of harvesting.

A wide range of general information on harvesting and postharvest care can be found in Faragher et al. (2010).

Detailed information can be found in the quality specification for Christmas bush (Appendix 2 or rirdc.infoservices.com.au/items/038).

When to harvest

Foliage

Flowering stems with less than the required density of flowers may be marketed as foliage. Foliage should be harvested and treated in the same way as flowering stems.

Non-flowering stems may also be sold as true foliage over most of the year. They are often used as foliage fillers in bouquets.

Flowering stems

Bud initiation is thought to be related to day length, but the role of insect pollination in flower set is yet to be determined. On the North Coast of NSW and in southern Queensland, bud initiation occurs around late June, followed by flowering in September and fruit development in October. These stages are delayed in Victoria and southern NSW by as much as 4 months. Flowering time is extended by cool, moist weather and conversely is shortened by hot, dry weather. Colouring is also affected by the amount of sun received by the plants. If some plants receive more sunshine than others they may be ready earlier.

The bush is harvested when almost all of the calyces have coloured. Dalley (1997) suggests that stems harvested with around 3% of white flowers remaining at the top of the stem have the best vase life. Stems harvested earlier will not have sufficient colour, whereas those harvested later will have a shortened vase life. Sepals start to fade if not harvested.

The quality of the final product is reduced by the packing of variable packs of poor colour. There is a need for trained pickers and packers and for picking and packing guides and standards.

Harvesting practices

To maximise postharvest life it is best to prevent the plant material from drying out and to minimise exposure of the cut stems to heat. By lowering the temperature of the stems you reduce respiration rate, water loss, ethylene production and microbial development (Dalley 1997). Temperature management begins by keeping freshly picked stems in the shade. Move them promptly into a shaded packing area that may be cooled with an evaporative air conditioner, or into an evaporatively cooled tunnel. Avoid picking in the hot times of the day. It is all right to harvest Christmas bush in wet weather, and on hot days it may be beneficial to spray the stems with water when they are brought back to the shed.

Place cut stems into pulsing solution (or water) within minutes of picking. All water used should be clean potable water, low in salt, with a pH of around 5 (citric acid at 0.25 g/L will help to acidify); rainwater is preferred. Use of a reputable commercial postharvest solution or addition of a registered biocide is recommended. As soon as possible after harvest, but definitely within 35 to 45 minutes of picking, place the stems into a high-humidity coolroom at 6 to 8 °C with water-scrubbed air (for example, Thermfresh®). To minimise water loss, cover
with plastic as soon as the field heat has been removed.

Hold the stems for a minimum of 4 hours, but preferably overnight, before further processing. If mechanical refrigeration is not available, an evaporative cooler should help. Well wrapped stems can be stored ‘dry’ in the cold for at least a week without appreciable loss of vase life. However, there is a high risk of flower drop and botrytis if the product is stored too long. Risk of botrytis can be reduced by fungicide dipping before storage (as described on the next page).
A bunch with excellent market appeal—well coloured and densely massed flowers in a well constructed and tied bunch.

**Postharvest handling**

Detailed information can be found in the quality specification for Christmas bush (Appendix 2 or rirdc.infoservices.com.au/items/038).

**Grading**

Stem lengths for the export market are 40, 50, 60, 70 or 90 cm, or longer, and some markets
also accept 35 cm. The number of stems per bunch varies, but the number must be consistent within a shipment. Usually 3, 5 or 10 stems are used, according to the size of the pieces. Some special bunches may be over 1.2 m long and contain a single stem. Domestically, bunches tend to be less accurately defined and much more variable. The smaller (shorter) bunches are more difficult to sell, except near Christmas.

**Dipping**

It is important that the flowers be disinfested for export and treated with a fungicide solution if they are to be held for any length of time.

An APVMA Minor Use Permit (PER 12785, expires 30 June 2016) allows the use of insecticide and fungicide postharvest dips for wildflowers, including Christmas bush. The permitted insecticides are Cislin Residual Insecticide, Barmac Delta Force Insecticide and Insectigone Insecticide, which contain 10 g/L deltamethrin as the only active ingredient. The permitted fungicides are Rovral Aquaflo Fungicide and Farmoz Civet Aquaflo Fungicide, which contain 500 g/L iprodione as the only active constituent. The permit and labels give the rates to be used and the duration of dipping. You can download a copy of the permit from the APVMA website (www.apvma.gov.au). The permitted formulations above contain no solvents, which reduces the risk of damaging the flowers, and no additional wetting agents need to be added.

Do your own disinestation trials to see whether the products work in your situation. Check to see that the insecticide kills the insects and that there is no damage to the flowers.

**Storage**

Temperature management is as much a management tool as a technical handling aid. A properly operating coolroom increases management flexibility. Where cooling is available, flowers can be picked at optimum maturity and held over for market, instead of being allowed to deteriorate on the bush.

Storage temperature is very important. It is preferable to store Christmas bush at 6-8 °C if it has to be refrigerated for more than a few days. Some trials have achieved better results for long-term storage (up to 4 weeks) at lower temperatures than this, but this needs to be confirmed before it can be recommended as a general practice. Christmas bush does not appear to be highly sensitive to ethylene, but it is susceptible to chemical injury, both before and after harvest, from both lime sulfur and some non-ionic wetters.

Coolrooms should be kept at high humidity (90% or greater) to avoid desiccation. More information on cool rooms can be found in Appendix 3 and Faragher et al. (2010).

**Sleeving**

Christmas bush is sold in sleeves, which improve the appearance of the product and make packing easier (Dalley 1997). Sleeving reduces damage and saves time in packing and unpacking and in subsequent handling. It is done after dipping and draining of the stems (but do not allow the bunches to completely dry out, as this will shorten vase life). Select the sleeve size to suit the bunch size.

For export, leaves are usually stripped from the bases of the stems (usually for 10 to 20 cm).

Sleeves protect the product and make packing easier. Sleeves should extend beyond the top of the bunch. These bunches are destined for the export market. Domestic market bunches may be larger.
Packing

Packing is the last stage at which you need to do simple and low-cost quality checks. Discard anything that does not come up to standard or does not meet order specifications. Check for insect and fungal damage, especially if stems have been stored.

Pack bunches firmly in boxes so they will not move and be damaged. Pack evenly graded bunches together in a box—do not include thick- and thin-stemmed bunches together. Ensure that the presentation looks neat and tidy, and make sure the count is correct. A carton liner of modified-atmosphere plastic film (LongLife®, FloraFresh®) that is folded over the stems improves Christmas bush quality. The liner increases humidity, reducing water loss, without the condensation and water droplets that result from ordinary plastic. It also reduces the absorption of water vapour by the carton, which helps maintain the carton’s strength. There is little or no benefit in sealing the liner to develop a modified atmosphere, and such a practice cannot be recommended. Christmas bush is susceptible to carbon dioxide injury, and a low-oxygen atmosphere affords little or no benefit.

