Taro Production
— mechanisation and industry development —

A report for the Rural Industries Research and Development Corporation

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Foreword

In Australia, taro is a minor crop, grown commercially in tropical and sub-tropical regions mainly for its edible corms. Production caters to a significant market mainly amongst Asians and Pacific Islanders in east coast capital cities. Further domestic and export market opportunities exist if production costs can be significantly lowered.

However, the industry is relatively poorly developed, characterised by small scale production and has high labour inputs. Sustained industry expansion is constrained by a lack of mechanisation of production, harvesting and handling.

This project investigated technology for mechanising taro planting, harvesting, washing and cleaning. A limited review of existing mechanisation practices and some equipment development was carried out.

Technologies exist for adoption of mechanised planting and harvesting in taro although further investigation and development of harvesting equipment is desirable. Agronomic studies and/or information gathering are also required to develop and optimise a production system based around mechanisation.

Additionally, further investigation and development of appropriate washing machinery is required as currently developed technology requires improvement or is inadequate.

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This report, an addition to RIRDC’s diverse range of over 1500 research publications, forms part of our Asian Foods Research Program, which aims to foster the development of a viable Asian Foods industry in Australia.

Most of our publications are available for viewing, downloading or purchasing online through our website:


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Abbreviations

DPI&F – Department of Primary Industries and Fisheries (Queensland)
NORADA – Northern Rivers Agricultural Development Association
TGA – Taro Growers of Australia Incorporated
RIRDC – Rural Industries Research and Development Corporation
UCQ – University of Central Queensland
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Executive Summary

What the report is about

This report examines mechanisation in the Australian taro growing industry covering the three mechanisation related activities associated with production to the farm gate: planting; harvesting and washing/cleaning. The report is focussed on large-corm taro production (*Colocasia esculenta*) however some discussion of technology for small-corm or ‘Japanese’ taro (*Colocasia esculenta* var. *antiquorum*) is also given—particularly in the areas of harvesting and washing.

Principally, the technology practiced or previously used by growers in Australia is reported. References to technology used/trialed overseas are noted where appropriate. Also, machinery development initiatives conducted within or using funds from the project are reported: a mechanical corm planter; a single row mechanical digger and a continuous throughput mechanical washer.

The report also tries to identify the impediments to adoption of mechanisation under Australian production systems and existing technology gaps. By way of introduction and background information, the cost structures of existing production systems are broadly discussed. Likely savings from effective adoption of mechanisation are outlined. Opportunities these create for expansion of existing markets or entry to new (export) markets are discussed.

Who is the report targeted at?

The project was developed in consultation with Taro Growers Australia Inc. and conducted in collaboration with individual growers. Therefore the report is principally for the benefit of taro growers or people considering entering the industry. The report should also serve as a reference for researchers conducting or developing research and development projects in taro. Finally, the report makes recommendations in relation to mechanisation of taro production which should be considered by growers, industry representative bodies, researchers and fund provider/investors alike in developing or assessing projects. Such projects need not necessarily be focussed on mechanisation in particular but should consider the recommendations because of the potential strong interrelationships between the production system and mechanisation.

Background

Taro is an old and important world crop—it is widely cultivated as a subsistence crop but also commercially. Generally however no significant mechanisation is practiced outside of countries like USA (Florida, Hawaii), Japan and Australia.

Production in Australia is mainly in Queensland coastal areas, north coast NSW and around Darwin in the Northern Territory. Estimated annual production in Australia is around 1000 tonnes with a wholesale value of about $3.5 million. Significant market opportunities exist based on expansion of the domestic market (volume and through import replacement) as well as selling into export markets. In addition to product promotion, this will principally rely on improving production efficiency through mechanisation.

The industry is characterised by relatively small individual production areas which are intensively cultivated. Also growers enter the industry in response to low entry costs and periods of lucrative prices, but often exit when prices fall. Significantly a core of long term growers has emerged who produce relatively consistent volumes and quality.

Australian growing systems are based on a diversity of planting material and layouts. Irrigation is always used—typically drip tube or overhead sprinklers. Effective weed management is important and often an issue. Harvesting and to a lesser extent planting have typically been performed manually. Manual washing of corms is also laborious, influenced by the condition of corms at harvest time.
Although mechanisation is practiced by a few growers and in all aspects of the production system there has been no widespread or consistent adoption of mechanisation in the industry. This is due to a range of factors broadly categorised by:

- growth habit
- wide diversity of growing systems
- small scale production
- staggered harvesting
- practice of ratoon cropping
- growing environment (soil, rainfall)
- limited financial capacity

**Aims and objectives**

This project was based on lowering production costs of Australian-grown taro through mechanising aspects of the production system. This would increase the competitiveness of product in domestic markets and the profitability of existing producers. In the longer-term, an expanded and more stable industry would have the potential to supply export markets by virtue of a lower cost-base.

The project aimed to bring about greater adoption of mechanisation in the industry by raising awareness amongst producers and undertaking technology development in an attempt to solve particular issues.

The three working principles employed in the project were:

1. Review and report on industry practices and technology in-use, attempted or envisaged in relation to mechanisation of taro production and processing—including relevant overseas technology—to raise awareness of previous experiences and possible options.
2. Cooperate with individual growers in development and trialling of existing technology for use in taro production.
3. Develop and trial new techniques/equipment specifically for taro and suitable for use by commercial growers.

**Methods used**

The project was conducted principally in co-operation with growers. Industry practices and experiences relating to mechanisation were documented based on visits and discussions with growers. In association with this, a secondary undertaking was to note relevant references to taro mechanisation from overseas sources/literature.

Using an action-learning approach, harvesting and planting equipment was developed and trialled in co-operation with growers. Also, independent work to design, develop and test a technique for mechanised washing/cleaning of taro was undertaken.

**Results and key findings**

**Mechanisation of taro planting**

With commencement of the project it became apparent that many growers were successfully using mechanical planters for planting taro as ‘setts’ (sections of corm and leaf stalk) and corm pieces. Typically the equipment was based on second-hand potato, vegetable or tobacco planters or had been developed by the growers themselves. Significant labour savings were achievable in comparison to manual planting.

In the project, a second-hand potato planter was sought for modification and trialling in taro. However a suitable machine could not be located. Instead funds were made available to construct and successfully test a simple tool-bar based planter for planting corms in a double-row configuration.
This machine was developed in collaboration with a grower and engineering workshop at Babinda in north Queensland.

**Mechanisation of taro digging (harvesting)**

Large-corm taro grown in Australia is almost exclusively manually harvested with only limited adoption of mechanised diggers. Those diggers which are or have been used by growers are typically based on simple, second-hand (and usually run-down) potato diggers in single or double row configurations. These machines are unsophisticated and do not offer major advantages from their use—uptake has therefore been limited.

One large scale taro grower in south-east Queensland successfully and exclusively employs more sophisticated mechanical harvesting machinery based on an evolution of equipment developed on farm. These include a tractor-drawn double row digger with collection of harvested corms in a chaser vehicle and a self-propelled harvester also with on-board collection of product and delivery to chaser vehicle. This machinery has been developed at considerable expense and effort. However it has some limitations relating to wet field performance, weed and vegetative matter separation and power requirements.

In the project, a second-hand potato/sweet potato digger was sought for modification and trialling in taro. However a suitable machine could not be located. Instead funds were made available to modify and test a simple digger which was purchased by some local growers. After a step-by-step development process the machine was developed to the point where it was successfully used to dig taro but requires further development to optimise its performance. Details of the development process and proposed modifications are reported.

Overseas references to mechanical taro harvesting technology are discussed. The design and potential to use more sophisticated and state-of-the art potato harvesters in taro is also discussed.

Some investigation of harvesting techniques appropriate for small-corm taro was also undertaken. A potato seed bed conditioning machine trialled in northern NSW appears to offer good potential for harvesting this crop and segregating the small corms (which have a dense clumping habit) at the same time. Also, information obtained on a Japanese developed ‘Universal Tuber Harvester’ suggests the machine would be very effective with this crop. It employs a similar mechanism for segregating corms as the soil conditioner seen in northern NSW.

**Mechanisation of taro washing**

Cleaning and washing of taro is a laborious task made more difficult depending on growth and field conditions at the time of harvest. Generally, market and grower preference is for corms to be completely free of any soil, rootlets and side shoots/cormlets removed, petiole trimmed neatly and skin with a natural appearance (not over-cleaned/abraded). Achieving this in the context of a continuous mechanical washing system is a significant challenge.

A single-corm mechanical washer designed specifically for taro by a north Queensland based grower in conjunction with an engineering workshop is described. Also, a rather unwieldy but nonetheless effective washing plant installed at a large taro/ginger growing operation in south-east Queensland is described. Other and less successful attempts to design mechanical taro washer are also noted. Finally a machine recently developed by a grower in north Queensland has been praised by growers who have seen it in operation for its effectiveness and simplicity (although this machine will not remove roots). Although viewed, this machine is not described in deference to preserving the intellectual property of the developer who intends to commercialise the machine.

In the project, significant effort was dedicated to design, construction and testing of a machine to continuously wash taro corms using a novel technique. The machine is described and its performance evaluated. Further development of this machine is required to improve its operation/performance but it offers significant potential with relatively modest modification. With the benefit of experience from development and testing this machine an alternative design based on the same technique is also proposed.
Other equipment – particularly onion topper-tailers, also appear to offer significant potential with taro for root removal. A simple topper-tailer machine previously used with taro is described.

A brief description of equipment used with relative success for washing small-corm taro is given. This equipment was imported from Japan and installed in a relatively small-scale washing/packing facility on a farm in northern NSW.

**Implications for stakeholders**

**Planting**

Mechanisation of taro planting is increasingly being practised by growers using either setts or corm material. There appears rather less impediments to its continued uptake in industry compared to mechanical harvesting for instance. Those factors which are of some significance would include field trafficability at time of planting, equipment availability and labour availability (assuming operators are required besides the grower/manager). Whilst mechanical planting will have implications for other mechanisation practices in the growing system – it does not of itself rigidly impose necessary changes to the subsequent growing and management of the crop.

Linked with the adoption of technology for mechanical planting is a decision on the type of planting material, layout and bed system. Choice and design of planting technology should be based on an understanding of the relative importance and economic consequences of such factors – not on the technology that may be available.

**Harvesting**

A number of factors have inhibited adoption of mechanical harvesting of large-corm taro and most are still evident. Most are related to the relative immaturity and small scale of the industry as well as technical difficulty and equipment availability.

While the technical feasibility of mechanically harvesting taro has been demonstrated by existing growers and in the project, there is not currently a technology that will suit all growers under all conditions. Greater industry scale and standardisation of the production system are required to fully capture the benefits of mechanical taro harvesting and drive adoption. This can be achieved through contract or pooled harvesting arrangements and a ‘bottom-up’ approach to re-engineering the production system in the context of mechanical harvesting.

Notwithstanding this, mechanical harvesting on the Wet Tropical Coast of Queensland will always be difficult for crops that are harvested during the wettest part of the year. Growing in drier climates would greatly enhance mechanisation potential.

Mechanical harvesting of small-corm taro is technically possible and in the event of significant production volumes would have a high likelihood/priority for adoption. This is because viable production of this product in Australia is more or less reliant on mechanised harvesting systems. However, any such technology should incorporate an effective technique for breaking-up and segregating the corm mass/clump on-board the harvester. A potential technique is identified and appears similar to the method employed on a well developed, Japanese designed corm harvester.

**Washing and cleaning**

None of the equipment/technology either used in industry or developed in the project for washing and cleaning large-corm taro is completely satisfactory. Unfortunately at the typical individual farm scale, a single machine for washing and cleaning taro that is relatively low cost and fully automated is probably not possible. However, such a machine/system is conceivable at the scale of large farms or co-operative style packing sheds. Such a system is proposed based on further development of existing equipment/methods and trialling/development of some new equipment. Such a system is propositioned on removal of most vegetative material (tops and weeds) in the field; manual trimming to remove daughter corms and relative uniformity in size and shape of corms through material selection, management practices and/or grading.
Mechanisation of washing and cleaning of small-corm taro is seen as feasible provided that mechanical harvesting of this product incorporates an effective means to segregate corms on the harvester and separate the majority of extraneous matter. The plant could be based on technology for washing potatoes or existing Japanese technology for handling this product. Application of computer vision techniques for sorting and automatic shaker packing should be possible in large scale operations.

**Recommendations**

**Large-corm taro**

No work on development of planters is recommended besides that aimed at improving the performance of existing equipment where clear benefits are proposed. However, growers may need more information to make the appropriate choice on the type of planting material they should be using in their production system (corms, setts or plantlets). This may require agronomic studies and/or review of literature and grower experiences coupled with economic analyses.

Trialling of current potato harvester technology in taro is recommended with capacity for modification and adaptation of the machinery as required. This may require setting up dedicated test blocks and purchase or hire of a suitable machine. Otherwise, researchers and growers undertaking trips overseas should try to examine harvester technology potentially in use and should be supported in this. Particular locations for such technology include Hawaii, Florida and Japan. The existing digger developed in the project should be made available for use and potential further development by grower members of TGA.

Furthermore, agronomic studies aimed at investigating an optimum or ‘standardised’ production system to enable mechanical harvesting should be supported—particularly if this helps open up potential export markets for product.

Further development of washing technology for taro is required. Development projects that should be considered/supported include:

- commercialisation of the Scopelliti drum washer
- further development of the washer developed in this project
- effective technology for removal of roots from corms
- industry initiatives to establish a centralised washing/packing facility (this is now occurring at Tully)
- examination of overseas developed technology (Hawaii, Florida, Japan).

From an overall perspective factors that will assist faster and wider adoption of mechanisation in taro include:

1. Agronomic and economic studies that attempt to identify an optimal growing system/environment in the context of mechanised production.
2. Product promotion to exploit greater market potential and lead to a larger production base.
3. Industry relocation or management systems to provide ‘mechanisation friendly’ sites.
4. Encouragement of grower/industry collaboration that through co-operative or contract planting, harvesting and/or washing facilities.

**Small-corm taro**

A program for development of harvester technology for small-corm taro should only be considered in the event of renewed prospects for selling into export markets. Initially such a program should assess the design and performance of the Japanese manufactured ‘Universal Tuber Harvester’. Any technology implemented (by design or importation) should incorporate a mechanism to segregate harvested material into individual corms.

