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Development of taro, yam, yam bean and sweet potato exports to Japan and USA

A report for the Rural Industries Research and Development Corporation

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Foreword

The coalition Government established, through Senator Hill, a Supermarket to Asia project, the aim of which is to spearhead market share within Asia of fresh foods, capitalising on the "Clean and Green" image of Australian produce. Input barriers and tariffs are disappearing in N.E. Asian (and S.E. Asian) countries, particularly as the farmers in the former can less effectively supply their own demand for food. This is in part due to shrinking areas of land favourable for agriculture, as a consequence of expanded construction, amenity and conservation use and due to an aging agricultural population. An opportunity was identified in principle from a desk top study for the export of root crops of commonly grown species in Asia, and this was followed up by visits to Japan and the USA to verify the market potential. Once determined, research then followed to set up the protocols necessary to produce and deliver the commodities. Focus in terms of immediacy of demand was on Japanese taro and sweet potato.

This project was funded from RIRDC core funds which are provided by the Australian Government, with contribution of some funds from the horticultural industry through Horticulture Australia Limited.

This publication and a related commodity-specific one on the production of Japanese taro, provide up-to-date information on the networking activities and research outputs of public and private sectors in promoting the Asian root crop industry.

This report, a new addition to RIRDC's diverse range of over 1500 research publications, forms part of our Asian Foods R&D program, which aims to support industry in its drive to develop new products and markets and to gain competitive advantage through improving productivity in, and achieving price premiums for, Australian production of Asian foods.

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

- downloads at www.rirdc.gov.au/reports/Index.htm
- purchases at www.rirdc.gov.au/eshop

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Contents

Executive Summary

What the report is about
This report provides summary and detail of the project aimed to establish ongoing export trade of the Asian root crops taro, yam, yam bean and/or sweet potato to Japan and/or USA. The project proceeded in two stages. The first stage involved market assessment through information available in literature and databases, and followed up by information from two visits by project participants to Japan and USA. This has been published and available on the RIRDC website under the title of *03/052 Selected markets for taro, sweet potato and yam (Vinning, 2003).* Stage two of the project primarily involved production, quality and marketing trials of a sato-imo cultivar already available in Australia. **This report details the activities and achievements of Stage 2.**

Who is the research targeted at?
The information generated from this project is of benefit for producers and marketers contemplating diversification into Asian root crops for domestic and export markets. It is also important as a general case study of attempts to establish relatively new crops for commercial production and export. As well as providing information about requirements for crop production and marketing, this report also indicates some of the challenges that were encountered.

The expected beneficiaries are primarily Australian producers who can establish cost-effective production of good to high quality produce for supply to an increased domestic market and to select export markets. It is also expected that consumers in Australia would also benefit from having an increased variety of nutritious vegetables to choose from.

Background
As Australian horticulture and agriculture producers are continually faced with increasing challenges in quality management, pests and diseases, competition from developing countries on the world market and competition from cheaper imports on the domestic market, many are seeking to diversify their production operations and are willing to explore non-traditional crops and markets in Australia and for export. As a result of recent efforts in Australia in the research and development of production and marketing of traditional Asian food commodities, there is increased awareness of the potential for profit by supplying high quality food products to Asian markets in Australia and overseas. This project now adds to the increasing knowledge of production of Asian food crops in Australia.

From information gathered in a previous RIRDC project, UCQ-10A, "Consolidating the Asian Vegetable Industry", and other RIRDC-funded reports on Asian food markets (Vinning, 1995) it was apparent that taro, yam, yam bean and sweet potato had potential for further development in Australian domestic and international Asian export markets.

Aims/objectives
The objectives (stage 1 & 2) are to investigate markets, define required quality attributes, to establish a supply chain for the successful export of taro, yam, yam bean and/or sweet potato to Japan and/or USA. In parallel, ensure the group of producers and suppliers has the capacity to stand alone for exporting and diversifying from these commodities.

Methods used
Stage 1: The first visit involved meeting with retail, wholesale, import and food processing companies in Japan and USA to gather information about seasonal supply and price patterns, preferred varieties and quality and presentation preferences. The second visit to Japan involved further investigation of Japanese domestic production and attempts to source germplasm of desired cultivars. The information gathered from the market assessment stage was presented at a workshop in Brisbane and one in Cairns, from which it was decided to focus stage two project activities on the development of production and export of fresh sato-imo, or Japanese taro, to Japan.