Cool cartons as soon as possible after packing. A forced-air cooling system can reduce the time to cool a box of flowers packed at 20–25 °C down to 2 °C from up to 72 hours to as little as 20 minutes.

A carton liner of modified-atmosphere plastic film folded over the stems improves Christmas bush quality.
Quality specifications and market requirements

Survey of marketed product

Exports of Christmas bush from Australia consist largely of one variety, ‘Albery’s Red’. Examination of flowers packed for export, as well as for the local market, has revealed large variations in the quality of the flowers, especially between growers and even within bunches. Greatest variations occur in flower colour, density, maturity and size, and in foliage-to-flower ratios, overgrowing of the flowers by foliage, and flower drop.

Colour ranges from deep red (strongly preferred by the US market) to orange red to pink to white and is determined largely by exposure to sunlight during flower development. Shading by upper foliage can dramatically reduce red colouration. Correct pruning techniques and wide row spacing will help to overcome this problem. Growing flowers under hail netting may result in red-orange colouration, even though these flowers may otherwise be of higher quality in terms of general appearance and vase life.

The acceptable hues are those of the two right-hand flowers shown in the photo below. These are equivalent to the Royal Horticultural Society’s (www.rhs.org.uk) colours 45A (strong deep red) to C (medium red), 46A (maroon red) to C, and 47A (deep pinkish red) and B. There is a need for some colour standard to be adopted by the industry, as colours, even of the same variety, vary enormously.

Purplish red may indicate drying out or other environmental damage. This may occur in the field from water stress or in the shed from failure to pack flowers properly to prevent drying out in the box. Plastic box liners are required, even if flowers are sleeved. Water stress in the field or box may also cause flower drop, especially of immature flowers.

Grow-through will also reduce value. This is especially a problem later in the season. Use of fertilisers, especially those containing N, should be restricted close to flowering.

Control of live insects by dipping is good, but evidence of psyllid damage (leaf curling) has still been found in many samples.

Detailed information can be found in the quality specification for Christmas bush (Appendix 2 or rirdc.infoservices.com.au/items/038).

Immature and not fully coloured flowers (2 left flowers) compared with flowers of the correct shades of red (2 right flowers).
Don't market immature or poorly coloured stems.

Packaging

Bunches of similar length and quality should generally be boxed together. Normally the price will be determined by the poorest-quality stem in the box, so accurate grading is important. Transport costs are a significant part of the cost of marketing Christmas bush overseas. It is important to pack the bunches as densely as possible without damaging them; this will increase the returns per box. Different markets have varying requirements for the optimum number of stems per box; Japanese buyers prefer a small number of stems, not more than about 40, offered as a unit for sale. Small (2-kg) boxes or ‘inserts’ (small packages, about 0.5 kg each, packed into a larger outer box) can achieve this. The extra costs of packaging and labour can be more than covered by a higher price. The highest prices for the US market will probably be achieved at around 20 bunches/box.

Keep the loss of water to a minimum. If boxes do not have a vapour barrier (plastic coating or waxing), then line them with plastic. However, the boxes should have holes at the end to allow forced-air cooling and fumigation. Do not block the holes with the liner.

Forced-air cooling after packing is important. Large boxes or stacked boxes will take many hours to cool naturally to the temperature of the cool room, significantly reducing storage life and subsequent vase life.

Labelling

Label each box or unit on the end with stem length, bunch count, variety (especially colour), grower (identification code) and shipping details. More detailed information on labelling can be found in Faragher et al. (2010).
References and further reading

Recommended references are highlighted in bold.


Appendix 1—Management of psyllids in Christmas bush plantations

Management of psyllids in NSW Christmas bush plantations

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Key facts
Christmas bush psyllids:
• cause economic damage by rolling the young leaves of infested plants;
• are difficult to control effectively because they are protected by rolled leaves and have several generations per year;
• encourage the growth of sooty mould on leaves;
• provide hiding places for other insects and spiders—these may be pests of Christmas bush or may cause problems in meeting quarantine standards;
• are largely a problem of well watered and fertilised cultivated plants, rather than of plants in the wild, as they preferentially attack young, actively growing shoots.

The host
Christmas bush, also known as Festival bush (Ceratopetalum gummiferum), is an Australian native flowering shrub to small tree with small white flowers which grow in clusters during late spring. After flowering, the sepals are retained and begin to grow and change colour from white to pink and then red in the most commonly grown varieties. This display of colour usually coincides with Christmas in the Sydney area, giving the plant its common name and commercial desirability. Christmas bush has become a major export crop, with large volumes selling in overseas markets such as Japan and North America.

What are psyllids?
Psyllids are a type of insect that infest many Australian native plants. The adults are small sap-sucking insects, with two pairs of wings held roof-like over the body. They are related to aphids, whiteflies and mealy bugs and are weak flyers. Adult psyllids of various species range from 2 to 10 mm in length. They are free-living and are able to move freely over the surface of foliage. They often jump when disturbed and return to the foliage by flight. In this way they are able to disperse over short distances but they can also disperse widely by wind-assisted flight.
Psyllid nymphs (juveniles) are generally free-living, but in some species secrete a solid covering (lerp), and a few are gall-forming. Psyllids damage their hosts by penetrating the phloem tissues and sucking up plant juices. They extract amino acids and other nutrients from the sap and excrete much of the balance as a sugary waste called honeydew. The honeydew provides nutrients for the growth of sooty mould, and is also often consumed by ants and other insects. Psyllids such as the Christmas bush psyllid may also inject compounds in their saliva (probably auxins) that cause the new leaves to roll. Severe infestations reduce plant growth and can cause new growth to distort, discolor and die back.

Psyllids are considered host-specific—they are usually associated with one host species or a group of closely related host species. For example, species of psyllid that occur commonly on other non-related hosts, such as lilly pillies or eucalypts, will not attack Christmas bush, and vice versa.

The Christmas bush psyllid

Psyllids were reported as a pest of the Christmas bush by Kerruish (1997), who noted that they may damage new leaves of nursery and mature plants. This psyllid, apparently specific to Christmas bush and its near relations, has been assigned to the genus Cerotrioza (G. Taylor et al., in press 2005). Cerotrioza belongs to the family Triozidae, within the superfamily Psylloidea. Other psyllids belonging to this family include Trioza, found on Syzygium (lilly pilly), and Schedotrioza, which forms galls on eucalypts. It is typical for closely related (but different) species in these genera to occur on closely related hosts (as is the case for lilly pillies).