Similarly work on washing and cleaning of this product should only be considered in the context of a proposal for a centralised washing/packing facility. It is likely that such a facility could be based on existing technology for washing mainstream vegetable crops. However, further investigation or development of equipment for root removal may also be required based on either existing Japanese root cutting machinery or onion topper-tailers.
1. Introduction

1.1 Taro cultivation

**World**

Taro is one of the oldest cultivated crops. It is grown for its edible corms and leaves and is an important world crop grown mostly in tropical regions. Annual world production is about 6 million tonnes. In its natural state it grows in shaded, damp and often swampy areas. Large-corm types (*Colocasia esculenta*) are predominantly grown and produce a large central ‘mother’ corm and 2-4 ‘daughter’ corms. Typically the mother corm is harvested at maturity, leaving the daughter corms in the ground to eventually develop to a harvestable size. Small-corm types (*Colocasia esculenta var. antiquorum*), are mostly grown in Asian countries. They produce 20-50 golf-ball sized corms in a clumping habit and are usually harvested altogether.

Propagation of taro is by corms, corm pieces or ‘setts’. Setts are the tops of main corms with a section of the petiole or stem still attached–usually trimmed to about 30 cm. Tissue culture is also readily performed.

Overseas, taro is widely cultivated as a subsistence crop but also commercially. Generally no significant mechanisation is adopted. There are few references to mechanisation having been implemented–either it is almost non-existent, or successful practitioners avoid publicity and exposure in order to maintain a commercial advantage.

**Australia**

Taro is not a new crop to Australia and is grown commercially in Queensland coastal areas, north coast NSW and around Darwin in the Northern Territory. In the last several years a significant industry has consolidated in north Queensland centred on the Wet Tropical Coast where high rainfall helps meet the water requirements of the crop and a warm climate permits year round production. Production in Australia is almost exclusively of large-corm types, with only recent emergence of commercial small-corm production–mainly on the NSW north coast.

The industry is characterised by relatively small individual production areas, generally less than a few hectares. There has also been a history of growers entering the industry during periods of high prices, but who then exit when an over supplied market results in lower prices. Taro is an attractive crop for new growers as prices can be lucrative, capital requirements are low and high yields mean that only small plantings are required to produce a worthwhile return. Taro has also been adopted by established growers diversifying from mainstream crops like sugar cane. However, there is now a core of long-term growers who maintain relatively consistent production and quality.

Although well established, the industry is not highly developed. There are no really large scale operators within a whole industry comprising less than 100 ha. A factor inhibiting larger scale production is the significant risk for a large operator in a relatively small industry. The crop also presents agronomic challenges, and weather conditions often constrain planting and harvesting operations. Finally a lack of mechanisation and high labour requirements means that economics of scale from larger plantings are difficult to achieve. While small plantings can be adequately managed by the owner/grower, returns from larger areas are diminished or capped due to the cost and difficulty of retaining hired labour.

**Summary of Australian growing systems**

In north Queensland and around Darwin, taro can be planted year-round although the predominance of plantings occur from October to May. In south-east Queensland and north-eastern NSW the crop is typically planted so that the growing cycle occurs during the warmest months–most planting occurs from September and harvesting from April to July.
After soil and bed preparation, planting is generally done by hand, typically using setts. A wide range of bed, row and plant spacings is used, giving planting densities in the range of 10,000-50,000 plants/ha. This is influenced by the type of cultivation equipment the grower owns, the irrigation system, the growing environment, the available land area, and grower preference.

Weed control is a major issue. It is important that good weed control is achieved during the phase after planting after which development of the crop canopy will usually shade-out weeds. Wider row spacings allow cultivation (‘hilling-up’) around corms and application of herbicides to the inter-rows during the early growth stages. Otherwise, some growers spread heavy mulch (such as bagasse) after planting for weed control—this has other advantages including increasing soil organic matter and even reducing rat damage to irrigation lines. Plastic mulches are not currently used in the industry—although anecdotal reports on its use indicate that suckering is reduced or eliminated. Significant weed growth often occurs in the period between canopy maturity and harvesting which is when the canopy regresses significantly. This often results in a relatively heavy weed cover by the time that harvesting is carried out.

Harvesting and processing are typically manual operations. Simple or modified potato diggers have been used by several growers for digging taro but are not currently in widespread use. This is principally due to four factors:
- they don’t offer growers a big enough advantage in the context of current cropping systems
- growers are discouraged by the hassle of dealing with complex machinery when it is simpler to do things manually and as they are used to doing
- harvesting is usually staggered so that only relatively small areas are harvested at each time
- the likelihood of wet weather occurring in the harvest period precludes the use of mechanical digging equipment—possibly for several weeks and particularly in heavy soils.

Washing and preparation of corms for market is also a labour intensive activity—rootlets, remnant petiole and emergent cormlets attached to the main corm are generally removed together with adhering soil. The stage of growth, soil type and weather conditions at harvest can make these tasks much more difficult and time consuming.

Transport and marketing of product is in cardboard banana boxes or other cartons sometimes depending on other crops grown on the farm. There has been a variation in the preference of growers and agents for grading and presentation of product. To counter this, Taro Growers Australia (formed in 2001) has set size grades and is promoting packing/quality standards.

1.2 Australian industry status and development

**Production**

Industry statistics are very limited but Australian production is estimated to be 1000 tonnes/year (industry sources) with a wholesale value of about $3.5 million. Most production comes from north Queensland. However there a few growers in the Northern Territory, north coast NSW and other growers scattered along the Queensland coast from around Brisbane to Townville.

Corms from large-corm types can weigh from one to several kg and yields are in the range of 15-25 tonnes/ha. Consumption in Australia is mainly by Asian and Pacific Islanders ethnic groups—currently there is no export production. Returns to growers range from modest to lucrative at typical wholesale prices (Sydney, Melbourne) of $2.50-4.50/kg. Significantly, a lot of imported taro is sold outside of the central market system—particularly in Brisbane. Here, up to 90% of product goes directly to the public or fruit and vegetable vendors sourced from nearby market gardeners or imported from Fiji.
**Market opportunities**

Even without product promotion, potential expansion in the existing fresh market is possible through improved supply continuity. Whilst southern growers tend to have a production window from April to August, north Queensland and Northern Territory growers can stagger plantings year round. However northern plantings are not generally uniform throughout the year either because of habit, seasonal weather conditions or commitments to other crops.

Additional domestic market opportunities are through import replacement of fresh product from Fiji and development of taro chip processing. However both these markets have high price sensitivity. About 1700 tonnes/year of the variety Taro Nieu is imported from Fiji and sold at prices of $2.00-2.20/kg. Although product quality tends to be low, Polynesian peoples prefer this variety. Production of Taro Nieu in Australia is constrained due to the low prevailing prices and because most of the product is sold outside of the metropolitan wholesale system.

Export opportunities are constrained by a lack of price competitiveness. An agent in New Zealand has expressed interest in sourcing Taro Nieu from north Queensland growers, with New Zealand currently importing about 6000 tonnes/year from Fiji. However, production for this market would depend on production costs significantly below the $1.40/kg offered (landed in New Zealand) and this could not currently be achieved.

There are also large markets in Japan and USA for small-corm taro. Japan imports at least 40 000-50 000 tonnes/year of frozen and fresh product with a supply shortage window coinciding with the likely Australian harvest period. Australian-based production for this potential market will only be possible if mechanisation can be implemented. Some NSW-based growers have attempted this.

**Industry development**

In November 2001, TGA was formed. There was a belief amongst north Queensland growers that the industry had good prospects for expansion if production and marketing practices could be improved—this would best be achieved by cooperation and industry representation. TGA could provide industry credibility in the marketplace, apply for and influence research and development funding, and represent the industry on trade and quarantine issues.

Expansion of the existing taro industry based on new entrants in response to good prices followed by oversupply is not sustainable or in the interests of established growers. It is preferable that individual growers are able to increase production through larger plantings. This could be achieved by mechanisation to increase productivity and ultimately lower costs. For industry resilience and expansion of markets it is hypothesised that production should be viable at farm-gate prices as low as $2/kg. Under good growing conditions, the current break-even price is thought to be about $2.50/kg (farm gate), so this target is realistic.

Harvesting and post-harvest processing on farm are two readily identified areas of major cost to growers. Labour costs for manual pulling are estimated at $0.25-0.30/kg. Labour costs for washing and trimming of taro for market are estimated at $0.50/kg. These two factors alone represent about 30% of the cost of production. Grading and packing costs are about $0.10-0.15/kg. These costs are strongly influenced by the size of corms—per kg costs are significantly reduced with heavier corms and vice versa.

**Mechanisation: opportunities and implications**

It is anticipated that mechanisation of digging and crop recovery could reduce harvest costs by at least half. For some growers a mechanised harvesting regime could require adopting a growing system that has higher planting and establishment costs. However, these could be compensated by opportunities for additional mechanisation of planting and operations during the growing phase as well as benefits arising from better crop management and higher yields.
Development of effective washing equipment could significantly reduce the current requirements and costs of labour for this operation. Therefore, adoption of mechanical harvesting and use of mechanised washing equipment could conservatively reduce production costs by about 15-20% (assuming a reduction of $0.35-0.50/kg).

Manual planting costs of taro on a hectare basis vary considerably because of the wide variation in planting layouts and density. However, a grower that uses a mechanical planter exclusively for planting taro estimates productivity of 1200 setts/hour with 2 people (at relatively low densities). This compares to about 75 setts/hour/person with manual planting. On a labour cost basis this equates to $0.20/sett for manual planting and $0.0125/sett for mechanised planting. Assuming a corm weight of 1.5 kg/plant, this represents a saving of $0.10-0.15/kg (even higher for smaller corms). Therefore, industry adoption of mechanised planting is worthwhile.

Other benefits arising from mechanisation could also be expected. Currently the strenuous nature of taro growing activities and often-uncomfortable working conditions makes recruiting and retaining hired labour difficult. Mechanisation should help to attract workers to the industry by providing easier working conditions and enabling of larger-scale production that support more constant staffing. Additionally, there is grower support for central washing/packing sheds which would be better placed to recruit and retain a reliable workforce. Mechanisation of harvesting and in particular washing are pre-requisites for developing these enterprises.

Finally, mechanised production provides an opportunity to implement ‘controlled traffic’ (or permanent bed) systems in taro. Environmental and production benefits from controlled traffic have been experienced in other crops. These include reduced tillage and compaction, erosion control, increased trafficability and eventually higher yields and improved ‘soil health’.
2. Objectives

2.1 Project rationale

This project was premised on lowering production costs of Australian-grown taro through mechanising aspects of the production system. If successful, this would increase the competitiveness of product in domestic markets and the profitability of existing producers. In the longer-term, this would promote an expanded and more stable industry with potential to supply export markets by virtue of a lower cost-base.

Lack of mechanisation in Australian taro production systems is the primary constraint to lowering production costs and therefore the project aimed to bring about greater awareness and adoption of mechanisation practices.

2.2 Primary objectives

The project was based on three working principles:

1. Review and report on industry practices and technology in-use, attempted or envisaged in relation to mechanisation of taro production and processing— including relevant overseas technology—to raise awareness of previous experiences and possible options. This was possible because of the willingness of most growers to share experiences and ideas in the interests of improving productivity and industry development.

2. Cooperation, as opportunity presents, with individual growers in development and trialling of existing technology for use in taro production.

3. Appropriate development and trialling of new techniques/equipment specifically for taro and suitable for use by commercial growers.

The operations in taro growing investigated in relation to mechanisation were:

- planting (setts and corms)
- digging (plant crops)
- washing and cleaning.

The project was mainly focussed on large corm taro types (*Colocasia esculenta*). However, because of considerable interest in growing of small corm types (*Colocasia esculent var. antiquorum*) in Australia for export markets, a limited investigation of technology for digging and cleaning these species was also conducted.

Secondary objectives

The project also provided a basis for on-going interaction with members of TGA (mainly in Queensland) and NORADA in northern NSW. This interaction served to:

- maintain industry contacts and keep abreast of industry developments
- update industry on project outcomes
- contribute to industry research and development prioritisation.
3. Methodology

3.1 Strategy

The overall approach of the project was to conduct the research and development activities in cooperation with growers. This was possible given there is a general a spirit of openness and willingness to share experiences and contribute ideas. Additionally the principal investigator had some input to the RIRDC-University of Central Queensland project UCQ13-A “Export opportunities for yam, yam bean and taro to Japan and USA” which provided contact with researchers on that project and further opportunities for contact with growers in other regions–particularly northern NSW.

The research and development work comprised three strategies:

1. Interaction with growers to evaluate existing planter and harvester technology used in the industry (or related industries) and co-operation with growers on development and trialling of planting and harvesting equipment.
2. Independent work on development and testing of potential technology for washing/cleaning of taro.
3. Documenting industry practices and experiences in relation to mechanisation–principally based on visits and discussions with growers but also noting overseas developments from any references in literature or contacts.

3.2 Research and development activities

**Planting technology**

**Large-corm taro**

Given the existence of technology that was likely suited or could be adapted for taro planting (including tobacco planters, vegetable transplanters and potato planters), it was proposed to purchase suitable second-hand equipment for evaluation and modification on grower farms. It was not intended to carry out formal, replicated trials–for example to examine performance in relation to soil type, planting material, accuracy and productivity.

However this strategy was subsequently modified for two reasons:

- several growers were already successfully using planters for planting sets
- a suitable second-hand potato planter could not be sourced at a reasonable price.

Therefore, the use of planting technology by existing commercial growers was reported and project funds were used to assist development of a simple corm planter which was subsequently field tested.

**Small-corm taro**

No investigation of planting technology specific to small-corm taro was conducted. This aspect of production is of relatively minor significance for small-corm taro compared to challenges presented by harvesting and washing. Additionally, the technology used for large-corm taro could in general be applied anyway.

**Harvesting technology**

**Large-corm taro**

Given that basic potato diggers had apparently been used in the past for digging taro in north Queensland and elsewhere, it was proposed to purchase a second-hand machine to verify this through on-farm testing and development. It was envisaged that modifications to the growing system to enable effective use of the equipment would also be required to give the harvester the best chance of success–foremost being planting of taro in a suitable bed or hill system.

The brief for a harvester that could be developed within the resources of the project was a relatively simple machine to dig the taro and lift the corm onto an elevating chain where some degree of soil separation would occur. The taro would then be either conveyed/dropped into a suitable container or
returned to the soil surface for hand collection. Although desirable, it was doubtful that extension of the elevating chain to provide further cleaning and a sorting platform would be possible.

Since a suitable second-hand machine could not be sourced, a digger was developed in co-operation with some Babinda-based growers who had themselves purchased a basic machine. In the long-run this unit required significant modification. Visits were also made to farms of the few growers using or experimenting with mechanical diggers in taro, to learn from their experiences. Advice was also provided to a yam bean grower on the Atherton Tablelands who was modifying a harvester previously used for sweet-potatoes.

**Small-corm taro**

No development of harvesting technology specific to small-corm taro was carried out. However, visits were made to farms in Northern NSW and Gin Gin in Queensland where growers were considering or trialling mechanical diggers, and machines were observed in-use.