Stage 2: Production trials were conducted at a number of locations in Queensland, NSW and NT. Quality assessment was conducted by NSW DPI and samples of fresh corms were sent to companies contacted during stage one visits to Japan. Several growers coordinated with an Australian export company to send a trial shipment to Japan. Attempts continued throughout stage two to import relevant Japanese cultivars of taro, sweet potato and yam for further production trials.

Results/key findings

Stage 1: The decision to focus on export of fresh sato-imo (as opposed to fresh or semi-processed sato-imo and the other root crops) was based on a number of key factors: reliable data was available for the Japanese markets which showed consistent seasonal price and supply volume patterns which were favourable to Australian production windows; the Japanese companies that were visited expressed most interest in sato-imo; a desirable cultivar of sato-imo was already available in Australia and under small-scale commercial production; and cultivation and harvest machinery already used for potato and sweet potato production could be used or modified for sato-imo production.

Stage 2: Production trials over three seasons have generated sufficient information to recommend production guidelines for Australia. A protocol of quarantine risk assessment for burrowing nematode (*Radopholus similis*) was established with the assistance of Biological Crop Protection and in conjunction with AQIS to meet Japanese plant quarantine restrictions for fresh taro corms. Results of quality assessment experiments of sato-imo corms have allowed recommendation of storage and transport conditions. Feedback from trial samples and a trial shipment sent to Japan has allowed further recommendations for quality control, sorting, packing and presentation of fresh corms. A Growers' Guide for the supply of sato-imo has been produced, and is being published by RIRDC.

Although sweet potato export was not included in stage two of this project, we were able to obtain six Japanese sweet potato varieties which Qld DPIF and NSW DPI will maintain and make available for further investigation by the sweet potato producers. We were, however, unable to source Japanese cultivars of sato-imo directly from Japan, due to a reluctance to release germplasm to other countries, and an unwillingness of AQIS to allow direct imports of germplasm from Japan. In 2003 project team members made contact with a source of Japanese cultivars in Hawaii and have since been involved in the process of importing a number of these into Australia. AQIS requires a long and expensive process of tissue culturing and virus testing for taro importation. So far, seven virus-free lines have been imported, with three more expected for mid-2006.

Five sato-imo producers who met quarantine risk requirements coordinated with an Australian export company to send trial samples and one 1000 kg trial shipment to Japan in 2003. These producers did not proceed with further exports as the price offered by the Japanese importer was too low to allow these producers to be profitable. At that time (2003 and 2004) the Australian domestic prices allowed greater profitability. An underlying issue is the very low price of sato-imo produced in China and imported into Japan. The Japanese are willing to pay more for "clean, green" good quality Australian sato-imo, however there are still a number of important limitations to profitability for Australian producers.

Implications for relevant stakeholders

One limitation is the current small scale of most sato-imo production operations in conjunction with high labour costs and high cost of specialised machinery to streamline the cleaning and grading or corms. Another is that there has been no established processing outlet for non-premium corms in Australia. Non-premium corms can be peeled then chilled or frozen whole, or further processed for a variety of other food of starch products. Recently (May/June 2005) there have been reports of cheap frozen sato-imo imports from China entering Australia and depressing demand, and therefore price, for fresh sato-imo in the domestic markets in Sydney and Melbourne.

During the time since this project was first proposed China's sato-imo production and supply has increased to Japan and Australia, influencing prices for Australian producers in export markets and domestically.

Recommendations

It appears that to be profitable, Australian sato-imo producers need to have medium to large scale operations with specialised harvesting, cleaning and grading machinery and, or alternatively, obtain higher prices by supplying high quality and/or specialty product to niche markets. Additionally, producers could be more profitable if they have an outlet for non-premium corms, such as peeled or even further processed product.

1. Introduction

Background to Project

At the commencement of this project taro, yam, yam bean and sweet potato were all relatively new to Australia. Domestic production was expanding from a small base, with producers then enjoying high prices (Table 1).

Table 1. Markets of Asian root crops in Australia.

	Taro		Yam		Yam bean		Sweet potato		TOTAL	
	Market (t)	Value (A$M)	Market (t)	Value (A$M)	Market (t)	Value (A$M)	Market (t)	Value (A$M)	Market (t)	Value (A$M)
NSW[1]	1 300	2.60	500	1.25	360	0.90	2 556	2.04	4 716	6.79
VIC[2]	520	1.04	400	1.00	260	0.65	988	0.79	2 168	3.48
Australia	2 000	5.00	1 000	2.50	800	2.00	10 000	7.40	12 905	16.50

[1]: Referred from Flemington Market Reporting Service, 1996.
[2]: Referred from Melbourne Retail Asian Vegetable Survey, 1999.
(Source Vong Nguyen)

Table 2. Japanese import markets of Asian root crops during a period of 3 years, 2001-2003.