The body of the adult psyllid is about 2 mm long, and with the wings included it is about 3 mm long (Photo 2). When adult psyllids (with wings) are resting they position themselves on stems with the head down and the body at an angle of about 45°, and ‘waggle’ or oscillate their abdomen once or twice a second, the rate increasing as the temperature increases. They fly away fast when disturbed. They also have a distinctive wing pattern (Photo 3).

The feeding activity of the Christmas bush psyllid causes the leaves to curl, protecting the nymphs from predators and many pesticides (Photo 1). Both outer margins of the leaflet curl over to meet at the mid-vein on the upper side of the leaflet.

The whole curled leaf may also become crescent-shaped. This effect is typical of Christmas bush psyllid, and may be used as a diagnostic tool because no other pest or disease is known to produce similar symptoms. Black fungus growing on the honeydew of the psyllids is also often present on the leaves of infested plants, although other sap-sucking insects can also cause this symptom.

The nymphs are about 1–2 mm long and are always found under the curled leaves. Generally, hard, semi-spherical, shiny white globules of solidified honeydew are found under the curled leaves with the psyllid (Photos 4 and 5). Nymphs are readily identified by their shape and their red eyes, which become relatively larger with each instar. Other insects, especially aphids, may be found cohabiting with the psyllid.
Heavy infestation causes the Christmas bush to be unmarketable. This damage also reduces the growth rate of affected plants. Even a low level of infestation can cause serious economic loss, both through downgrading of material and through greatly increased grading costs. Infestations appear to be spreading beyond their natural habitats in NSW and Queensland, by natural dispersal and as a result of infested plants being planted in new areas.

Other insects, notably aphids, can also shelter in the rolled leaves and produce honeydew. Aphids sheltering with the psyllids can be attended and spread by ants, but ants do not appear to spread Christmas bush psyllids. Both the psyllids and other arthropods (including spiders) that shelter with them can cause serious disinfection problems in meeting quarantine standards. Most of the standard disinfection methods are not 100% effective so it is important for levels of both psyllids and damaged foliage to be as low as possible before harvest.

The Christmas bush psyllid can also infest Coachwood (*Ceratopetalum apetalum*), which is closely related to Christmas bush. Both Christmas bush and Coachwood often occur in native forests adjoining areas where Christmas bush is cultivated. However, both usually do not occur together. Coachwood usually grows in subtropical rainforest, with the Christmas bush usually growing on the margins. It is not known if the Christmas bush psyllid can infest the other three species of *Ceratopetalum*. However, these only occur largely in rainforest in northern Queensland, especially on the Atherton Tablelands, and their natural range does not overlap with either Christmas bush or Coachwood.

### The psyllid lifecycle

The typical lifecycle of psyllids commences with an egg which is inserted by a short stalk (pedicel) into the host tissue. The egg obtains moisture from the host tissue via the pedicel, and if the plant host dies, the egg fails to develop. The larva that emerges from the egg passes through five larval instars, with a moult between each. Generally each instar can be identified by differences in size, relative size of the red eyes, and increasing development of wing buds. Their rate of development and consequent generation time is temperature dependent and there are a number of generations each year. In tropical and subtropical climates, generations often broadly overlap, so that all life stages can be found at any one time. This appears to be the case for the Christmas bush psyllid and there may be five or more generations per year. In temperate climates, there are usually three generations per year, with a distinct winter generation and two summer generations.

In psyllids, the final moult results in the emergence of a winged adult, which is able to disperse to new host plants (psyllid nymphs do not have wings and can only move very short distances by crawling). Adult psyllids live for between a week and several months, depending on the species and conditions. Fecundity is highly variable between species, and in some species each female can produce over 500 eggs.

Adult Christmas bush psyllids are present all year round in the Central Coast and Mid North Coast regions of NSW. Traps indicate that populations are greatest from autumn to early spring, with few adults present in summer.

### Factors favouring psyllids

Psyllids are rare in the wild, even on Christmas bush and Coachwood close to infested plantations. The spread and growth of similar psyllids is favoured by young vigorous growth high in nitrogen, and high humidity. Cultivated Christmas bush that is irrigated and fertilised to achieve maximum growth rates appears to provide ideal conditions for the psyllid.

The level of infestation of psyllids is partly controlled by the weather, with growers reporting ‘good’ and ‘bad’ years for psyllids. Psyllids prefer cool, moist weather—Christmas bush psyllid is no exception, with maximum numbers of adults occurring from autumn to spring, peaking in cool, moist weather.
Managing psyllids

Pesticides

Christmas bush psyllids are difficult to control effectively, especially with pesticides that have a contact action only (see Non-systemic pesticides), because they are often protected from direct contact by the curled leaves of the host plant. Under the tropical and subtropical conditions of the main production areas on the North Coast of NSW and in southern Queensland, there will be many generations of the pest each year. As a result, pesticide sprays for psyllids may not greatly reduce foliage damage unless they are applied at the right time and frequency and the correct chemicals are used. For example, if only one application of a contact pesticide is made, subsequent new growth will not be protected, and this new flush will be susceptible to damage by any psyllids that survive the initial spray, or migrate from untreated plants to plants that have already been treated.

No treatment can restore damaged foliage—the foliage remains distorted until it is pruned off or replaced by new growth. Infestation lower down the stem will also often result in new growth becoming distorted, even if it has no psyllids living on it. Leaf rolling may also continue to occur for some time after the psyllids have been removed due to residual levels of auxins in the leaf. It is also very important to keep the level of psyllids in the field at a very low level to reduce the chance of any survivors of disinfestation treatments after harvest.

Broad spectrum systemic insecticides may seem an attractive management option as they are especially effective where pests are protected from direct contact by the host tissues. However, these chemicals also kill a wide range of other insects and can harm natural enemies. Pesticides with a narrower range of efficacy, or which are ‘softer’ on the environment due to their low residual toxicity, are more desirable for managing psyllids. These pesticides may have to be applied several times during the growing season to protect the Christmas bush against the next generation of psyllids. It is of concern that many growers may be relying exclusively on one chemical—sustained use of one chemical can lead to the development of resistance in the psyllid. Other growers may be using less-effective products, which allow survival of some of the psyllid population.

Systemic pesticides

Systemic pesticides are pesticides that are absorbed into the plant and then distributed through the plant, so they are active throughout the plant and not just at the application site.