Given that actual digging of small-corm taro is unlikely to pose any challenges beyond those for digging large corm types, the primary issue was and still is the subsequent mechanical separation of corms and soil from the mass of attached corms–preferably on-board the harvester. It was proposed therefore to test a technique for removal and separation of the corms in the workshop that could be implemented on harvesters. The method envisaged was based on techniques used in direct peanut puller/stripers and processing tomato harvesters. It was not proposed to adapt any successful developments to harvesters for field testing.

Development and testing of these techniques was not conducted after seeing a machine in northern NSW working relatively successfully in small-corm taro. Additionally an apparently well-designed and proven harvester exists in Japan which incorporates a device for corm separation which–as it turns out–is similar in principle to the mechanism on the NSW machine.

**Washing and cleaning technology**

**Large-corm taro**

Development of effective washing and cleaning equipment is perhaps the highest priority for taro mechanisation. At the commencement of the project a small-scale individual corm washer was available–this unit required manual processing of corms through the machine and was too aggressive in the view of some growers. Otherwise there was limited awareness of any equipment being used satisfactorily with taro.

Therefore it was proposed to develop prototype technology with the aim of continuous automatic throughput. This activity was undertaken in the project and a prototype washer was designed, constructed and tested.

**Small-corm taro**

Priority was given in the project to development of equipment for large corm taro. However some limited testing of equipment for use with small corm taro was conducted in addition to some visits to farms growing and packing small-corm taro. During the course of the project it also became evident that equipment specifically designed for small corm taro was manufactured in Japan. A northern NSW based grower actually imported some of this equipment for a central packing shed facility so a visit was subsequently made to this operation.

**Industry practices**

Experiences of Australian taro growers and overseas developments in relation to mechanisation are documented where relevant in this report. This is based on farm visits and meetings with growers arising principally from word-of-mouth contacts and grower meetings.

Interactions with growers were mainly in relation to issues directly related to mechanisation but since general crop management factors are closely related–such as planting layouts, planting material, irrigation system, weed control and packing shed practices–these were noted as relevant. A formal comprehensive review or industry survey was not proposed or conducted.
4. Results and discussion

4.1 Mechanisation of taro planting

**Planting material**

Most commonly taro is propagated from ‘setts’. Setts are fashioned by trimming 20-30 cm lengths of leaf stalk with about 2-3 cm of the top part of the corm still attached. Alternatively the entire corm is retained with the petiole section. This is done when the corms are only small–about 4 cm diameter or less. Setts are usually obtained from daughter corms left in the field after harvesting or from nursery beds grown especially as a source of propagation material. Ideally, the largest and healthiest corms are selected for the planting material–preferably disease and virus free. In practice, limited availability of material may mean that more inferior material is used. Setts are planted with the corm section 15-20 cm below ground level, with the new ‘mother’ corm growing upwards from that point.

Less commonly growers just use pieces of the corm itself for propagation. Irregular shaped pieces of corm are cut from the source corm–ideally each with an ‘eye’ or point where a new petiole is about to emerge. These are placed below ground and a new plant emerges. This method is no less successful but is usually slower than using setts since it takes additional time for the petiole to emerge. However it may actually be a preferable method when conditions are hot and dry.

**Manual planting**

Manual planting of taro is slow and laborious. With dry-land cropping systems (as practiced in Australia) the field is usually mechanically cultivated and well prepared prior to planting. While this makes digging or scooping a planting hole, placing the sett or corm piece and backfilling the hole relatively easy–this takes a considerable amount of time given the high planting densities (typically 15-20,000 plants/ha for single row plantings and 25-30,000 plants/ha for double row plantings). If the soil is well cultivated, one person can typically plant about 800-1000 setts per day.

With traditional wetland taro growing (as practiced in Hawaii) manual planting is perhaps faster (but similarly laborious) than the dryland equivalent since setts can be pushed into the mud of a flooded paddy.

**Mechanical planters used with setts**

**Introduction**

Soon after the commencement of the project it was evident that a few growers were already successfully using mechanical planters for planting taro setts (and corm pieces) in both single and double row configurations. Additionally, some growers were also applying fertiliser in bands adjacent to the planting rows in conjunction with mechanical planting.

**Tobacco and vegetable planters**

For planting setts a couple of growers had sourced second-hand tobacco planters: in one case a single-row planter and in another case a double-row planter.

These units are usually mounted from the three-point linkage of a tractor. The basis of the machines is a furrow opening tool (V-shaped plate) mounted at the front followed by a pair of angled ground-wheels which act as press wheels to close the planting furrow. In between is a planting wheel that is driven by a belts or chain from the ground-wheel. The planting wheel comprises a series of clasps made from spring steel. The clasps are in a normally open position but are closed by a cam mechanism adjacent the planting wheel. As they rotate past a seated operator, the clasps are in the open position. The operator places a sett into each open clasp just before the clasp is closed by the cam mechanism. The clasp continues to rotate past the operator and down into the planting furrow. In the furrow the cam disengages and the clasp opens under spring tension releasing the sett which is now in an upright orientation.
The plant spacing depends on the gearing ratio between the ground-wheel and the planting wheel—typically this would only be changed when the machine is first set-up. The tractor speed is adjusted to match a comfortable work rate for the operator/s.

These units apparently operate very well with taro setts. In north Queensland they have usually been purchased second-hand from tobacco farms or second-hand machinery dealers. Vegetable transplanting machinery is also available new from manufacturers like Cheechi and Maglii presumably in a range of configurations and one such unit is used by a grower at Tully. Figure 4.1 shows the ground-wheel and planting wheel of a second hand tobacco planter (single row) and Figure 4.2 shows a field of taro setts planted by the same unit.

**Figure 4.1** Planting mechanism on a tobacco planter as used for taro setts

**Figure 4.2** Mechanically planted taro setts (tobacco planter used)

**Mechanical planters used for corms**

**Traditional potato planters**

Potato planters are also used by growers for planting corm pieces. Typically, older second-hand machines have been utilised. These tractor-mounted machines drop individual corm pieces into a planting tube mounted between furrow opening and closing implements. The corm pieces are segregated automatically by a bucket chain drawn through a bulk bin containing the corm pieces. Therefore, other than the tractor driver there is no need for another operator. Plant spacing is set by adjusting the chain speed relative to groundspeed. Typically, potato planters are in a double-row configuration.

At Noosafresh (via Cooroy) a double row potato planter is used exclusively for planting taro (and ginger) and this machine is shown in Figures 4.3 and 4.4.
**Development of a corm planter**

Project funds were used to assist development of a double-row planter for planting taro corm pieces. This simple machine was designed and built by Vicarioli Engineering at Babinda in north Queensland and is pictured in Figures 4.5. The machine was used successfully in the field in 2003.

A basic description of the machine is as follows:

- a pair of planting tubes and furrow openers are mounted from a three-point linkage toolbar
- two operators seated on the unit feed corm pieces into the planter tubes one piece at a time
- each planter tube contains a steel flap which is in a normally closed position under spring tension
- each piece of corm falls onto the flap until the flap opens which allows the corm to fall down the planting tube and into the planting furrow
- the flaps are opened by a lever arm which is in-turn actuated by a spigot attached to a ground-wheel
- the spigot for each planting tube is mounted on opposite sides of the ground wheel and 180° out of phase
- this results in alternate positioning of corms in the double row layout with the in-row plant spacing equal to the circumference of the ground wheel.

The machine is pictured in operation in Figure 4.6; note that irrigation line is also being placed in conjunction with planting.
4.2 Mechanisation of taro harvesting: large corm types

Introduction

Mechanisation of taro harvesting must be seen in the context of the whole production system. Successful mechanisation of harvesting will very likely depend on adapting the growing system to suit the machinery. This is because it is highly unlikely that any machinery can be developed which works so well that it could be used in any commercial taro block—that is, without regard to planting layout, row or bed formation, irrigation system, soil type, weed management, stage of maturity, market preference or weather conditions. Notwithstanding this however, the machinery will need to be developed to suit the scale of taro growing operations both from physical and capitalisation perspectives.

Therefore, mechanisation of taro harvesting presents a significant challenge which is not necessarily attributed to any technical difficulty in actually digging and handling the crop. The challenge arises principally from the lack of a well evolved and widespread cropping system. This situation has been perpetuated by the predominance of taro as a relatively small-scale crop often grown in conjunction with other farming pursuits. However, this situation is changing.

Mechanisation practiced overseas

An extensive review of the literature for mechanical harvesting of taro was not conducted. However, a few references have been noted. They are generally from literature on growing taro/root crops in Florida and Hawaii.

Jakeway and Smith (1979) report on an improved version of a single operation, one-row harvester for harvesting complete taro plants in Hawaii. The machine was designed for digging taro in flooded or wetland fields (as is common practice). It employs a screw auger for digging the taro, a cam-actuated pick-up mechanism and a conventional rear conveyor for soil and mud removal. From reading this paper it is difficult to determine the exact workings of the auger and pick-up mechanism suffice to say the machine is a unique design unlike conventional potato diggers. The machine is reported to work very effectively in wetland conditions even though traction problems were often experienced. Corm recovery was almost 100% and the harvest rate was about 3000 kg corms/hr. However, additional unwanted material (mud, roots and petioles) comprised up to 75% of the harvested weight of material.
When tested under dryland conditions, the machine was much easier to operate and the weight of unwanted material harvested reduced to 25%–but corm recovery reduced to about 75%. The subsequent uptake of this technology in the Hawaiian industry is not known.

Prior to this, Kawabe (1975) reported on research into mechanical harvesting of dryland taro using conventional potato digging equipment. Jakeway and Smith (1979) also mention a company in Hawaii moving to dryland taro production in the late 1970’s and using modified potato diggers for harvesting with some success. This company was also trialling other harvesting methods.

O’Hair (1990) mentions lifting devices similar to potato diggers being used in Hawaii as aids to harvesting taro. An attempt to contact Stephen O’Hair (Florida Extension Service) was made in May 2004 without success.

Valenzuela and Sato refer to the use of modified potato diggers being available for digging taro under commercial conditions. They cite the use of such a machine for demonstration purposes by the Cooperative Extension Service in Molokai. Two unsuccessful attempts were made to contact Hector Valenzuela in 2002.

In Taro–Mauka to Makai (p. 81) it is claimed that harvesting times for taro can be reduced using tractor pulled potato harvesters or a harvester developed by Gallenberg Equipment Inc. (Antigo, Wisconsin, USA). A letter was sent to Gallenberg Equipment in 1999 to enquire about their harvester, but no response was received.

New Zealand Crop and Food Research recently conducted a small program on small-corm taro. On a web page mention was made of mechanical harvesting of taro corms using a modified potato harvester. This was followed up in July 2001 with Mr John Scheffer, an agronomist in charge of the taro program. A response from John was not encouraging. They had made one attempt to harvest a Japanese taro cultivar with a potato digger but the ground was very compacted and the exercise was not successful.

**Manual harvesting**

Currently, taro grown in Australia is almost exclusively harvested by hand. Under ideal conditions, mature corms can be pulled from the ground by pulling on the main growing stem. Often however, the corm will first have to be loosened–particularly if it is the plant crop which is being harvested.

One grower has developed a specialised digging tool to assist with this. It is a gently curved bar with a fluted end that is pushed beside and underneath the main corm by pushing on a foot bar. The tool is then levered slightly to loosen the corm. In general however, manual harvesting is slow, laborious, hard and uncomfortable (hot and itchy) work only made relatively easy if there is good soil moisture, the root system is not in an active growing phase and the weather is cool.

The cost of labour for harvesting taro is a significant proportion of total cost of production. Costs are best expressed in $/kg (marketable) since this is the basis of the price received. However growers sometimes talk in terms of cost in $/corm since this is the unit that is harvested. Costs expressed in $/ha are even less helpful since planting densities and yields vary widely and block sizes are usually smaller than a hectare anyway. Some typical harvesting rates and calculated costs quoted by growers are given in Table 4.1.

**Table 4.1** Calculated costs for manual taro harvesting based on typical information from growers

<table>
<thead>
<tr>
<th>Number of people</th>
<th>Time taken (hours)</th>
<th>Amount Harvested</th>
<th>Conditions</th>
<th>Cost ($/corm or kg - assuming $15/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3</td>
<td>400 corms</td>
<td>Difficult – due to active root systems</td>
<td>0.23</td>
</tr>
<tr>
<td>3</td>
<td>3.5</td>
<td>400 kg</td>
<td>Unknown</td>
<td>0.39</td>
</tr>
<tr>
<td>1</td>
<td>2.5</td>
<td>500 corms</td>
<td>Very good going (March)</td>
<td>0.08</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>500 kg</td>
<td>Unknown</td>
<td>0.24</td>
</tr>
</tbody>
</table>
Mechanised harvesting in Australia

Traditional single-row potato diggers

Several growers have used un-modified second-hand potato diggers in taro with good results. An example of such a unit is shown in Figure 4.7. It is mounted to the 3-point linkage of a tractor and comprises a fixed digging blade and powered elevating conveyor. This particular machine is used at a farm in Kingscliff in Northern NSW to harvest taro and sweet potato—it is very basic and was in need of maintenance.

![Figure 4.7 Basic, second-hand potato digger as used for taro and sweet potato by a northern NSW grower](image)

To use these machines, the taro is typically grown in beds or mounded rows and is usually slashed prior to digging. There is some soil separation on the elevator of the digger and the corms are dropped back onto the soil surface to be gathered manually. For small farms (up to a few hectares) this system is sufficient—there is less of a requirement for more sophisticated cleaning or on-board collection.

Figure 4.8 shows an even older machine purchased cheaply by a grower at Feluga in north Queensland. It incorporates an elevator which deposits the harvested material on a sorting platform at the back. With this machine, coulters were run each side of the taro row prior to harvesting to pre-cut the bed and reduce weed material entering the harvester.

These machines have the advantage of being simple and cheap. They offer growers a means to mechanically dig taro with minimum outlay or changes to the farming system. Since they appear to offer a ready solution to the hard-work of manual harvesting, why then are they not in more widespread use? A range of proposed factors are:

- persistence by growers with small scale blocks that can be managed by hand harvesting anyway; this could be expressed as reluctance to change (i.e. the perceived “pain” of change is less than the “pain” of staying the same)
- harvesting and marketing of taro from particular plantings is staggered over several weeks or months rather than in one pass or at one time
- wet weather (a feature of coastal Queensland taro production) can frequently prohibit their operation
- difficulty in finding good used machines in reliable condition
- probable limitations of these machines for harvesting very large taro corms (in excess of 250 mm in length)
- difficulty of using these machines when there is a large amount of weeds (often the case when the taro has reached maturity)
- need to move or change the irrigation system to accommodate diggers
- movement of growers in and out of the industry does not support development of more advanced growing systems, larger production units or equipment development.
**Mechanical harvesting at Noosafresh**

**Tractor-drawn harvester**

At ‘Noosafresh’ (via Cooroy), both ginger and taro is mechanically harvested. During a visit in July 2003, a tractor-drawn digger developed by the previous owners was observed working in taro. This machine was based on a traditional style double row potato harvester. The unit was videoed in operation and later shown to north Queensland taro growers attending a TGA meeting.