	2001		2002		2003	
	Volume (t)	Value (M¥)	Volume (t)	Value (M¥)	Volume (t)	Value (M¥)
Fresh market:						
Taro	20,254	1,121	24,887	1,139	29,782	1,291
Yam	3,613	454	4,815	601	4,104	557
Sweet potato	2,034	197	12,408	1,206	13,956	1,200
Frozen market:						
Taro	55,425	7,489	49,660	6,140	49,071	5,153
Yam	2,192	321	3,161	464	2,762	383
Sweet potato	1,139	104	1,433	130	1,351	116

(Source Vong Nguyen)

The crops were thought to have a good potential for export to selected countries, but little work had been done to validate this belief. It is desirable to identify cultivars that are suitable for export early, so that they can become established on the domestic market. The crops are tropical to subtropical, and are therefore well suited to production in Queensland and northern NSW. Multiple production centres would complement each other by extending the availability of a product.

Currently, most of the produce imported by Japan (Table 2) is sourced from China. Even small access to this market represents sizeable income for Australian farmers and others in the supply chain. Example data are presented in Table 2 for three of the crops. This project updated these data and contacted importers in Japan (and USA) to establish preferred supplier status for Australian producers.

Taro (*Colocasia esculenta*) is a major crop worldwide with an annual commercial production of around 6 million tons. Australian production is known to be increasing in northern New South Wales, Queensland and Northern Territory. QDPIF extension staff have valued the industry in the Tully /

Innisfail region alone as being in the millions of dollars and expanding. Domestic prices are good at $2 - $3/kg, though the crop is labour-intensive and prices are likely to drop due to increased supply. Japan has been identified as a viable export market in numerous studies (Vinning 1995, Lee 1996, JETRO 2004), however, the taro imported into Japan is not the Pacific Taro referred to earlier in this section, but a small-corm taro, (previously classified as *Colocasia esculenta* var. *antiquorum),* a species not widely grown in Australia. The ¥8.6 billion of taro that Japan imported in 2001 at an average of ¥113/kg, was, as mentioned before, sourced mostly from China (figures for fresh and frozen taro combined). This provides opportunity for Australia to deliver taro of higher quality, with a more stable supply and a lower health risk. Australia is currently unable to enter this market because the taro that is grown on a large scale is not that which is preferred by Japanese consumers. This project aimed to overcome this barrier, and to forge links between Australian producers and Japanese buyers through analysis of demand chains. The study also aimed to observe the US market, which imported 27 000 t fresh in 1997, worth US$23 million, for potential Australian opportunities. This market has been expanding throughout the 1990's and is not limited to specific immigrant communities, as the demand exists on both east and west coast of USA. Therefore it represents a stable opportunity for Australia, with a market that might eventually exceed the growing Japanese market.

One of the major premises for the project was the high price for taro during the summer in Japan (Table 3).

Table 3. Consignment and prices (Japanese yen) of Sato-imo at the Tokyo Central market, Japan (Average of 5 years, 1998-2002)

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

Source: Tokyoto Chuo-Ichiba – Seikabutsu Ryutsu Nenpo, 2002. Tokyo Seikabutsu Shoho Centa. Tokyo, Japan.

Yam bean (*Pachyrhizus erosus*) is native to Central America. It was cultivated by the Toltec, Aztec and Mayan civilisations before its distribution by Spanish galleons to the Philippines. It then spread through other South East Asian countries, India, China the Pacific and West Indies. It is a leguminous plant that produces a refreshing, moist, crisp storage root relatively high in protein. It is consumed raw in salads and low calorie snacks and is favoured in Asian and Latin American dishes where it can replace water chestnuts. Yam bean is not well recognised in Australia although retail prices in 1999 were $6/kg in Adelaide and $7/kg in Cairns, indicating an unsatisfied demand. The USA and Canada import Yam bean (also known as Jicama and Mexican water chestnut) from Mexico. Viable Asian markets may exist. Additional potential uses such as starch and natural insecticidal properties require investigation. Apart from marketing, research needs at this stage are basic, including agronomic and phenology studies to coordinate production and quality with market requirements.