Advantages of systemic pesticides:

- The chemical can reach pest organisms already in the plant.
- The whole plant surface does not need to be treated—the spray can be applied anywhere on the plant, or as a drench to the soil to be absorbed through the roots.
- New developing foliage can be protected from the pest.
- Once applied, the pesticide is not washed away by rain or irrigation.
- These chemicals are especially useful against sucking insects.

Disadvantages of systemic pesticides:

- They are not necessarily distributed evenly within the plant.
- They may persist in the plant for a long time, affecting withholding periods. The residues cannot be removed by washing the plant.

Non-systemic pesticides

Non-systemic pesticides are not absorbed into the plant and are only effective at the site of application. An example of this is a contact pesticide, which kills the insect by being absorbed through the insect’s body.

Recommended pesticides

Some insecticide efficacy trials have been carried out to determine the most appropriate chemicals for growers to use in managing Christmas bush psyllids. However, further trials are needed to determine if newer chemicals now available would provide a commercially acceptable level of control.

Table 1 lists chemicals which are registered for control of psyllids (lerp insects) or plant bugs on ornamental crops in NSW. Growers should always check the label before using any pesticide and are advised to trial new products on a small area of the crop first, in order to monitor efficacy and any possible side effects such as phytotoxicity (damage to the plants).

Psyllids are technically ‘bugs’, and some product labels state more generally that the product is registered for use on ornamental plants against bugs.

Other arthropod pests

The effect of those pesticides (chosen to control psyllids) on other pest species and non-pest species that occur on Christmas bush will also need to be considered. Pesticides effective in controlling psyllid may or may not be effective against these other pests, and vice versa. Listed below are some of the more common pests:
- **Monolepta beetles** have been found in northern NSW, swarming in spring and early summer.

- **Leaf roller and webbing caterpillars** are found infesting growing tips, binding young leaves together.

- **Fruit tree borer** (Oecophoridae, Lepidoptera)—caterpillars produce webbing of the leaves, and frass at the junction of twigs or branches.

- **Longicorn beetle** (Cerambycidae, Coleoptera) larvae may tunnel in trees weakened by regular and severe pruning.

- **Aphids and thrips** can attack new shoots and cohabit with the psyllid under the curled leaves. They also exude honeydew on which fungi grow, causing blackening of the leaf. Ants, in large numbers, can also tend these and other pests, facilitating their spread, protecting them from enemies, and causing an infestation problem themselves.

- **Scales**, including olive brown scale, white palm scale and black scale, are often found on young plants.

- **Thrips** (plague thrips—*Thrips* sp.) suck the sap from calyces which brown and fall, preventing the development of the red bracts.

The effect on non-pest species that may be an issue for quarantine, for example spiders, should also be considered.

It is essential that any control program for the Christmas bush psyllid should be part of an overall integrated pest and disease management (IPDM) system. For example, even the fungicide iprodione can cause significant mortality of the Christmas bush psyllid.

### Quarantine

It is thought that psyllids are readily spread through propagation material. This would explain the rapid spread of this pest into new cultivation areas. Some plantations have remained psyllid free, although they are in major growing areas, indicating that quarantine can be effective in preventing spread. Any new plant material introduced should be quarantined and sprayed with insecticide to kill all psyllids, especially if there are any rolled leaves. Even if there are psyllids already in the plantation, new sources should be excluded. There is a possibility that the new psyllids may be resistant to insecticides to which the existing population of psyllids are not resistant.

Psyllids are also readily transferred on cut material. Thus it is important not to bring cut material into the area without it first being treated. This is an important consideration for propagation material and for packing houses.

### Monitoring psyllids

The level of infestation is indicated by the percentage of rolled leaves. The highest quality ‘flowers’ will have no rolled leaves. For lower grades, up to 5% or 10% of leaves may be rolled; however, there must be no live psyllids or visible black fungal growth. In the field the number of live psyllid nymphs and eggs may also be counted to determine relative levels of infestation.

Levels of infestation, as indicated by the number of flying psyllids, may also be determined by the use of yellow sticky traps (see photo 6), which are readily available commercially. Psyllids appear to be readily attracted to the colour yellow. The traps are left out for predetermined intervals, usually 1 week, and the number of psyllids counted. The psyllids are quite distinctive and easily identified. Maximum levels usually occur in spring and summer. Sticky traps may also be used to determine the level of other flying insects, especially thrips.

![Photo 6. Yellow sticky traps placed at the shoot tips are an excellent tool for detecting psyllid infestations early.](image)

Another possible indication of psyllids is the presence of large numbers of ants on the Christmas bush. Although they do not appear to be a direct factor in the spread of psyllids, ants do ‘farm’ aphids, which are commonly found in association with the psyllid under the curled leaves.

### Biological control

Biological control has been successful for certain psyllid pests. However, in Australia natural enemies have not been effective in all cases. Psyllids can be attacked by chrysopids (predator lacewings) and several other insects, but until there is further research in this area, growers will need to rely on pesticides to manage this pest. Choosing a ‘low residual’ chemical will help conserve any beneficial insects that may be present in the crop.

In deciding which pesticide(s) to use, it is important to consider the following:

- **Effectiveness on pests.** The pesticide must kill a very high percentage of the psyllid.
• **Mode of action.** Systemic or contact.

• **Psyllid resistance.** If the psyllids become resistant to the chemical, then the chemical loses its effectiveness to kill them.

• **Toxicity to the plant.** The pesticide should not harm the host plant.

• **Toxicity to humans.** It is preferable to choose the least toxic chemical available.

• **Toxicity to the environment:** Residual effect: How fast does the pesticide break down? Does it affect non-target organisms and the psyllid predators (which could be developed as a biological control)?

**Recommendations for further research**

Further research is needed in the following areas:

- assessing and monitoring Christmas bush psyllid resistance to chemicals due to long-term use;
- screening of other types and groups of chemicals for control, both singly and in combination;
- finding an effective biological control;
- studying the life cycle of the psyllid to find the best times to apply pesticides.