At Noosafresh, taro is grown in semi-permanent raised beds. The plant spacing is about 60 cm within the row and 48 cm between rows. The centre-to-centre spacing of the beds was a little less than 2 m. Before harvesting, the mature taro plants (and weeds) are slashed using a flail type mulcher. This operation needs to be performed regardless of whether the leaf stalk is still prominent or has significantly degraded. At Noosafresh, this operation is now done at the same time as harvesting–whereby the mulcher is mounted on the front of the 4WD tractor to which the digger is also attached. After harvesting the field is re-worked and the raised beds are re-formed using coulters. A final rotary-hoeing operation flattens the bed in readiness for planting. Overhead sprinklers are used for irrigation based on permanent field laterals (which set the position of the raised beds). A cover or green-manure crop is often grown in rotation with the taro (and ginger).

The tractor-drawn digger is shown in Figure 4.9; it was mounted to the three-point linkage and is powered by a combination of the PTO and tractor hydraulic remotes. At the rear of the machine a transverse conveyor delivers the harvested material into bulk bins carried at the front and rear of another tractor driven alongside. Ground-engaging coulters, mounted on each side of the digging blade, cut the sides of the bed along with weed and plant material.

When viewed the digger was operating in a relatively poor crop of taro with a high level of weed growth. The soil was a light loam (areas of the property also have heavy soils). The effectiveness of the machine at digging the taro and moving material onto the main conveyor was entirely satisfactory. The soil texture resulted in good separation of soil from the harvested corms aided by eccentric star wheels mounted under the main conveyor.
However, since the machine had no mechanism to separate extraneous vegetative material from the harvested corms, all this material was delivered to the bulk bins which resulted in extraneous matter making up about half the volume of harvested material (estimated). Therefore, these bins only took a few minutes to be filled. Whether this amount of extraneous material was normal–or higher than usual because of the poor crop–was not ascertained.

**Self-propelled machines**

Noosafresh also used a self-propelled harvester which had also been constructed on the farm–this original machine is shown in Figure 4.10. It was track-mounted, to allow the machine to work in very wet conditions. The harvested material was stored on-board, however the low capacity of this on-board storage apparently made the machine cumbersome to use. The conveying system on the machine also caused undesirable levels of damage. Therefore, when conditions allowed, the tractor drawn digger was used in preference.

At a visit in June 2003, the new owners of Noosafresh were developing another self-propelled harvester, shown under development in Figures 4.11 and 4.12. Design of the new machine attempted to overcome some of the limitations of the previous self-propelled unit–namely excessive damage to corms. The new machine has a main conveyor which empties harvested material directly into bulk bins carried at the rear of the machine. However, the system has proved inefficient in the field and the bulk-bin arrangement was removed and replaced with a slewing elevator which instead delivered harvested material into bulk-bins transported on a tractor travelling alongside the machine (this current version of the machine is shown in Figure 4.13). Although the arrangement works well, a problem with the machine is its weight. Due to poor ground clearance the machine bottoms-out on the raised beds in boggy conditions. This causes the machine to bulldoze soil against the chassis leading to engine over-heating. So in this way the machine has defeated itself. The owners now prefer to use the original tractor-drawn unit in most circumstances–even wet conditions. This is now possible because a larger 4WD tractor has been purchased.
Development of a taro digger

An objective of the project was to source, trial and modify as necessary; a mechanical digger with the aim of demonstrating mechanical harvesting of taro. Initially, an advertisement was placed in Atherton Tableland local newspapers seeking a second-hand potato/sweet potato digger. There were several responses and a couple of days were spent examining machines on offer but none was purchased. The machines were either run-down, too large, expensive or all of the above.

Soon after this foray, two local growers (Don Zanolleti and Philippe Petiniaud) decided to look for a second-hand digger to use in their own taro plantings. They had similar experience in trying to find anything suitable. However, after examining a range of machines they did purchase a simple digger comprising a fixed digging blade which directed material onto a reciprocating side delivery ‘sieve’ at the rear. The machine had seen little use and was inexpensive—also the sieve (operated by a PTO-driven cam mechanism) offered interesting possibilities for separating the harvested taro from soil etcetera.
Unfortunately, their initial use of this machine showed it to be incapable of effectively digging. Given the simplicity of the machine and relatively lightly constructed digging blade (probably designed for use in light and well-tilled soils), this was not surprising. Subsequently it was agreed that project funds would be used in on-going development of this unit on the basis that it could be demonstrated to, or used by other taro growers. Vicarioli Engineering at Babinda carried out the modifications to the machine and contributed mostly to the design process. Modifications performed on this unit are summarised in Table 4.2, in chronological sequence.

<table>
<thead>
<tr>
<th>Problem</th>
<th>Modification</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging blade not engaging ground.</td>
<td>Angle of blade reduced and digging point welded to centre.</td>
<td>Digging point resulted in better ground engagement and successful digging. However shattering of soil meant that the corms and soil mass could not be pushed successfully along the inclined chute and onto the sieves. Build-up of material resulted in bulldozing and eventual ‘floating’ of the digger back to the soil surface.</td>
</tr>
<tr>
<td>Bulldozing of soil and non-transfer of material to sieve.</td>
<td>Inclined chute behind digging blade removed and replaced with conveyor (ex cane harvester); PTO gearbox installed to drive conveyor, jockey wheel added to support rear of machine.</td>
<td>Continued problem with transfer of material away from the digging blade and onto the conveyor. Problem a result of geometry of the conveyor relative to the digging blade–steepness of the conveyor and shaft running between idle sprockets immediately behind the digging blade.</td>
</tr>
<tr>
<td>Non-transfer of material onto or up the conveyor.</td>
<td>Angle of conveyor reduced to about 15° requiring extension to the frame of the machine and repositioning of gearbox. Shaft connecting conveyor idle sprockets behind digging blade removed and internal bearings and stub-shafts installed. Rear sieve and jockey wheel removed.</td>
<td>Machine digging much better with improved transfer of material onto and along the conveyor. However, improved cutting of the bed by the sides of the digging blade was required to reduce break-up of the soil mass and improve transfer of material onto the conveyor.</td>
</tr>
<tr>
<td>Break-up of bed in digging process.</td>
<td>Coulters mounted to a toolbar to pre-cut the bed in a separate operation prior to digging. Extra cleats added to conveyor cross members. Chute installed beneath initial part of conveyor.</td>
<td>Coulters were not mounted to the digger itself due to the low forward speed of the machine and likelihood that they would therefore not work properly (unless powered). Simpler and less costly to mount the coulters on separate toolbar which could be worked at a faster speed. This resulted in improved machine performance when used in double row taro. Chute beneath conveyor also assisted transfer of material up conveyor and further reduced any ‘bulldozing’.</td>
</tr>
<tr>
<td>Blocking of machine.</td>
<td>No modifications performed.</td>
<td>Digger used in single-row plant crop with large corms/plants. Bed was not pre-cut using coulters. Machine dug well but opening at the front of the digger was too narrow for good entry of material. Also experienced problem where the frame restricts taro (and associated leaf material) from dropping off the conveyor onto the ground. Subsequent blockages caused frequent breaking of the shear bolt on the conveyor drive.</td>
</tr>
</tbody>
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Modification of this machine has now ceased with completion of the project. In its current state of development, the machine could probably not be used reliably for harvesting commercial taro blocks. However this could occur with relatively minor alterations to improve clearance.
Further trialling of the machine under a range of conditions would also be worthwhile. It is currently available for this purpose to interested growers and has been recently used as such.

Other improvements would be possible with more major modifications (and higher expense). Probably, these would be limited to installation of powered coulters beside the cutting blade and changes to the conveyor design to improve material transfer and cleaning. Beyond these improvements the only other development would be reinstallation of the cam operated sieve at the rear to deliver harvested material into bulk bins. This would require extra framing and re-fitting of a jockey wheel at the rear of the machine for structural support. Beyond these suggested improvements further development of this machine is probably not warranted.

The machine is shown in Figures 4.14 and 4.15 in various stages of development.

Other potential technologies

Modern potato harvesters

Modern potato diggers offer pre-existing technology that could likely be applied to taro. They are well designed, high capacity machines incorporating proven ground engagement geometry, efficient cleaning conveyors and mechanisms for removal of vegetative material, stones and clods. Examples of modern potato harvesters are shown in Figures 4.16 and 4.17.

With reference to taro however, these machines are expensive (at least $50,000), require larger tractors and are designed for larger production areas (10’s of hectares). Unless smaller examples of these machines come onto the second-hand market at affordable prices it is unlikely that they will be adopted in taro. The predominance of production in coastal regions where use of these machines will be more difficult in wet conditions is another impediment to their uptake.
Notwithstanding this, the potential of such equipment should not be dismissed. There could well be an opportunity for a harvesting contractor or grower cooperative to operate such a machine. This potential would be higher if there is a shift to a smaller number of larger growers or a move to production in drier regions where soil moisture levels can be better controlled. A trial of such a machine in (north Queensland) taro through hire of a machine from the nearby Atherton Tablelands is something that could be considered. This may require planning so that a trial crop is planted to suit the machine. If this was successful, it is likely that an appropriately sized, second-hand harvester could be sourced—particularly from major potato growing regions in Victoria and South Australia.

**The Universal Tuber Harvester - Japan**

In Japan, the Institute of Agricultural Machinery in conjunction with Toyo Noki Co. Ltd and Kobashi Kogyo Co. Ltd. have developed the ‘Universal Tuber Harvester’. A colour brochure on this machine was obtained through the RIRDC-Central Queensland University project ‘Development of taro, yam, yam bean and sweet potato exports to Japan and USA’ in 2002 after a visit by project members to Japan. This brochure is reproduced in Appendix A together with basic specifications of the machine taken from the IAM website.

The machine itself is self-propelled and track-mounted—it appears to be very well designed and sophisticated. Not surprisingly then, it’s Japan 2002 list price was about US$95,000—according to the CQU project members who visited Japan at that time. This puts it out of consideration by individual taro growers in Australia even without the extra costs and hassles of importation.

Although the machine is specified as being suitable for harvesting small-corm taro—it is also specified for potato and sweet potato. Therefore it is also likely to be suitable for large-corm taro—perhaps with some minor adaptations. Whether or not the machine has been tested with large-corm taro in Japan or elsewhere is unknown but considered unlikely. Neither is there knowledge about the sales or success of this machine. It is possible that a harvest contractor or grower cooperative could import this machine for use in Australia—particularly if it could be used on a range of tuber crops as claimed. However, this would be risky without further knowledge of its performance.

**Alternative approaches**

The principle of traditional style potato diggers is to cut the sides and bottom of the bed and transfer this more-or-less intact ‘mass’ (including the root crop) onto an inclined conveyor. The conveyor construction allows separation of soil by agitation and gravity. Other mechanisms may be installed to separate extraneous vegetative material, stones and clods—requiring conveyors on the machine.

An alternate approach is to try and harvest just the crop, without soil and other material. This is the technique used with carrot and peanut harvesters that rely on a pulling mechanism to extract the crop from loosened soil. The design involves running a cutter bar under, or partially under the crop, and a mechanism to grasp and pull the crop at the soil surface almost immediately above the cutter bar. Typically, the stem/petiole section of plants is grasped between spring loaded belts or chains. The pulling action is achieved by inclination of the belts/chains upwards from the soil surface combined with powering them slightly faster relative to the groundspeed.

A potential problem with this technique with taro is whether sufficient pulling force can be applied at the base of the petioles, to extract large corms or difficult to remove corms. To assist with this, the soil could be vibrated via side mounted tines or the cutter bar itself. If such a technique could be used, it could offer significant advantages including:

- exclusion of weeds
- avoids the need to slash before harvesting
- removal of suckers and daughter corms by a stripping mechanism
- automatic cutting of the top part of the plant from corms

Figure 4.18 shows such a crop lifting device mounted to the original self-propelled harvester at Noosafresh—presumably this was previously used with ginger.
4.3 Mechanisation of taro harvesting: small corm types

Introduction

Interest in commercial production of small-corm taros—more commonly referred to as ‘Japanese’ taro—was in response to a reckoned export opportunity to Japan. However, developing this market has so far been unsuccessful and the interest has probably declined. The few remaining growers have instead focussed on domestic markets to offload production from initial plantings.

In any case, competitive production of this crop in Australia will require mechanisation of the production system as much as possible, particularly for harvesting and washing/packing. Growers experimenting with commercial production of small corm taro in Australia consider that mechanical harvesting will be mandatory.

Within this project, no development of techniques or equipment for mechanically harvesting small corm taro was undertaken. However there have been some experiences with mechanical harvesting of the crop in northern NSW.

Trials in northern NSW

In June 2002 a visit was made to the farm of Col Foyster near Burringbar in northern NSW, a fairly large potato growing enterprise where about 2 hectares of small corm taro had been planted as a trial crop. At the time of the visit the crop had reached maturity but conditions were very wet. Also, flooding of the paddock during the growing phase had resulted in weed growth to the extent that the crop was ‘let-go’.

Despite this, the intention was to use a soil conditioning machine to try and harvest the taro. This machine was designed for breaking clods in preparing seed-beds for potato planting. The machine hadn’t been used for two years. In principle it was quite similar to a traditional double row potato digger but with the addition of a draper chain above the main conveyor (designed to break clods). There was a large area where soil could fall through the conveyor back to the ground.
Only unbroken clods (or in this case taro corms) would remain on the conveyor and be transported to the rear of the machine to be dropped onto a transverse conveyor which deposited material in the inter-row (between seed beds).

With some misgivings due to the weeds, wet conditions and presumed poor crop, the machine was put into the field and performed remarkably well. It easily dug and lifted the plants and clumps of attached corms onto the main conveyor despite the weed growth. Particularly encouraging, was that as the plant and corm clump passed under the draper chain, the corm clump was broken apart into individual corms or clusters of corms. This then allowed quite good separation of any soil bound-up in the original clump. Had the weed growth been less and soil conditions drier, an even better result would probably have been achieved. Another hindrance was that the draper chain could not be adjusted due to a stuck solenoid on the controlling hydraulic ram.

At the rear of the machine, the transverse dropped corms to the ground—they could just as easily have been collected by a chaser vehicle. As well, with some redesign, this conveyor could have been utilised for additional soil separation and break-up of the corms (and even perhaps removal of undersized corms).