### Table 1. Chemicals for the possible control of psyllid. These are registered for use on ornamental crops to control psyllids (lerp insects) or plant bugs

<table>
<thead>
<tr>
<th>Name of chemical</th>
<th>Systemic or contact</th>
<th>Effective against</th>
<th>Chemical group (for the purpose of resistance management)</th>
<th>Toxicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethoate, e.g. Rogor®</td>
<td>Systemic</td>
<td>Aphids, thrips, jassids, spider mites, leafhoppers, azalea lace bug, green vegetable bug, rutherfordian bug, leafminers, greenhouse whitefly, wingless grasshoppers.</td>
<td>1B insecticide, organophosphate.</td>
<td>Toxic – schedule 6 poison. Marine pollutant. Dangerous to bees and fish. Do not contaminate streams, rivers or waterways with the chemical. <strong>Warning:</strong> Do not spray flowers as it has been reported to cause serious damage to them.</td>
</tr>
<tr>
<td>Imidacloprid, e.g. Confidor®</td>
<td>Systemic</td>
<td>Aphids, azalea lace bug, bronze orange bug, harlequin bug, citrus mealy bug, greenhouse thrips, fullers rose weevil, hibiscus flower beetle, longtailed mealy bug, psyllids, soft scales.</td>
<td>4A insecticide, chloronicotinyl. On perennial crops use a maximum of 3 sprays in any 12 month period; rotate with registered insecticides from other groups.</td>
<td>Moderately toxic to mammals and birds; low toxicity to aquatic organisms; highly toxic to bees.</td>
</tr>
<tr>
<td>Methidathion, e.g. Supracide 400®</td>
<td>Systemic</td>
<td>Aphids, armyworm, caterpillars, cutworm, grasshoppers, leaf hoppers, leaf miners, lerp insects, mealy bug, plant bugs, sawflies, scale insects, soft scales, thrips, weevils.</td>
<td>1B organophosphate.</td>
<td>Toxic—schedule 6 poison. Dangerous to bees and fish. Avoid contamination of waterways or water storages with the chemical.</td>
</tr>
</tbody>
</table>

*Source: InfoPest, May, 2005 version.*
Recommended reading and references

Bodman, K et al. 1996, Ornamental plant pests, diseases and disorders, Queensland Department of Primary Industries, Information Series Q196001.

Carson, C (coordinating author) 2000, Should I grow wildflowers? Agrilink (Queensland Department of Primary Industries), Agdex 294/10, Nambour, Queensland.


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Updates of this Primefact are available at www.dpi.nsw.gov.au/primefacts

Disclaimer: The information contained in this publication is based on knowledge and understanding at the time of writing (December 2005). However, because of advances in knowledge, users are reminded of the need to ensure that information upon which they rely is up to date and to check currency of the information with the appropriate officer of New South Wales Department of Primary Industries or the user’s independent adviser.

Recognising that some of the information is provided by third parties, the State of New South Wales, the authors and the publisher take no responsibility for the accuracy, currency, reliability and correctness of any information included in the document provided by third parties.

Reference to trade names, specific products and companies in this publication does not necessarily imply endorsement of the product or company by the NSW Department of Primary Industries. Any exclusions are unintentional.

IMPORTANT: Always read the label

Users of agricultural (or veterinary) chemical products must always read the label, and any Permit before using the product, and strictly comply with the directions on the label and the conditions of any Permit. Users are not absolved from compliance with the directions on the label or the conditions of the Permit by reason of any statement made or not made in this publication.
Appendix 2—Christmas bush quality specification

Product: Christmas Bush
Botanical name: *Ceratopetalum gummiferum*
Cultivar: Albery’s Red
Harvest times can be variable from year to year at any one site. 
Christmas bush is vulnerable to damage by adverse weather during the 6–8 weeks before harvest. Excessive temperatures and low relative humidity, particularly when accompanied by strong winds, can cause flower drop and excessive growth, which can lead to ‘grow-past’, or ‘grow-through’, when the shoots at the stem tip grow through the flowers.

Severe frosts or hot dry winds at flowering can cause complete loss of flowers.

Ensure that the product does not dry out during or after harvest – harvested product may need to be sprayed with an atomiser to keep it moist.

Grade is determined by the ratio of flowers to foliage and by flower density, and therefore redness. This needs to be taken into account when you select stems to form a bunch.

Grading Christmas bush to maximise profits may require a high labour cost. There are currently large variations in flower colour, density, maturity and size and in foliage-to-flower ratios between growers.

Flowering season:
Variable, but generally from mid October in southern Queensland to January (to as late as March) in Victoria.

Typical vase life:
7–14 days.
Export can reduce the vase life, especially if the transport conditions are not cold, the product dries out, or transport takes too long.

Other products to which this specification can be generally applied:
Other cultivars and selections of Ceratopetalum – these may be red, white or pink.

The contrast of the green foliage with the bright red flowers, which are produced around December, gave Christmas bush its name. It is also sometimes called Festival Bush.

Christmas bush has been enjoyed as a garden plant and sold as a cut flower in Sydney for over a century, originally picked from the bush or from garden-grown plants. Plantation production for cut flowers began as early as 1912, but it was only in the 1990s that large plantations were set up.

Albery’s Red, currently the most commonly grown cultivar, is a compact, upright, early, free-flowering plant with dark red flowers.

There is a strong demand for Christmas bush on the domestic market during the week before Christmas, especially in Sydney, when the best prices are often achieved. Prices drop dramatically just after Christmas.

Christmas bush as an export product can supply the high-quality flowers in demand in Japan before the Japanese New Year (1 January) and in the USA at Thanksgiving (the 4th Thursday in November). Chinese New Year and Valentine’s Day are also suitable targets for later product in Asia and the USA.

Christmas bush flowers from mid October in southern Queensland through to January or later in Victoria. To supply key markets before Christmas, areas between Gympie in the north to the Sydney basin in the south appear most suitable for production.

It may be more difficult to export this product after Christmas, except for markets associated with Chinese New Year.

Harvest time may be a limiting factor in crop profitability. Along the east coast of NSW and Queensland, flowering is affected by temperature and daylength, with flowering progressing from north to south.

Typical bunches look like this.

Other colours of Ceratopetalum are available.
Product: Christmas Bush  Cultivar: Albery’s Red

**PERCEIVED VALUE (REDNESS) AND GRADE**

The chart below shows stems of varying flower density and perceived value.

- **FOLIAGE GRADE**
  - Flower density sparse and limited to shoot tips; more foliage than flowers

- **A GRADE**
  - Flower mass denser than foliage grade, with some foliage visible below the flower masses

- **AA GRADE**
  - Flower mass denser than A grade – suitable for domestic market

**COMMON DEFECTS**

**Common defects to be avoided at market entry:**
- Psyllid damage (curled leaves)
- Grow-through
- Flower drop
- Poor coloration (immature or shade grown)
- Flower darkening (overmaturity or burning due to poor handling)
- Wilted product
- Poor foliage
- Excessive foliage in relation to flowers
- Insect contamination
- Poorly constructed bunches

- Immature and not fully coloured flowers (2 left flowers) compared with flowers of the correct shades of red (2 right flowers)

- Missing flower masses in centre of stem – do not market

- Shoot grow-through

- Wilted tips and prominent grow-through – do not market
Christmas bush differs from many flower products in terms of when it is ready to harvest: time to harvest and quality depend largely on the flower density and the 'perceived value' of red on a flowering stem. This is determined by the density of the flower mass and the ratio of flowers to foliage. Stems are harvested once most of the flower masses are red (and ≤3% of young flowers at the very ends of the stems are still white and immature). There is little additional development of flowers after harvest.
FLOWERS

Appearance
Flowers perceived as predominantly red (as shown in chart ‘Perceived value (redness) and grade’) – and see ‘Grading’.