Interestingly, the draper chain on this machine is mounted in a similar position and arrangement to a mechanism shown on the schematic diagram of the Japanese Universal Tuber Harvester (Appendix A). On the Japanese machine, it is labelled as a ‘small taro separating conveyor’—presumably designed to break up the corm clump as it is forced to pass between it and the main elevating conveyor. On the Japanese machine it also appears to be powered in a counter-direction to the main conveyor.

Other growers of small corm taro in northern NSW have apparently been using traditional style potato diggers with some success. It is not known however, if there have been any developments with this machinery beyond its capacity to just dig the crop, separate most of the soil and deposit the corm clumps back on the surface.

There was mention that a more sophisticated machine was under private and confidential development at a local engineering workshop in northern NSW but this was not verified.

4.4 Mechanisation of taro washing and cleaning: large corm types

Introduction

The task of washing and cleaning taro is generally a difficult one. Typically, hand harvested corms will have the petiole roughly trimmed in the field so that product presented at the packing shed for washing comprises the main corm with a short length of the leaf stalk attached. A range of contaminants need to be removed prior to packing for sale including:
- soil and mud adhering to the corm,
- roots/rootlets attached to the main corm,
- remnants of old or dead leaf stalk still attached at the top of the corm,
- emergent corms attached to the main corm.

The soil type and weather conditions at harvest will influence how much soil is present and how difficult it is to remove. Also, the maturity of the taro influences how many roots and daughter corms are attached to the main corm. If the crop is still in an active growing phase then corms tend to have an vigorous root system with many roots attached—as well as being difficult to remove these can retain soil and clods. Even towards maturity, crops may go through a cycle of active root growth in response to weather conditions.

The tops of corms can also have a fine covering of lapped, fibrous material near the base of the leaf stalk. Generally, this material is more easily removed along with any adhering soil.

Manual taro washing (including trimming) typically costs at least $0.25/kg and up to $0.50/kg based on a labour cost of $15/hr, but this will depend markedly on the state and size of corms.
Market preferences

There is a range of opinions on the preferred presentation of taro for market; and resultant quality consigned. Certainly, the corms should be cleaned of soil, any daughter corms should be cut off, and there should be few if any remaining roots. There is some opinion that corms should have a ‘natural’ appearance whereby the brown and sometimes flaky surface skin is retained but the corms are otherwise clean. Many growers also leave 10-20 mm of cleanly cut leaf stalk rather than remove it completely flush with the top of the corm. The section of retained leaf stalk should be free of any loose or ragged material to give a neat appearance. A good example of taro corms dressed in this fashion is shown in Figure 4.19.

![Well-dressed taro corms with leaf stalks trimmed above the main corm. (photo courtesy Peter Salleras)](Figure 4.19)

Achieving this appearance with mechanical washing/cleaning presents a challenge since cleaning aggressively to remove roots from corms will likely result in the surface brown skin also being removed leaving the taro with a pale or white appearance. Whilst some growers accept this in the context of existing mechanical cleaning devices, others don’t. In any case, cleaning should not be so aggressive that the skin is abraded and the ‘flesh’ part of the corm exposed.

An additional problem for mechanised washing and cleaning is the wide range of corm sizes marketed. Sizes range from a few hundred grams (down to 75 mm diameter) up to at least several kg (>150 mm diameter). Obviously this range of sizes makes mechanical washing devices difficult to implement unless a very adaptable technique can be developed. More likely a suitably developed technique will require grading of corms or production of more uniform corm size (based on market research and/or optimum production and mechanisation parameters).

Manual taro washing

If no mechanical aids are used for washing corms, the simplest method is to wash corms with water at good domestic pressure using a hose and nozzle. Corms can be washed individually or placed in a single layer in a vessel and washed in bulk. Roots are removed by hand pulling or trimmed using a knife. Likewise daughter corms are broken off or trimmed.

A considerable improvement is to use a hose fitted with a fan nozzle and handpiece. The water fan enables washing of corms in a more systematic fashion and can be applied in such a way as to slough off material, particularly from near the top of the corm.

Some growers have experimented with portable high pressure cleaners—however they say it is an inefficient method and tends to remove the outer skin from corms. Of course, working with such high pressures is also potentially dangerous.
**Mechanical taro washing**

**Washing aids**

Even if a significant amount of washing and cleaning of corms is manually based, many growers use mechanical aids to speed up the process. These include chutes to contain and trap the water and debris from washing to simple drum washers where corms are passed through a slowly rotating (30-50 rpm) inclined cylinder (600-800 mm in diameter) which is rubber lined and equipped with water sprays. Such washers are commonly used by sweet-potato growers.

**Zanolleti single corm washer**

A dedicated taro washer has been developed by a Babinda-based taro grower in conjunction with Vicarioli Engineering (see “References” section). Several north Queensland taro growers now use the machine.

The machine (pictured in Figure 4.20) is designed for washing taro corms singularly. It comprises flexible fingers mounted on the inside face of two counter rotating steel rings. The fingers do not meet in the centre of the machine which means a ‘hole’ is formed when the machine is running. Water jets are positioned inside the rim of the machine aimed at the centre.

A sufficient length of stem is left on each corm for grasping by hand. The corm is then manually pushed into the machine. The fingers remove remnant leaf, soil and roots from the corms. At the completion of cleaning the corm can be pushed through the machine and released–usually into an inclined trough or onto a conveyor. Alternatively, the corm is withdrawn, inverted and the opposite end also pushed into the machine to complete the cleaning process.

The aggressiveness of cleaning is determined by the stiffness of the fingers and how long each corm is held in the machine. Growers alter the stiffness of the fingers by cutting grooves in each side. For thorough cleaning, including removal of most of the roots–the corms must be held in the machine for at least several seconds and both ends of corms need to be alternately pushed into the machine. A disadvantage of this is that the outer brown skin of the taro can also be removed leaving corms with a pale appearance. The alternative is to wash the taro less aggressively and spend more time hand-cleaning the corms afterwards. For this reason some growers do not see much advantage with the machine and continue with manual based washing methods.

Nonetheless, the attraction of this machine is the productivity improvement and reduction in costs of washing. The other advantage of this machine is that is small in size, simple to set-up and relatively low cost. Water use is not high.

**Mechanical washing plant at Noosafresh**

At “Noosafresh” (via Cooroy), both ginger and taro are mechanically cleaned in a substantial washing plant. This was viewed in operation during a visit in June 2002. The plant was designed by the former owners of the business and manufactured on-farm. Whilst the whole system takes quite a large area and appears cumbersome it works demonstrably well. At the time of this first visit the plant and packing shed operated as follows:

1. Mechanically harvested taro was unloaded from field bins into a bulk receival hopper comprising a ‘live’ floor which slowly moved material toward one end where the hopper floor was inclined so that corms were elevated (Figure 4.21).

2. Corms then fell onto a conveyor which transferred them to the primary washer. While on this conveyor any loose soil present could fall through large openings in the conveyor assisted by some agitation of the conveyor drive chain (Figure 4.22).

3. The primary washer (Figure 4.23) comprises of co-joined inner and outer drums—which are slowly rotating. They are supported and driven via the outer drum so that there is no central shaft. The inner drum is constructed of pipe wound in a spiral fashion and with a small gap between each wind of pipe. The outer drum is for catching the waste wash water. A large volume of water is flooded onto the taro from fixed pipes mounted inside the length of the inner drum. As the drum rotates, the taro is worked toward the outlet end where it drops into a water trough.
4. The water trough is designed as a trap for stones and heavy sediment. A conveyor elevates the taro out of the trough and into the secondary cleaner.

5. The secondary cleaner (Figure 4.24) is in the shape of a large trough. In a cut-away section at the bottom several counter-rotating rollers are mounted lengthwise (in a similar design to onion topper-tailers). Each alternate roller had a spirally wound strip which acted as a cutting/pulling edge for the removal of roots and extraneous vegetative material. The taro is worked through the machine by a large central auger constructed of rubber flights to minimise damage.

6. The cleaned taro was then delivered onto a final sorting conveyor where operators manually removed any reject corms and carried out some trimming/cleaning of the marketable corms. At the end of the sorting conveyor, the cleaned corms were deposited into bulk bins which could be transferred to the packing shed by forklift.

7. Prior to packing, the taro was skin-dried in the bulk-bins using a centrifugal fan mounted to a lid which was placed on each bulk-bin. The fan draws ambient air through the taro from holes in the base of the bin (Figure 4.25).

8. Packing was carried out inside a fully enclosed room. The bulk-bins containing cleaned, sorted and skin-dried corms are emptied at each packing station. Corms have a final inspection and clean as necessary and are then packed into cardboard boxes. Each packing station (Figure 4.26) had a stainless steel work bench incorporating a chute for waste and a roller conveyor for the packed cartons.
Figure 4.21 Noosafresh: Elevator at end of bulk receival hopper

Figure 4.22 Noosafresh: Conveyor from bulk receival hopper to primary washer

Figure 4.23 Noosafresh: Primary washer construction (left) and working (right)

Figure 4.24 Noosafresh: Side view of secondary washer (left); bottom view of root cutting rollers (right)

Figure 4.25 Noosafresh: Skin drying washed taro in bulk-bins prior to packing

Figure 4.26 Noosafresh: Packing station set-up
Considering the level of extraneous material present with the taro delivered from the field, the washing plant performs well. Material is handled in the plant without human contact (except at the sorting conveyor) in a continuous process. The corms delivered to the sorting conveyor were clean and free of the majority of extraneous matter which was present at the start. However there was still quite a lot of extraneous material present which has to be removed by hand either on the sorting conveyor or in the packing shed. The system would perform better if improvements in the removal of extraneous matter at harvesting could be achieved. Throughput of the plant is probably at least 2 t of washed corms per hour. The water usage in the plant was high and somewhat excessive.

Some changes have been carried out to the washing plant at Noosafresh since the original visit. The bulk receival hopper has been raised about 300 mm off the floor to allow easier cleaning. The ‘live’ floor of this hopper previously comprised steel bars about 500 mm apart linked between continuous drive chains at the sides. Overlapping rubber flaps have been installed to reduce damage which was previously being caused by the steel bars. Most significantly the secondary washer is no longer used—it was not completely effective at removing roots from corms and also caused some mechanical damage and loss of corms for planting material. Instead, corms from the wash plant are now air-dried for a longer period in the bulk-bins with lid-mounted centrifugal fans. The attached roots are then dehydrated to the point that they are easy to remove by hand at packing. The owner claimed that this method was more efficient and was much preferred by the packing staff.

A problem with plant such as the one at Noosafresh is the high level of capital infrastructure investment relative to the scale of most Australian taro growing operations. Investment in the plant at Noosafresh is made possible by the large scale ginger growing operation on the same farm. For exclusive use with taro, such a plant could only be considered if it was a ‘central’ processing facility servicing several growers. Alternately it could be justified on a large farm growing significantly larger volumes than currently typical. Another factor is that the equipment in the plant is not commercially available.

**Silkwood machine**

Recently a taro grower near Silkwood in north Queensland (Steve Scopelliti) developed a simple taro washer that is apparently very effective at cleaning corms although it is not really designed to remove roots. The washer can clean taro continuously at a rate equivalent to about 12 cartons/hour (about 180 kg). Although the machine has been viewed (not in use) its details are not reported as the grower wants to maintain confidentiality. His intention is to develop the concept into a saleable machine and this may be done in collaboration with another taro grower in north Queensland.

**Other mechanical washers**

**Stark Engineering - Laidley**

A washing and root removal machine specifically designed for taro is used by growers near Mossman. This machine was designed and fabricated several years ago by Stark Engineering in the Lockyer Valley (Queensland), commissioned by a former Tully-based taro grower. The machine has a “Patent Pending” label but it is not clear if a patent was ever obtained. In any case it has a very similar design to the root-puller used at Noosafresh with a set of counter-rotating rollers forming the ‘floor’ of a rubber lined drum. The machine has a slowly rotating ‘auger’ mounted on a central shaft and constructed of light gauge steel sheet. The auger slowly pushes corms from the inlet to outlet end and agitates them in the process.

According to the owners, this machine does not perform particularly well. The rollers are not very effective in removing roots from the corms and the steel auger flights cause some abrasion to the skin—especially when corms become obstructed in the machine. However the owners continue to use the machine since it is somewhat effective at cleaning corms by virtue of water jets and movement of corms through the machine against the rubber lining. Final cleaning and root trimming is completed by hand.
Daradgee Welding Works

A taro washer was constructed for an Innisfail-based grower about 5 years ago by Daradgee Welding Works. This was a well-built unit but unfortunately proved to be less effective than expected for washing taro. It comprised a large receival tank filled with water. Submerged water jets in the tank pushed corms toward an inclined roller conveyor leading from the opposite end of the tank and mounted across its entire width (about 1.2 m). The rollers on the conveyor were lagged with ‘rough-top’ rubber and rotated as they were pulled through the machine so that they caused a rolling motion to the corms on the conveyor. The conveyor passed beneath a washing booth equipped with water jets delivering a high volume at moderate pressure. At the end of the conveyor, the corms were manually transferred to a packing wheel.

Whilst the machine effectively washed loose soil from corms, more firmly adhering soil was not always removed and the machine did not really remove any roots or remnant leaf material. This machine also relied on a relatively clean sample of material from the field since there was no provision for the removal of extraneous weed and vegetative matter.

The owner of this machine no longer grows taro and it has been modified for use with another crop.

Japanese manufactured equipment

A brochure was obtained from Japan showing a range of vegetable washing equipment manufactured by a company called Takahashi Suiki. However, little could be determined about the application or performance of this equipment with taro so an attempt was made to make contact with Takahashi Suiki. A reply was received from an employee of Tsukiji Sangyo Co. Ltd. who distribute vegetables in Japan and have a partnership of some kind with Takahashi Suiki. Since a significant part of their business is importing, Tsukiji Sangyo sometimes has opportunities to export equipment manufactured by Takahashi Suiki. From the correspondence this mainly seemed to be carrot washing equipment.

Tsukiji Sangyo noted that companies like Takahashi Suiki did not really think about exporting so they had no product information written in English. Furthermore their machinery tended to be quite small scale. They make washing machines for carrots, taro, burdock, potatoes etc. The machines are normally used in the processing industry to peel skin using brushes but not for fresh market produce. However, Tsukiji Sangyo did facilitate the export of grading and root-cutting equipment to a northern NSW grower producing Japanese taro (see page 35).

The product brochure from Takahashi Suiki is reproduced in Appendix B.

Development of a continuous flow taro washer

In the absence of available and effective equipment that could be adopted by typical growers, an attempt was made to develop a continuous flow washer for taro within the project. A prototype machine was designed, fabricated and tested at DPIF’s South Johnstone Research Station.

Due to the effectiveness of the Zanolleti single corm washer, the design of the prototype machine was based on trying to simulate the mode of action of the Zanolleti washer, but in a configuration where corms could pass through the washer automatically and continuously. The method adopted was the use of rubber ‘chook-plucking’ fingers mounted to a rotating drum, to act against the taro corms. These fingers are commercially available in various lengths and sizes at modest cost.

Test-rig

Initially, a test rig was constructed to assess the effectiveness of the technique before a full-sized machine was designed and developed. Figure 4.27 shows the test rig (equipped with a variable speed drive) at rest and in motion.
Figures 4.28–4.30 show examples of corms before and after being held against the fingers at various drum rpm and for various time periods. For scale, each corm is photographed on an A4-sized piece of paper. In each case the amount of ‘interference’ between the ends of the rotating fingers and corms was about 20-25 mm and the corms were rotated slowly by hand.
Results from experimentation with the test-rig were encouraging since it achieved a good degree of cleaning and root removal whereas skin damage/removal was only evident at higher drum speeds and/or more severe ‘interference’. This suggested a compromise could be achieved between effective cleaning and excessive abrasion provided a means could be found of mechanically presenting the taro to the fingers. Also, the cleaning was achieved without any water being used at the same time—corms could only be wetted prior to being held against the fingers—whereas a more fully-developed machine would include water sprays to assist the washing process.

**Prototype washer description**

A diagram of the prototype washer is shown in Figure 4.31. Basically it comprises 5 drums equipped with rubber chook plucking fingers mounted above a roller conveyor. The drums are mounted on a separate frame which is adjustable for height relative to the conveyor (by threaded bolts). The speed of the drums and the roller conveyor could be changed by a mechanically variable gearbox (or independently by changing drive sprocket ratios). As set-up, the drum speed could be varied from 32 to 196 rpm which corresponded to a throughput of 3 to 18 corms/min.

The conveyor comprises two chains between which are mounted freewheeling rollers (mild steel pipe). The rollers are located by stub shafts welded to the insides of the conveyor chains. The rollers are coated with ‘rough-top’ rubber. In the upper section of the conveyor the rollers are not supported by the conveyor chain but rest on metal side strips also coated with rough-top. Therefore, forward motion of the rollers caused by their attachment to the driven conveyor chain causes the rollers to rotate as they interact with the supporting strips—in the same way the wheels of a vehicle rotate as they roll against a fixed surface. In the bottom (return) section of the conveyor, the rollers ‘hang’ from the conveyor chain and so do not rotate. This principle is the same as was used on the taro washer constructed by Daradgee Welding Works for an Innisfail grower (described previously).

The corms are placed individually on the conveyor rollers and are conveyed underneath the rotating drums. As the corms pass through the machine they rotate slowly due to the previously described rotation of the rollers on which they are resting. Sheet metal sides and hooding constrains the corms in the machine. Water is sprayed onto corms from fan nozzles mounted at the entrance of the machine and between each rotating drum. The clearance between the drum fingers and the conveyor is adjusted depending on the size of taro being washed.
**Initial modifications to the prototype washer**

When the machine was first operated it was quickly apparent that the ‘groove’ formed between rollers on the conveyor would not provide sufficient restraint to the corms when they came under the influence of the rotating fingers. This meant that corms were flung forward in the machine from one rotating drum to the next. The corms passed through the machine too quickly and in an uncontrolled manner. This occurred regardless of the direction of travel of the conveyor relative to the drum rotation.

Therefore it was necessary to fit barriers to restrain corms when they were being worked by the plucking fingers. The design of the retainers was constrained by the existing set-up and need to fashion them from materials at hand. It comprised a piece of angle iron bolted between small supports which in turn were welded to the heavy conveyor chain at the required spacing. To each horizontal section of angle iron, flexible rubber plucking fingers were mounted which were similar to those on the rotating drums but shorter and stiffer. The arrangement is shown in Figure 4.32. While rigid ‘fingers’ could have been used it was thought that they would cause premature wear to the drum fingers since there was (necessary) interference between the two.

![Figure 4.32 Prototype washer without retainers (left) and with retainers fitted (right)](image)

**Performance of the prototype washer**

Examples of corms washed in the machine are shown in Figures 4.33–4.35. While no objective measurements of cleaning were made, subjectively the machine did quite a good job of removing all adhering soil, a large proportion of any attached roots and most of the remnant leaf material around the base of the petiole. As a prerequisite, any small corms were cut from the mother corm since they reduced the effectiveness of cleaning by deflecting the rubber fingers and preventing rotation of corms on the conveyor rollers. The machine also needs to be adjusted according to the size of corms being washed. Once done this then requires that reasonably consistent sized corms are fed into the machine. Generally the machine was adjusted so that there was 25-40 mm ‘interference’ between the corms and the rubber fingers.

The largest corms that the machine could probably handle would be up to 275 mm in length and about 175 mm in diameter. Speed of the plucking drums was tested between limits of 100 and 200 rpm which corresponded to a throughput of about 500-1000 corms/hour for the gearing used.
One feature worth remarking on was the effectiveness of the first water fan in cleaning material from corms. This brass nozzle (Spraying Systems Co. Flatjet 3/8P 3540) provided an excellent fan of water as shown in Figure 4.36. The upper side of corms rotated towards the fan as they passed beneath it and this provided a good cleaning action. Unfortunately the corms were not exposed to the water fan for a full rotation so only part of their surface was cleaned. A corm passing beneath the water fan created by the nozzle at the entry to the machine is shown in Figure 4.37. Subsequent water fans mounted between the finger drums in the machine (plastic nozzles) did not provide as effective cleaning action but did assist in washing away material loosened and removed by the rubber fingers.
Problems and limitations

A problem with the machine is ‘over cleaning’ of the corms whereby the outer brown skin on corms is removed leaving a pale fleshy surface exposed. This occurs because of a few reasons:

1. The problem mainly occurs to the middle (largest) section of corms where there is most pressure exerted by the rubber fingers. To try and reduce this pressure the rubber fingers were progressively trimmed towards the centre of the drum creating a ‘profile’ with the shortest fingers in the middle (see Figure 4.38). This probably helped the situation (including helping to keep corms ‘centred’ in the machine) however as the fingers are shortened they also become relatively stiffer so that there is not a corresponding reduction in cleaning pressure imparted. To negate this effect, the same length fingers could be mounted further away from the corms to create a similar ‘profile’.

2. The problem is made worse by corms not continuing to rotate when under the influence of the rubber fingers—this is because the corms are forced sufficiently hard against the retainers to stop them rotating under the influence of the conveyor rollers.

3. The problem is worse with the largest corms since if the machine is adjusted (height between corms and rubber fingers) for an average size of corm then the larger corms are more aggressively washed (and correspondingly the small corms are washed less aggressively).

A potential problem occurs if corms are pushed into orientations in the machine other than with their long axis parallel to the gap between rollers—for example jammed lengthwise against the sidewall of the machine. This wasn’t observed with the limited feedstock available for testing in the machine but if it did occur it would invariably result in corms being over-cleaned on one side only.
Possible improvements to the design

The machine performs effectively enough that modifications to improve its performance would be warranted—as opposed to abandoning the concept entirely.

Mostly these improvements would add extra complexity and cost to the machine which is significant given that the machine would already be a significant cost to a small/average sized taro grower. These modifications (indeed the whole machine concept) would better be considered in the context of a centralised taro washing facility or for a larger sized grower. Potential design improvements and comments are summarised in Table 4.3 listed in order from most simple to most difficult to implement.

<table>
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<tr>
<th>Design Improvement</th>
<th>Likely Result</th>
<th>Complexity or Difficulty</th>
<th>Cost and Comment</th>
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<tr>
<td>Fit extra brass fan nozzles:</td>
<td>Better cleaning.</td>
<td>Achievable with existing machine but preferably with extended conveyor.</td>
<td>Low. May require more water pressure.</td>
</tr>
<tr>
<td>• mount higher for better coverage</td>
<td></td>
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</tr>
<tr>
<td>• mount 3-4 nozzles at entry of machine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• replace nozzles in middle of machine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase ‘throat’ width of machine (from 300 mm to 400 mm.)</td>
<td>Accommodate larger corms.</td>
<td>Possible with new machine</td>
<td>Significant. Will require new rollers.</td>
</tr>
<tr>
<td>Independent speed variation of conveyor and rotating drums</td>
<td>Increased/optimised throughput relative to cleaning time/aggression.</td>
<td>Achievable with existing machine.</td>
<td>Significant.</td>
</tr>
<tr>
<td>Fit larger conveyor rollers to form larger ‘groove’ for corms</td>
<td>Better retention of corms as they pass through the machine and more effective rotation imparted.</td>
<td>Achievable with new design of machine.</td>
<td>Moderate. Dependent on availability of larger sized pipe end caps.</td>
</tr>
<tr>
<td>Design and fit alternate retainer bars incorporating roller on leading edge</td>
<td>Ideally would allow rotation of corms even when against the retainer. This would reduce ‘over cleaning’ of corms.</td>
<td>Possible with existing machine.</td>
<td>Significant.</td>
</tr>
<tr>
<td>Fit profiled drums with centre section having smaller diameter than sides.</td>
<td>Finger profile matched to taro profile giving same stiffness of fingers and more even cleaning.</td>
<td>Possible with existing machine.</td>
<td>Significant depending on design adopted.</td>
</tr>
<tr>
<td>Fit automated feeding and outlet chute.</td>
<td>Automatic delivery of corms to machine from pre-soaking tank and exit of corms from machine.</td>
<td>Possible with existing machine – delivery section likely to be separate unit.</td>
<td>High.</td>
</tr>
<tr>
<td>Mount drums on pivoted arms (spring loaded).</td>
<td>Automatic clearance adjustment depending on size of corms giving more even cleaning and eliminating need to pre-sort corms into similar sized batches for passing through the machine.</td>
<td>Possible with new design of machine.</td>
<td>High. Would still need to remove daughter corms from main corms.</td>
</tr>
</tbody>
</table>
**Other equipment: onion topper-tailers**

The principle of onion topper-tailers offers potential for application with taro. Such a machine was first seen at a packing shed in the Lockyer Valley. It employed an inclined bed (approximately 1.2 m long x 1.2 m wide) of fluted and gently tapered counter-rotating rollers about 50 mm average diameter. The action of these rollers pulled and cut the tops and tails from mechanically harvested onions. Unfortunately this machine was not able to be tested with taro and enquiries to the agent and importer of the machine (Proud Machinery, Highbury, South Australia) were unfruitful. The machine was apparently manufactured by Nicholson Machinery in the UK. In any case this unit would probably have caused too much skin damage to taro—being robustly constructed to accommodate a significant level of soil, sand and even small stones ex field. Another factor with this machine was its price which was about AU$20,000.

However an early model onion topper-tailer was trialled with some small corm taro on a farm near Cape Kimberley (Daintree region). The machine was quite old and in need of maintenance but according to the owner had been previously used for cutting roots from large corm taro at a farm in northern NSW. It was the intention of the owner to use the unit for the same purpose but they have now ceased growing taro and the machine has not been further developed. The machine is pictured in Figures 4.39 and 4.40.

![Figure 4.39 Overall view of a small onion topper-tailer used for cutting roots from Japanese taro](image1)

![Figure 4.40 Close-up view of rollers on small onion topper-tailer](image2)

The machine was only tested briefly due to failure of the electricity supply at the farm on the day of the visit. However it did quite a good job of cutting roots from hand segregated small-corm taro. The machine was a different design to the Lockyer Valley unit. It comprised 4 pairs of rollers about 1400 mm long. Each pair had one plain roller (50 mm diameter) and one fluted roller (40 mm diameter). Each fluted roller had 2 spiral strips about 5 mm high x 5 mm wide, mounted 180° out of phase with a 200 mm pitch. The rollers were not tapered but the inclination of the machine could be adjusted to regulate throughput. The machine did some damage to the small-corm taro which was processed but this was attributed to their small size relative to the rollers and susceptibility to being ‘pinched’. Also the plain roller had a steel ‘ring’ welded mid-way which was designed to hold material temporarily. However material caught here was invariably nipped and damaged.

Interestingly the first stage of the Japanese-sourced root cutter for small-corm taro (described page 35) uses the exact same principle and the same can be said for both the secondary washer at Noosafresh and the Stark Engineering washer (described pages 24 and 26 respectively). However, the poor performance of the last two machines is attributed to them having significantly larger diameter rollers.
4.5 Mechanisation of taro washing and cleaning: small corm types

Introduction

Mechanising the washing of ‘Japanese’ taro is perhaps an even greater pre-requisite for Australia-based production of these types than mechanised harvesting. The large number and small size and weight of the corms makes manual-based washing and handling very tedious and expensive on a per kilo basis. Since many of the corms produced are unsuitable for market due to their size or shape, an effective grading method is also required.

Within this project, no development of techniques or equipment for mechanically washing Japanese taro was undertaken. However there have been some experiences with handling the product in northern NSW.

Japanese equipment used in northern NSW

A grower in northern NSW has set-up a ‘central’ wash and pack-house for a small number of small-corm taro growers in the region. The basis of the system is small-scale root cutting and grading equipment specifically designed for small-corm taro and imported from Japan. When viewed, the plant had finished being used for the day so it was not actually seen in operation and due to some sensitivity of the owner; no pictures of the equipment were taken.

Initially the corms are pre-washed in a drum washer lined with rubber and similar to units used by sweet potato and taro growers elsewhere. This unit removed most of the soil adhering to corms (perhaps requiring multiple passes).

The corms were then passed through the imported Japanese ‘root-cutting’ machine. The first part of this machine is identical in principle to onion toppers (discussed in the previous section). The machine uses only one pair of rollers mounted on a slight incline. The corms are fed continuously onto the rollers from a hopper and as they pass along the length of the rollers many of the roots are presumably removed.

At the end of the rollers, the corms fall into a root-cutting device which is essentially an inclined trough (half-circle in cross section) made of slotted sheet metal. A secondary slotted trough is mounted below and in direct contact with first. The secondary trough is oscillated back-and forward beneath the upper trough by a mechanism of reciprocating linkages. The gaps created by alignment of the slots on each trough are effectively opened and closed by the oscillating motion; therefore any roots which pass through are cut away.