Deep red, glossy flowers – the acceptable hues are those of the two right-hand flowers in the photo showing the range of flower colour (from immature to fully coloured) under ‘Common Defects’ on page 3. These are equivalent to the Royal Horticultural Society’s (http://www.rhs.org.uk/) colours 45A (strong deep red) to C (medium red), 46A (maroon red) to C, and 47A (deep pinkish red) and B.

The youngest 3% of flowers at the stem tip are still white.

Not faded.

Not purplish – similar to RHS 53A (purplish maroon) or darker (this occurs when product is overmature or heat damaged).

Avoid shaded flowering stems that have failed to redden.

See chart showing stems of varying flower density and perceived value. There is little additional development of flowers after harvest.

No grow-through longer than 6 cm.

When to harvest
Time to harvest and quality depend on the flower density and the perceived value of red on a flowering stem. This is determined by the density of the flower mass and the ratio of flowers to foliage.

Harvest when almost all of the flowers have coloured and no more than 3% of young flowers at the stem tips are immature and white.

Damage
Minimum damage to flowers.

Flower drop
Not more than 3% of flowers have been shed after harvest.

Contamination
Product to be free of grit and soil, weeds or weed seeds, living or dead insects, and signs of insects or spiders, such as webbing.

Pests and diseases
No insects, insect damage or disease.

LEAVES

Appearance
Dark green, glossy.
Not overly soft.

At harvest
Remove leaves from the lower 10–15 cm, or 1/3, of the stem.

Damage
Minimum evidence of pests, disease or other blemishes.
No visible chemical residue.
No more than 3% leaf curling due to psyllids for domestic markets. No leaf curling due to psyllids for export markets.

STEMS

Appearance
Rigid and strong enough to support blooms. Neatly cut end.
Flowering stem pyramidal (‘Christmas tree’) shape.

Length
According to market demand.

RECOMMENDED HANDLING AT HARVEST

Minimise drying out and exposure to heat – pick when it is cool, preferably straight into buckets of clean, potable water or a reputable commercial postharvest solution, and hold cut stems in the shade.

Move cut stems promptly to a cool, shaded packing area and reduce temperature to <15 °C within 1 hour and to <10 °C within 2 hours.

Some growers run two cool rooms – one to hold just-harvested Christmas bush and the other for processed product.

GRADING AND BUNCHING

Grading
Reject any contaminated stems.
Sort stems according to grade, length and thickness.
Grade is determined mainly by the volume of flowers and leaves on the marketed stem. A range of grades is marketed – see Chart ‘Perceived value (redness) and grade’. Generally the higher grades have a greater volume of flowers per stem. The highest grade is marketed as AAA++.
Sometimes product with few flowers and a significant amount of good-quality foliage may be marketed as ‘foliage’ grade, but some buyers do not consider this product to be Christmas bush, and returns may be poor.
The domestic market generally requires three grades: AAA, AA and A.

Bunching
Prepare bunches to buyer requirements.
The number of stems per bunch varies, and is determined by bunch size, stem diameter, and market and buyer requirements.
There is no prescribed stem diameter in relation to length. However, presentation is important, so for example if 5 stems make a thin looking bunch, then increase bunch size. Stay consistent for the grade and make all bunches the same.
Especially for export, stems should be approximately the same diameter within a bunch, with the ends aligned.
Use 1 tie at the base plus a sleeve to support the bunch.
Return bunches to hydrating solution (see ‘Postharvest solutions’).

<table>
<thead>
<tr>
<th>Stems per bunch</th>
<th>Stem length (cm)</th>
<th>Av. no. of stems per bunch</th>
<th>Av. bunch weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Export</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90+ (extra long)</td>
<td>2–3 (1–2 stems of 100 cm + 1 stem of 90 cm + 1 stem of 80 cm)</td>
<td>600</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>4</td>
<td></td>
<td>600</td>
</tr>
<tr>
<td>70 (long)</td>
<td>3–5 (2–3 stems of 70 cm, remaining stems 60 cm)</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>60 (medium)</td>
<td>5 (3–4 stems of 50 cm + 40-cm stems)</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>50 (small)</td>
<td>5</td>
<td></td>
<td>300</td>
</tr>
<tr>
<td>40</td>
<td>7–10 (stems ≤40 cm)</td>
<td>250</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>10</td>
<td></td>
<td>250</td>
</tr>
<tr>
<td>Domestic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90+ (extra long)</td>
<td>3</td>
<td>up to 3</td>
<td>600 g</td>
</tr>
<tr>
<td>60–70 (long)</td>
<td>2 or 3 each of 60 and 70 cm stems</td>
<td>450</td>
<td></td>
</tr>
<tr>
<td>40–50 (medium)</td>
<td>3–6 each of 40 and 50 cm stems</td>
<td>350</td>
<td></td>
</tr>
<tr>
<td>30–40 (small or posy)</td>
<td>equal numbers of 30 and 40 cm stems</td>
<td>250 g</td>
<td></td>
</tr>
</tbody>
</table>
**HOLDING AND STORAGE**

**Cooling**

Effective cooling soon after harvest is important to retaining quality and maximizing vase life. There are two options:

- Cool, process, cool – for example, remove field heat by cooling flowers immediately on entry into shed to 10 °C in buckets of solution, process flowers (bunch, grade), and then cool to 6–8 °C by either forced-air cooling (if boxed) or holding overnight in a cool room.
- Process within 1 hour of cutting, and then cool to 6–8 °C by either forced-air cooling for 20–30 minutes (if boxed) or holding overnight in a cool room (if in buckets).

**Temperature and humidity**

Keep product damp to avoid drying out. Aim to store stems in a high-humidity cool room (95%) at 6–8 °C (as Christmas bush is sensitive to chilling injury at lower temperatures) within 12 hours of cutting.

Hold in cool room until ready to process: at least 4 hours or preferably overnight.

Another way of achieving high humidity is to cover the flowers with plastic sleeves or plastic sheeting. If storing for a few days, you may need to treat with a fungicide to protect against botrytis.

**Postharvest solutions**

Hydration solution: Hold in clean potable water or preferably a reputable commercial postharvest solution.

Postharvest solution: Same as hydration solution. No extra treatments are recommended.

**Longer-term storage**

For longer storage seek professional advice and test in the market before committing product. There is a high risk of flower drop and botrytis if this product is stored too long.

**PACKAGING**

Pack product damp.

Pack bunches of the same size (stem number or weight, thickness and length) together.

Pack evenly graded bunches together.

Use paper to separate layers of product in the box.

Pack bunches firmly but ‘springy’ so the product will not move and be damaged.

Pack boxes according to customer requirements.

Use boxes with holes to allow forced-air cooling and to facilitate fumigation. Minimise water loss and maintain strength of the carton, especially for long-distance transport, by lining boxes with plastic. Cool packaged flowers to 5 °C before transport.

**LABELLING AND DOCUMENTATION**

Label boxes and buckets as recommended in Postharvest Manual or as required by customer.

Ensure that box contents are exactly the same as specified in the documentation and on the end of the box.

**TRANSPORT**

Refrigerated vehicle at lower than 10 °C but no lower than 5 °C.

**COMMON POSTHARVEST PROBLEMS**

Refer to Postharvest Manual for general advice.

- **Fungal decay in storage due to botrytis (grey mould)**
  - Use preharvest fungicide sprays during wet weather to reduce the risk of botrytis disease.
  - Use preharvest insecticide sprays to reduce the pest population at harvest.
  - Dip flowers that are to be packaged and held for any significant length of time (export product) in a registered fungicide or insecticide solution for not less than 1 minute, then dry naturally for 2 hours to ensure thorough disinfestation. (Do not allow bunches to completely dry out after dipping).
  - Or: Fumigate flowers before dispatch to kill insects.

- **Ethylene sensitivity**
  - Christmas bush appears to be susceptible to ethylene only at very high concentrations. Therefore, treatment with anti-ethylene products is usually not necessary. Sensitivity to low to moderate levels of ethylene is not known, so avoid transporting with fruit.

- **Chemical sensitivity**
  - Some wetting agents may be phytoxic to Christmas bush – test on a small sample before using.

**Messages for importers and wholesalers**

- Recut stems and place into fresh water containing a reputable commercial postharvest solution, preferably including sugar.
- Cool product before marketing or sending on and keep it cool.
- Maintain good hygiene and keep containers clean.

**Messages for retailers**

- Recut stems and place into fresh water containing cut-flower food or a registered chlorine biocide.
- Use clean buckets and containers for displays.
- Do not display flowers in areas that are exposed to full sun, draughts, high temperatures or vehicle exhausts, and preferably do not display near fruit and vegetables. Use refrigerated displays if possible.
- Tell the customer how to care for the flowers and emphasise the need for cut-flower food in solutions. Give the customer a sachet of cut-flower food to take home.

**Messages for consumers**

- Keep vase filled with the correct solution of cut-flower food. Check daily, as flowers can use a lot of water. If cut-flower food is not used, change the water at least every second day. Always use clean vases and clean water.
- Do not display in areas that are exposed to full sun, draughts or high temperatures. Keep as cool as possible without freezing.

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Sleeves

To maintain quality, sleeve bunches. This improves product appearance, reduces drying out and makes it easier to pack. Select the sleeve size to suit the bunch size. Microperforated sleeves are recommended, as they assist in preventing the formation of condensation. Ensure the product can breathe within the sleeve, and go up a sleeve size if the bunch is large. The sleeve should extend well past the top of the bunch to prevent drying out (but finding sleeves long enough for stems 90 cm or longer may be difficult).
Appendix 3—Cool room design and layout

General

Good design is critical for the proper functioning of a cool room. The room should be suitably sized for the business and planned to suit the current or intended handling procedures.

Before building a cool room, consider how your business might expand and what could improve handling efficiency. For example, provide for access and manipulation, as well as for pressure cooling if the room will be used to cool stacks of cartons before dispatch or during storage.

The room must be designed to operate reliably with a uniform temperature of 6–8 °C and at high relative humidity (90%) when fully loaded. If you are intending to grow other flowers as well, design your cool room with the capacity to run at a lower temperature (2 °C) when required. Adequate refrigeration capacity also needs to be included, which will require good insulation.

Make rough sketch plans, which cost nothing but help get the best result.

This appendix examines cool room design and procedures in more detail. There is a checklist at the end to assist in cool room design.

Storage and access

Tiered racks can be used to stack several buckets. Straight racks of open mesh can be used to lay out packed cartons. Mobile racks that can be moved between the packing area and cool room are efficient. Alternatively, trolleys or carts can be used. Another option is to install a small hatchway in the wall of the cool room, where buckets or cartons can be moved through on a roller conveyor. Allow adequate aisle space for access, enough clear space to manipulate trolleys and carts, and air gaps for free circulation of air. At least 25% of the floor area will be taken up with aisles and gaps.

Room height

Room height must be adequate for ease of movement and stacking of buckets or cartons. The cooling unit should be hung beneath the ceiling at a level where nothing needs to be stacked higher than its base. In cool rooms with operations done by manual handling, the height should be at least 2.75 m.

Gaps for air circulation

Allocate space to allow unimpeded circulation of air around the room and between stored objects. Circulating air takes away the heat that comes in from outside and from stored products, carrying it to the cooling unit. Heat that leaks in from outside is best removed by air that flows over the entire inner sides of the ceiling, walls and floor. Similarly, air should be able to circulate freely around each object in the room.

Recommended clearances for good air circulation and appropriate size of air spaces are given in Table 1.
Table 1 Recommended clearances for good air circulation.

<table>
<thead>
<tr>
<th>Item</th>
<th>Space to allow (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clear space in front of cooling unit</td>
<td>At least 2000 mm</td>
</tr>
<tr>
<td>Space between buckets or cartons and floor (buckets and</td>
<td>50–100 mm (must be 100 mm if the floor is not insulated)</td>
</tr>
<tr>
<td>cartons must be stood off the floor on pallets or racks)</td>
<td></td>
</tr>
<tr>
<td>Space between buckets or cartons and the outer walls</td>
<td>75–125 mm if the wall is unshaded and faces north to north-west</td>
</tr>
<tr>
<td>Clearance between top of flowers and ceiling</td>
<td>Absolute minimum of 300 mm. Preferred space is 450 mm or greater</td>
</tr>
<tr>
<td>Space between individual buckets or stacks of cartons</td>
<td>50 mm</td>
</tr>
</tbody>
</table>

**Insulation**

Adequate insulation is essential if the room is to maintain a uniform temperature and high humidity while using electricity efficiently. Select insulation to suit each application and location. A minimum specification for a cool room built inside a shed is for the walls and ceiling to contain 100 mm and the floor 50 mm of expanded polystyrene or equivalent; the common provision of 75 mm polystyrene is usually inadequate. All new floors should be insulated, but where an existing floor is in use the cost of insulation may not be justified, especially if the room is not used for storage. Be aware though that problems are likely if flowers are stored in rooms without floor insulation.