A rotary trommel (also imported from Japan) is used to size corms prior to hand sorting and packing. This unit comprised a round screen constructed with sections of longitudinal bars—in each section the bar spacing is progressively larger so that correspondingly larger corms are allowed to pass through and fall into chutes mounted underneath.
5. Implications

5.1 Mechanisation of planting

Mechanical planting of taro is technically possible and is currently practiced by a several of growers. With the machinery used, ground preparation for planting would appear to be little different from that required/practiced for manual planting, so presents no significant impediment to adoption. This includes implications for the type and placement of the irrigation system—which is a consideration for pre-planting tillage activities in any case. Also, trafficability at the time of planting will be a consideration with mechanical planting since wet field conditions may prevent planting when manual planting could otherwise be carried out. This limitation can be improved by adopting bed systems with permanent ‘traffic’ lanes. Such systems need to be implemented in the context of the whole-of-crop management.

Plant spacing accuracy is not perceived to be of major importance in taro and in any case once an optimum planting density/arrangement has been selected, mechanical planting can probably improve accuracy of placement. Good ‘strike-rates’ can be achieved with mechanical planting at least comparable to manual planting and additionally mechanical planting offers scope for mechanised placement of fertiliser, irrigation drip line and pre-emergent herbicides (assuming any are suitable) all in the one operation. Finally, mechanical planting–whilst having implications for other mechanisation practices in the growing system–does not of itself impose necessary changes to the subsequent growing and management of the crop.

Despite the above, ready availability of machinery for mechanical taro planting is probably a factor inhibiting adoption. Although various technologies are used in the industry for planting both corm material and setts, there is no specific equipment designed/marketed for taro because of the small size and early development of the industry and this is unlikely to change. Growers have to search-out, purchase and modify used machinery; purchase new machinery used in other crops which may then still require some modification; or construct equipment themselves. All these choices rely on a significant level of motivation and know-how on the part of the grower.

Another factor is labour. Most mechanical planters require operators on the planter in addition to the tractor driver. This will certainly be the case when planting setts or plantlets where at least one operator will be required for single-row plantings and probably 2 for double-row plantings. Hiring or accessing this labour may be inconvenient for smaller growers–particularly when it may only be for relatively short periods. With manual planting the growers can do it themselves without the need to hire labour.

Finally, linked with the adoption of technology for mechanical planting is the decision on the type of planting material–corm material, setts/suckers or possibly tissue culture. Each type of planting material has a set of implications relating to availability, selection, preparation, cost, storage and viability, disease control, risks from post planting weather conditions (including heavy rainfall or high temperatures), irrigation and weed management. It is beyond this work to examine these factors in any detail but if planting mechanisation is to become well established in the industry then the relative importance and economic consequences of these factors should be understood. Choice of planting material should be based on the importance of these factors to growers rather than on the planter technology available.

5.2 Mechanisation of harvesting

Large-corm taro

Mechanised harvesting of large corn taro has been trialled by a few growers but has is currently only practiced by one or two growers in the industry. There a number of factors inhibiting adoption of mechanisation historically and most these are still evident. In summary they are attributed to:

- lack of a ‘standard’ production system across the industry (including production of consistent corm size)
- limited equipment availability and capital outlay required
- risk of wet weather at harvest
- practice of staggered harvesting which means only relatively small areas are harvested at a particular time
- practice of ratoon cropping
- reluctance to deal with the complexities/risks of operating machinery when simple hand pulling will do.

Whilst the technical feasibility of mechanised taro digging has been demonstrated a number of issues remain:

1. While basic second-hand potato digging equipment can be utilised it is often in poor condition and performs a basic job. The taro is dug from the ground and a reasonable degree of soil separation can be achieved before the corms are deposited back on the soil surface. Even though productivity of harvesting is high relative to manual harvesting, this rather limited functionality does not generally offer growers enough incentive to change. Other factors which hamper uptake are wet weather conditions that frequently prohibit mechanised harvesting anyway; the likely need for pre-harvest operations including bed cutting and maceration of the petioles and leaves above the soil surface and production by some producers of very large sized corms (greater than 300 mm in length).

2. While growers could access more sophisticated machinery that presumably is capable of doing a more comprehensive job i.e. more effective soil/weed removal and on-board or chaser vehicle collection of harvested material; this equipment is typically designed for larger scale applications. Purchase cost, size and power requirements are generally incompatible with taro farms. Alternatively, growers could build or commission their own ‘tailor-made’ machinery. However this is not without significant challenges and risks. For example, difficulties were experienced in the project developing a basic taro digger; at Noosafresh, despite investment of a significant amount of time and money, the self-propelled harvester developed is still somewhat compromised in performance.

3. Enabling effective mechanical harvesting has many implications for the rest of the cropping system and probably entails a higher level of management. Factors that will be important or are effected include the growing site/soil, irrigation system, bed system, planting material, planting density, weed management, machinery availability and even marketing arrangements. This implies a ‘bottom-up’ approach to growing which takes time, effort, trial and error to evolve.

One approach which may overcome these issues is through increased scale of production. Mechanical taro harvesting will be most cost effective when harvested material is able to be cleaned-up as much as possible on-board the harvester and harvested corms are collected in-bulk for transfer to the washing/packing shed. This will require larger and more sophisticated machinery which can only be justified by increasing scale of production.

Leveraging cost benefits of mechanised harvesting through scale of production can be achieved in two ways–increasing the size of individual farms or ‘pooling’ of capital infrastructure that services a number of farms. Greater production size of individual farms has and will continue to occur in some cases. However, recognising the character of the industry, many growers will prefer or are constrained to remain at relatively modest scales.

Therefore a ‘pooled’ approach may be sustainable based on a contracting or ‘co-operative’ system. The harvest machinery will need to perform well and provide a clear benefit to growers to justify the cost and effort of relocating between relatively small farms. Such a system would continue to allow growers to carry out relatively small ‘staggered’ harvesting. However it should also be based on greater standardisation of growing practices across the industry since successful harvester technology will likely depend on that. Such an approach could actually be based on more wide-ranging co-operation to capture additional benefits: central packing shed; regular supply to markets; ‘branding’ of product based on quality and grade standards. Successfully following through with this approach could ultimately lead to increase power in the marketplace and higher product demand.
**Small-corm taro**

Mechanical harvesting of small-corm taro is technically possible and in the event of significant production volumes would have a high likelihood of adoption considering that viable production of this product in Australia is more or less reliant on mechanised harvesting systems. Sustained production for export markets would require reasonably large and coordinated plantings with relatively standardised growing systems. In a particular region, these factors would encourage development of a harvester for use amongst a grower co-operative, or support a contract harvesting scheme. Additionally, the actual mechanised digging presents no particular difficulties since the crop is neither particularly deep-rooted nor prone to mechanical damage from fracturing or splitting. However, a particular challenge of this crop is to break-up the corm mass and segregate the cormels. It is suggested here, that this be done on-board the harvester since this provides the opportunity to remove the likely significant quantities of soil and undersized corms in field rather than at a packing shed. A potential technique for achieving this has been observed on a potato bed conditioning machine harvesting small-corm taro in northern NSW. Significantly, this appears similar to the mechanism for segregating corms installed on a Japanese harvester designed for tuber crops including small-corm taro.

Therefore this technique should be pursued in the development of any Australian designed harvester for small-corm taro. Initially this should be assessment of the performance of the Japanese machine by observing it working in Japan or elsewhere. Such an assessment could lead to a recommendation for purchase and importation of the Japanese machine to Australia provided there is a commensurate industry development and the machine meets or exceeds performance expectations. In lieu of this, independent development of the principle or alternate approaches could be carried out in Australia with a co-operator grower or engineering works.

5.3 Mechanisation of washing and cleaning

**Large-corm taro**

Further research/trialling is required to develop a system/method for mechanical washing and cleaning of large-corm taro. Whilst a range of technologies are used in industry or have been attempted none of them provide a completely satisfactory solution. Drum washers used by many growers do a reasonable job of washing away soil but do not remove roots. The Zanoletti single corm washer does a good job of soil and root removal but requires manual handling of corms and is criticised for cleaning too aggressively. The prototype washer developed in the project shows good potential for soil and root removal without manual handling but requires further development. The system used at Noosafresh is fully mechanised and cleans corms well but root removal is performed manually in the packing shed (after air dying of corms to dehydrate the rootlets). Also, this ‘home-grown’ installation is large, complex and appears to use a relatively large amount of water.

Unfortunately a single machine for mechanical washing and cleaning of taro that is relatively low cost (affordable) and fully automated is probably not possible. At the typical individual farm scale growers will to continue to rely on existing machines/techniques that reduce the labour required for full manual washing and cleaning.

However in the context of large scale farms or contract/co-operative packing sheds, a fully mechanised system should be possible. Accepting that there is probably no avoiding some manual input initially— for removing daughter corms and any gross extraneous matter prior to processing in the mechanised system—this would then allow the mechanical system to do the best possible job. Assisting this, would be achieving reasonable uniformity in size and shape of corms ex-field through genetic selection and/or well developed management practices.

A proposed system for a (mechanised) wash plant for taro is outlined in Figure 5.1 based on the assumption that taro from the field is either manually or mechanically harvested and is free of weed and loose soil matter.

**Table 5.1** Proposed process for mechanised taro washing

---

38
<table>
<thead>
<tr>
<th>Operation</th>
<th>Equipment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receival hopper</td>
<td>Water trough with variable speed inclined discharge conveyor;</td>
<td>Material ex harvesting emptied directly into the receival hopper or stored in bulk bins prior to emptying.</td>
</tr>
<tr>
<td></td>
<td>* alternatively*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>bulk bin with ‘live’ floor and variable speed inclined discharge conveyor.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trimming</td>
<td>Horizontal belt conveyor</td>
<td>1-2 operators working to side of belt conveyor depending on throughput. Manually remove (cut) daughter corms and gross extraneous matter e.g. remnant leaf stalks, stone and clods; reject any corms as necessary.</td>
</tr>
<tr>
<td></td>
<td>receiving material from receival hopper discharge conveyor.</td>
<td></td>
</tr>
<tr>
<td>Washing</td>
<td>If wide range of corm sizes/shapes use washer based on improved design of drum washer (Steve Scopelliti);</td>
<td>Operator/s place corms back on belt conveyor for direct delivery to drum washer;</td>
</tr>
<tr>
<td></td>
<td>* alternatively*</td>
<td>* alternatively*</td>
</tr>
<tr>
<td></td>
<td>if reasonably uniform corm size/shape use washer based on improved design of prototype plucker-finger washer.</td>
<td>Operator/s place corms on end of roller conveyor which continues through washer.</td>
</tr>
<tr>
<td>Root removal</td>
<td>Root removal device based on onion-topper tailer design;</td>
<td>Corms pass directly to topper-tailer directly from washer;</td>
</tr>
<tr>
<td></td>
<td>* alternatively*</td>
<td>* alternatively*</td>
</tr>
<tr>
<td></td>
<td>dry corms until rootlets are dehydrated – for subsequent removal by hand</td>
<td>corms stored in bulk-bins for air drying of rootlets.</td>
</tr>
<tr>
<td>Skin drying</td>
<td>Remove surface moisture in hot-air tunnel drier</td>
<td>Corms ex topper-tailer pass directly to roller conveyor for hot air drying.</td>
</tr>
<tr>
<td>Size grading</td>
<td>If size grading use diverging roller or diverging belt grader</td>
<td>Could be integrated with or separate from main process i.e. after tunnel drier or as a stand-alone process.</td>
</tr>
<tr>
<td>Packing</td>
<td>Packing bench for inspection, trimming and manual packing into cartons.</td>
<td>Corms rejected as necessary; leaf stalk trimmed or removed; if applicable dehydrated rootlets removed; final trim of any remaining daughter corms and roots.</td>
</tr>
</tbody>
</table>

**Small-corm taro**

In the context of Australian production systems that target large export markets for small-corm taro, the need for mechanised handling at the packing shed (washing, root removal, sorting, grading and packing) is even greater than for large-corm taro. However, this is seen as technically feasible provided that mechanical harvesting of this product incorporates an effective means to segregate corms on-board the harvester and separate the majority of loose soil matter as well as any vegetative matter.

On this basis it is likely that washing plant based on equipment used for washing potatoes would be applicable with the addition of machinery for root removal and possibly some manual sorting of product before washing. For small-scale operations (processing up to say 2 tonnes of product daily), equipment manufactured in Japan is available and has been imported by a grower of small-corm taro. For larger scale operations other equipment could be available from the same manufacturer or alternatively larger scale machinery could be developed locally based on onion topper-tailer designs.
For grading of this product, simple sizing trommels can be built (or imported) which will effectively discriminate on the basis of diameter—although not necessarily shape. Since regular shaped (round) corms are preferred then hand sorting will be required. However a sophisticated pack-house could very likely apply computer vision technology for effective grading of product by shape. Some degree of manual inspection and sorting may be required before final packing. Provided the grading system is effective then the chosen packing carton could be volume filled by shaking.

All of this implies a scale of operation that is probably beyond that likely to be achieved from selling into a domestic market for this product. Therefore the domestic market needs to be expanded significantly or export markets developed. Recent efforts to export product to Japan appear to have stalled and product has gone instead to domestic markets. Unless export initiatives are revived this situation is unlikely to stimulate major investment in pack-house technology for this product at significant scales.
5.4 Cropping systems for mechanised production

To try and extract some value from the information and experiences arising from the project, a cropping system for mechanised taro production (large-corm types) is summarised. This serves as much to identify knowledge and technology gaps so that future investigation of agronomics and technology for mechanised taro production can be prioritised.