**Vapour barrier**

Protect the insulation from moisture in cool rooms used for flower storage with a high-grade vapour barrier. The barrier is formed by the outer skin of a sandwich-panel room. All joints (and holes) must be sealed with an approved high-quality sealant.

A contract for employing a tradesperson might say: ‘The room shall be constructed so that a continuous, impervious vapour barrier is established. Only installers with extensive experience in the construction of vapour-proof cool rooms shall be employed.’

Never allow holes to be cut or drilled in the outer skin of a cool room by anyone other than an experienced installer.

**Cooling unit**

The unit cooler for the ceiling consists of a refrigeration evaporator and fans that circulate room air over the evaporator coils. The correct selection of the unit cooler is a job for an experienced refrigeration engineer.

The unit must have sufficient surface area and airflow to provide high humidity. The optimum humidity will depend on how flowers are held and the length of time they may be stored. For most purposes a target humidity of 90% should be satisfactory and can be achieved with a coil diffusion temperature of 3 °C.

The airflow from the unit should give at least 60 room air changes per hour when hot material is first placed in the room. The air change rate should be reduced to 15–30 per hour when already cooled flowers are being stored. This reduction can be achieved with a two-way switch on the unit fans, which run continuously during temperature pull-down but cycle with the cooling unit afterwards. If electric defrosting is not installed as recommended below, then the fans must be left to run continuously.

A room operating at 2 °C and used for the storage of flowers must have electric defrosting. The daily defrosting cycle should be turned on by a clock and terminated by a refrigeration pressure switch. However, take note that Christmas bush needs to be held at 6–8 °C.

Take care in deciding the size of the unit and the velocity of air it discharges. Low-profile units are essential in small rooms so that stor-
age space not be wasted. Most units discharge air at a velocity too high for contact with flowers exposed in buckets. The air velocity also makes working conditions uncomfortable. Low-profile, low-velocity units that still provide adequate air circulation and humidity are preferable. Such units typically have a discharge velocity of about 0.7–1 m/s. The velocity of air over exposed (unpacked) cut flowers once they have cooled down should not exceed around 0.3 m/s. Even with low-velocity units it may still be necessary to hang plastic sheets in the room to act as windbreaks.

Refrigeration capacity

The refrigeration machinery installed must have adequate capacity to properly cool the largest, hottest load that will ever be put into the room under the worst probable heatwave conditions. Estimating the refrigeration capacity is a job for an experienced engineer. But a reliable estimate can be made only if you provide reasonable and realistic information. Ask yourself:

- What is the largest quantity of flowers that will be harvested and placed in the room on the same day at the peak of the season?
- How hot is this load of flowers likely to be?
- Will a similar quantity be harvested the next day or the day after that?
- What is the largest amount of flowers that will be held in storage (after cooling down) at any one time?

Thermostats

Room temperature must be controlled by a sensitive and accurate thermostat, because flowers are easily frozen. It is often desirable for the thermostat to control the refrigeration cycle through a liquid-line solenoid valve. An electronic thermostat is recommended, set to a differential of 1 °C, with the determined temperature appearing on a digital display outside the room. Models that have an under-temperature warning alarm should have the sensing element located in the return air stream to the cooling unit and kept at least 300 mm away from the walls, ceiling and lights. The best location may have to be established by trial and error. Never assume that by setting the thermostat to 2 °C the room will necessarily operate at precisely 2 °C, as the operation of any cool room below 5 °C always carries a very real risk of freezing. Take great care during initial set-up and in maintaining safe operating conditions. Independent thermometers must be used to set up and maintain the correct conditions.

Thermometers

Thermometers are used to check that the air temperatures in different parts of the room are uniform and that flowers are being held at the correct storage temperature. Glass or electronic thermometers of good quality are suitable, provided that the latter are specifically recommended for use in cool rooms. The scale should be readable to at least 0.5 °C. Thermometers used to gauge air temperature should have the bulb or sensing element immersed in a small vial or jar of water (20 to 100 mL) that smooths out short-term fluctuations in the air temperature and must remain in the room.

Always test thermometers after purchase and at least once each season or if they have been damaged in any way. Test by inserting the thermometer into a slurry of crushed ice and water and noting the temperature shown—melting ice should read 0 °C.

Checklist for cool room design

This checklist summarises many of the items that need to be considered and other information needed when you are designing a good cool room.

1 Capacity of room

- What is the maximum weight of flowers that will be picked and placed in the room on any one day?
- What is the maximum weight of flowers that might be stored in the room (not dispatched before flowers from the next harvest start coming into the room)?
• What is the weight of each water-filled bucket without flowers?

2 Desired cooling time
• How quickly do you wish to cool the flowers?

3 Handling method
• Are flowers handled entirely in buckets, or is some or all of the harvest packed into cartons?
• Are buckets and cartons handled manually, or are handling aids such as mobile racks, pallet trucks or roller conveyors used?
• Are forklift trucks used?
• Are changes in handling anticipated in future?

4 Handling flow
• How will flowers be handled when picked?

5 Commodities to be cooled
• Is Christmas bush the only flower that will be cooled? (See Table 2.)
• Will only your produce be stored in the room, or will it be shared with another grower’s?
• Will other types of flower be cooled?
• Will the room be used to store any other types of produce?
• If the room will be used for storing other produce, will there be times when Christmas bush and other produce might be put into the room together?

Table 2 Commodity roster for multi-purpose cool room.

<table>
<thead>
<tr>
<th>Commodities to be cooled</th>
<th>Months of year when cooling will occur</th>
<th>Maximum expected commodity temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2

3

4

5
Growing Christmas Bush for Cut Flowers
A guide for commercial growers
By Ross Worrall and Paul Dalley
Pub. No. 12/089
This ‘how to’ guide has been produced for members of the Australian wildflower industry who grow and market Christmas bush, including growers, wholesalers, retailers, florists, exporters, importers, research, development and extension workers, and students.
It provides advice and information for growers, wholesalers, exporters and retailers with practical information about growing, harvesting, postharvest handling and treatment of Christmas bush.
RIRDC is a partnership between government and industry to invest in R&D for more productive and sustainable rural industries. We invest in new and emerging rural industries, a suite of established rural industries and national rural issues.
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