Table 5.2 Considerations for mechanised taro production

<table>
<thead>
<tr>
<th>Management Factor</th>
<th>Possibilities / Options</th>
<th>Comments and Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing location</td>
<td>Dry climate with lighter soils (compared to Wet Tropical Coast)</td>
<td>Industry currently centred on wet tropical coast and heavy soils though some move to lighter soils in Tully/Kennedy area.</td>
</tr>
<tr>
<td>Production period</td>
<td>Bi-monthly for year-round production considering market seasonality and influence of climate</td>
<td>Is this possible? i.e. Do later plantings ‘catch-up’ with earlier plantings during warm weather? Currently wet weather constrains harvesting opportunities.</td>
</tr>
<tr>
<td>Planting material</td>
<td>Setts or corm material or tissue culture</td>
<td>Need studies on management implications of each type and economics.</td>
</tr>
<tr>
<td>Bed system</td>
<td>Permanent double-row bed or single-row bed; rotate with green manure crop and re-form if necessary prior to replanting</td>
<td>Need for compatibility with permanent bed system/mechanical harvesting.</td>
</tr>
<tr>
<td>Irrigation system</td>
<td>Drip tube/tape placed at planting alternatively overhead sprinklers on fixed laterals</td>
<td>What is ideal relative to cost of material, size/productivity of plants, weed competition and mechanical harvesting? Wide range of densities used in the industry.</td>
</tr>
<tr>
<td>Plant density</td>
<td>?</td>
<td>May not be possible with tissue cultured plantlets?</td>
</tr>
<tr>
<td>Planting method</td>
<td>Mechanical</td>
<td>Chemical registration. Use of pre-emergent herbicides.</td>
</tr>
<tr>
<td>Mulching</td>
<td>Heavy mulch application post planting.</td>
<td>What is ideal relative to cost of material, size/productivity of plants, weed competition and mechanical harvesting? Wide range of densities used in the industry.</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>Applied in band in conjunction with mechanical planting. Subsequently by broadcast or fertigation.</td>
<td>Need for compatibility with permanent bed system/mechanical harvesting.</td>
</tr>
<tr>
<td>Weed control</td>
<td>Pre-emergent herbicide with corms. Spot application herbicides as required during growing phase.</td>
<td>Impact of wet weather and heavy soils. Need sophisticated machines to capture full benefits of mechanisation–contractors or co-operative owned.</td>
</tr>
<tr>
<td>Pre-harvest treatment/s</td>
<td>Herbicide application prior to harvest if required. Slashing, flailing or shredding immediately prior to harvest.</td>
<td>Impact of wet weather and heavy soils. Need sophisticated machines to capture full benefits of mechanisation–contractors or co-operative owned.</td>
</tr>
<tr>
<td>Harvest method</td>
<td>Mechanical with corms recovered in bulk bin.</td>
<td>Impact of wet weather and heavy soils. Need sophisticated machines to capture full benefits of mechanisation–contractors or co-operative owned.</td>
</tr>
<tr>
<td>Washing</td>
<td>Central packing shed.</td>
<td>Contract or co-operative.</td>
</tr>
<tr>
<td>Root removal</td>
<td>During mechanical washing or using onion topper-tailer immediately after washing; alternatively use onion-topper topper or brush finisher after air drying of rootlets.</td>
<td>Appropriate size, quality and packing standards.</td>
</tr>
<tr>
<td>Packing</td>
<td>Appropriate size, quality and packing standards.</td>
<td>Appropriate size, quality and packing standards.</td>
</tr>
</tbody>
</table>
6. Recommendations

6.1 Mechanisation: large-corm types

**Planting**

At this stage no work on development of technology for planting taro is required. Simple equipment is already available or is within the ability of most growers to develop. This assumes that no particular issues with planter technology that is currently in use exist or will arise due to changes in the growing system.

However, there needs to be agronomic work coupled with economic analyses, on the implications of the choice of planting material type, be it setts, daughter corms/corm pieces or tissue culture plants. Also, any work aimed at further development of planters to improve performance should be considered where clear benefits are proposed/likely.

**Harvesting**

Trialling of up-to-date potato harvester technology in taro is recommended and industry efforts to pursue this should be assisted. Whilst basic potato diggers have been used in taro successfully they have not incorporated the more sophisticated features of modern potato diggers for soil and weed separation. Such a program should allow the possibility for modifications of the machinery to be carried out as required for optimum performance in taro. Also a ‘trial block’ may need to be pre-planted in a manner suited to use of the machinery. It is suggested that this work might be in the context of trying to set-up a contract or co-operative based system for mechanised taro harvesting in a particular growing region.

Work aimed to optimise/standardise the production system in order to carry out mechanised harvesting should be supported. This includes selection of an appropriate corm size that best meets criteria for market, efficient production and mechanical harvesting and washing.

Also, researchers and growers should continue to try to ‘un-earth’ information about the design and performance of taro harvesting machinery developed overseas through personal contacts and visits. Particular locations where such equipment is likely to have been developed include Hawaii, Florida and Japan. Provided access to worthwhile contacts and farms could be arranged—a grower study tour to Florida and Hawaii should be supported. Such an activity would obviously encompass a broader program than just ‘mechanisation’.

The existing digger developed in the project should be made available through Taro Growers Australia for testing and use by grower members or for further development in consultation with the owners of the original machine (Mr Don Zanolleti and Mr Philippe Petiniaud).

**Washing and root removal**

Further development of effective washing technology for taro is required. Industry or grower driven proposals for commercialisation of the Scopelliti drum washer or further development of the prototype washer developed under this project should be supported. Also the prototype washer could be installed in conjunction with the taro chip plant now being constructed at Babinda.

Effective technology for removal of roots from corms is required. Two approaches to this are possible:

1. Dehydration of roots after washing for hand removal at packing or mechanical removal prior to packing (dehydrated roots are much easier to remove from corms).
2. Mechanical removal immediately after washing.
For the first approach, burning roots from corms with a naked flame has been suggested and may be possible but more likely there is potential for a mechanical device to brush, rub or pull roots from corms.

For the second approach development of a machine based on onion topper-tailer technology is recommended (this would also work with dehydrated roots). Matt Debman (Noosafresh) has some profiled rollers which would appear well suited for such a machine and he has offered them for use. Terry Mather (Daintree) is willing to sell his second-hand onion topper-tailer which could be renovated and trialled with taro.

Industry initiatives to establish a centralised washing/packing shed facility or augment an existing facility should be supported. This includes support to investigate existing commercial equipment and develop new equipment for installation in such a facility. It is believed that this approach to post harvest handling can deliver growers economies of scale as alternative to scaling up their own enterprises which will take longer and involve a higher level of risk.

As in the case for harvesting, growers and researchers should be supported in efforts to learn about the design and performance of taro washing/processing machinery developed overseas through personal contacts and visits. Again, the likely locations for existence of such equipment include Hawaii, Florida and Japan.

**General**

From an overall perspective factors that will assist faster and wider adoption of mechanisation in taro include:

1. Agronomic and economic studies that attempt to identify an optimal growing system/environment in the context of a mechanised production system.
2. Product promotion to exploit greater market potential that will lead to a larger scale production base.
3. Industry relocation to sites with environments offering reduced impediments to mechanisation or growing practices that aim to address these factors (e.g. controlled traffic bed systems).
4. Encouragement of grower/industry collaboration that mitigates and provides higher returns on capital investment through co-operative or contract planting and harvesting and washing facilities.

**6.2 Mechanisation: small-corm types**

**Harvesting**

In the event of renewed interest in production of small-corm taro, availability of an effective mechanical harvester should be a priority. In the absence of a suitable machine having been developed in Australia, any development program should attempt to assess in some detail the design and performance of the Japanese manufactured Universal Tuber Harvester. Depending on the strength of investment in the industry this could lead to direct import of the machine to Australia. Alternatively it would provide insights for development of an Australian machine for local conditions.

Design of a mechanical harvester for small-corm taro should incorporate a mechanism/s to segregate harvested material into individual corms and separate the majority of soil on-board the harvester.

**Washing and handling**

Production and marketing of small-corm taro for export markets should be co-ordinated through a central washing and packing facility. This would enable maximum implementation of technology and reduction in labour costs as well as more uniform product quality.
In designing such a facility it is likely that existing technology for washing mainstream vegetable crops could be used (e.g. potatoes, carrots) and the latest technology in use should be examined as well as any used plant which could readily be modified. An attempt should also be made to find out the actual purpose and functionality of the various washers manufactured in Japan (see Appendix B).

A root cutting machine already imported from Japan is suited to relatively small scale operations only. In the absence of larger capacity equipment then suitable alternative equipment will need to be developed and should be supported. As with large-corm taro, an approach based on the design of onion tipper-tailers is recommended.

6.3 Extension activities

Recommended extension activities arising from the project include:

- Inclusion of this report in the Taro Industry Information Resource (collated by Jeff Daniells) as a means of documentation for future reference and access by TGA members.
- Offer or invitation to make a presentation of the project results/outcomes to a meeting of TGA.
- Collation of taro mechanisation related photographs from this project (and arising from any future industry activities) into a reference album/CD.
- Preparation of a video/DVD showing functionality of taro equipment/machinery and/or in operation.

Points 1 and 2 can be undertaken in the normal course of ‘post-project’ duties. However points 3 and 4 would require a significant amount of time and effort (and funds in the case of point 4). Therefore whilst these may be conducted with/by DPI&F staff working on current taro projects they may in themselves form part of future project proposals.

6.4 Exploiting market opportunities

Major market opportunities exist for Australian-grown taro. Firstly, this lies in production of large-corm types for import replacement of Fijian product and export to New Zealand (also predominantly in competition with Fijian product). Fijian product is characterised by risks from pest and disease that could result in supply disruptions with long-term consequences thereby enhancing the opportunity for Australian product. A realistic 20% penetration into these markets would represent about a tripling in size of the current Australian industry. Secondly, production of small-corm types for export to Japan remains a possibility for quantities of 1000 tonnes or more.

However this is very much a “chicken-and-egg” situation. These opportunities can only be realised if prices are competitive and this implies a well mechanised production system. Unfortunately the current industry lacks scale and capacity for the significant capital investment required or to bear the risks of equipment and market development.

Therefore, robust proposals by industry or individuals to capture these markets should be supported. In particular, such proposals need to recognise the importance of mechanisation in the production system and the means to address this issue (which was a shortcoming of previous research and development on production of “Japanese” taro for export to Japan). Funds would be needed to support worthwhile undertakings such as overseas study trips; importation, trialling and modification of overseas manufactured equipment and fabrication and testing of Australian designed/sourced equipment. All of this should take place in the context of related agronomic research and development into an appropriate growing system.
7. Appendices

Appendix A. Universal tuber harvester

*Product brochure*
**Universal Tuber Crop Harvester**

**Easy to harvest tuber crops riding on the machine**

- **Research unit**: Vegetable machinery laboratory
- **Research period**: 1993 - 1995
- **Project participants**: Toyo Noki Co., Ltd. and Kobashi Kogyo Co., Ltd.

**Specifications**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Overall length</td>
<td>516cm</td>
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<tr>
<td>Overall width</td>
<td>220cm</td>
</tr>
<tr>
<td>Overall height</td>
<td>271cm</td>
</tr>
<tr>
<td>Weight</td>
<td>3,900kg</td>
</tr>
<tr>
<td>Engine</td>
<td>water-cooled diesel, 46PS</td>
</tr>
<tr>
<td>Transmission</td>
<td>hydrostatic transmission (HST)</td>
</tr>
<tr>
<td>Crawler</td>
<td>width 27cm × ground contact length 203cm, variable tread (adjustable range 0-66cm)</td>
</tr>
</tbody>
</table>

![Harvesting sweet potatoes](image)

**One machine covers whole harvesting operation**

The harvester has the function of digging crops, removing leaves and stalks, manual sorting, and loading into tank. It is available for harvesting potato, sweet potato, taro (*Colocasia antiquorum*) and short-rooted carrot. It can surely remove the stalks of sweet potato, and separate the daughter tubers from the mother crop of taro while passing through the digging conveyer. So, the machine provides high harvesting efficiency and easy unloading.
Harvesting mechanism and flow of tuber

1. Driving Seat
2. Leading roller
3. Digging knife
4. Colter
5. Soil separating conveyer
6. Vibrator
7. Small taro separating conveyer
8. First snapping roller
9. Stalk leaf guide
10. Small potato tank
11. Damping conveyer
12. Rotary conveyer
13. Forward feeding conveyer
14. Second snapping roller
15. Small potato removing roller
16. Sorting conveyer
17. Unloading tank
18. Rubber crawler

Highly efficient harvesting

Harvesting is done by one operator and two or three persons to sort the clods, leaves and extraneous materials. The harvester has the ability to harvest more than 7 a/hr for potato, 10 a/hr for sweet potato, 5 a/hr for taro and 6 a/hr for short-rooted carrot.
Appendix B. Japanese vegetable washers

*Product brochure*
References

Bibliography


Valenzuela, H & Sato, D, ‘Taro production guidelines for Kauai’


Possible sources of mechanisation information overseas

**Tsukiji Sangyo Co. Ltd.**
6-33-1 Minaminagareyama Nagareyama Chiba, Japan
Tel: +81 (4) 7178-9911
Fax: +81 (4) 7150-0177

- Japanese vegetable distributor having a partnership with Takahashi Suiki who in turn manufactures vegetable washing equipment in Japan.

**Nicholson Machinery Ltd.**
33 Common Lane, Southery, Downham Market, Norfolk, PE38 0PB
Tel: +44 (0) 1366 377458
Fax: +44 (0) 1366 377331
URL: http://www.nicholson-machinery.co.uk/ (accessed September 2005)

- Manufacture onion topper-tailers, bed toppers and a range of related vegetable handling/processing equipment in the UK.

**Institute of Agricultural Machinery (Japan)**

Useful Australian based equipment manufacturers, sellers and contacts

**John Beattie & Son**
1 Vaughan Street, Mareeba, Queensland
(07) 4092 2036
- Agricultural engineering workshop with experience in potato and sweet potato diggers

**Add-Up Engineering**
30 Wylie Street, Bundaberg, Queensland
(07) 4153-6989, 0407-335916
- Agricultural engineering workshop with experience in vegetable washing and grading equipment

**Wild HBS & Co Pty Ltd**
229 Murradoc Road, Drysdale Victoria
(03) 5251-2705
- For potato digger accessories
Vin Rowe Machinery Pty Ltd
3 Endeavour Street, Warragul, Victoria
(03) 5623-1362, 1300 880 056
• New and used potato diggers

DOBMAC Agricultural Machinery
36-38 Industrial Drive, Ulverstone, Tasmania
(03) 6425-5533
• For potato and vegetable equipment

David Evans Group
Tent Hill Creek Road, Gatton, Queensland
(07) 5462-1266
Macquarie Street, Boonah, Queensland
(07) 5463 1044
• Agricultural machinery dealers

Daking Welders and Fabricators
PO Box 13, Willaston, South Australia
(08) 8524-8142
• Manufacture and repair of horticultural machinery and produce handling/processing equipment including onion trimmers

Vicarioli Engineering
155 Howard Kennedy Drive, Babinda, Queensland
(07) 4067 1634
• Agricultural engineering workshop and manufacturer of taro corm washer

Plucker Industries
138 Walli Creek Road (PO Box 57), Kenilworth, Queensland 4574
(07) 5472 3182, (0428) 747 775
• Supplier of rubber chook plucking fingers (as used in prototype taro washer).

Stark Engineering and Hardware Pty. Ltd.
Laidley Road, Forest Hill, Queensland 4342
(07) 5465 4190
• Manufacturers of horticultural products and equipment.

Sustainable Agricultural Machinery Developments Pty. Ltd.
3 Bradford Street (PO Box 1321), Wodonga, Victoria 3690
(02) 6056 2844
• Horticultural machinery manufacturers (specialising in raised bed cropping systems).

Silvan Australia
Brisbane Branch
Sales (07) 3345 9500
• Importers of Checci & Magli transplanters (agents Australia wide).

Proud Machinery
18 Williams Circuit, Pooraka, South Australia, 5095
(08) 8349 9033
• Australian agents for Nicholson Machinery (also manufacture/install potato washing plants etc.)