Sweet potato (*Ipomoea batatas)* has long been a very important food crop to many peoples and despite advances in plant breeding of cereal crops, remains the seventh most important food crop in the world and fourth in the tropics. It was introduced into Australia relatively recently by British colonists while the popular dessert type was first imported as recently as the early 1970's. Only since then has the domestic sweet potato industry developed to its current value of $10-12 million annually. The many attributes and uses of sweet potato have not yet been exploited in Australia. Australian annual per capita consumption of sweet potato is only 0.5 kg while in the USA it is approximately 3 kg. In China it is estimated to be as high as 100 kg (60 kg fresh plus 40 kg via stock feed) (George Pan, personal communication) and up to 200 kg in parts of Papua New Guinea. Consumption in Australia is increasing and is supported by strong demand from our increasing ethnic Asian and

Islander population to whom it is a traditional food. Research and development of the industry in Australia is very recent and limited primarily to plant introduction and evaluation and some aspects of agronomy including plant nutrition. There is a need for a better understanding of specific product requirement and feasibility of industrial uses. Post harvest handling such as curing, semi processing and packaging, including canning, have not been seriously attempted in Australia but would lead to greater consumer convenience, reduced perishability and increased consumption. Efficiencies in production could be achieved with improved mechanisation and handling.

Yam (*Dioscorea* species) is an even less-well known crop in Australia, although much information as to its production requirements has been generated in Africa (eg, at IITA).

Export development of these four commodities face similar challenges in regard to the size and nature of potential export markets, in questions of varietal attributes, and in environmental effects on yield and quality. The experience of the CQU Plant Sciences Group in answering similar questions (Chinese waterchestnut and bamboo industries specifically, and other Asian vegetables generally) was valuable in the conduct of this research, as was our ability to develop and maintain close linkages with receptive growers, exporters and others in the demand chains.

Relevance and Benefits

Current domestic value of the four crops is not known, since much produce bypasses the fresh market system. Sweet potato is estimated to be worth $10-12 million annually, Pacific taro perhaps $4-7 million, and yam bean perhaps $2 million. Data do not exist for yam, but it is known to be imported from overseas into Australia.

As a major outcome from the project, domestic wholesalers will be expected to benefit from a more consistent product in terms of supply and quality, a greater proportion sourced from within Australia, and a more organised industry with which to work. Producers and transporters will be closely linked through a formal association. This will lead to further growth in domestic supply and the possible emergence of secondary industries. We believe that the involvement of local food processors will probably open even more opportunity for export to other countries eg, Korea, Taiwan as frozen and/or dried product.

2. Objectives and Methodology

The overall outcome is an established supply chain for the successful export of taro, yam, yam bean and / or sweet potato to Japan and / or USA. This will be achieved by:

- developing product specifications for exporting taro, yam bean and sweet potato to niche markets in Japan and USA, addressing:
  - seasonal windows
  - market preferences (retail and food industry) for variety and quality
- determining suitable production and postharvest methods, addressing:
  - cultivar identification
  - cultivar evaluation / agronomy
  - location / season effect on quality
  - mechanised harvesting and cleaning / sorting
  - other post-harvest and storage requirements for shipment
- facilitating the development of a supply chain, addressing:
  - association of potential exporters
  - trial shipments

Methodology

The project took place in two stages, with outcomes of the first stage affecting the second.

Stage 1: Market assessment, August 2001 – to assure confidence amongst Australian producers and export agents of the extent of market opportunity, and to determine product ideotypes.

Four representatives (producer, germplasm manager, production coordinator, market analyst) spent one week in Japan, followed by one week by one person (market analyst) in the USA. They:

- Met with appropriate companies, including contacts already established by AusAID, Grant Vinning (Asian Markets Research), Vic Lavery (TARA Foods), Michael Daysh (QDPI Cairns), Peter McLaughlin (NORADA), Dr. Vong Nguyen (NSW DPI) and other organisations and companies.
- Identified seasonal price and supply fluctuations of different varieties of each commodity.
- Identified and detailed market preferences for product quality and presentation. Where possible, samples were obtained for RAPD genetic analysis at CQU, for comparison with locally available material in Australia.
- Attempted to obtain preferred varieties and arrange delivery to Australia (they were to have been imported via a parallel project by Dr Vong Nguyen)
- Identified machinery used for commercial production in Japan and USA, and assessed relevance to an Australian industry.
- Observed the Japanese and USA supply chains.

It was essential to the project that a consensus be arrived at among Australian researchers and industry, as to what markets were most achievable and what work needed to be done to secure them. There is already expertise within Australia, but it is by no means complete. A collation of this knowledge and connections within target countries, supplemented by up-to-date input from overseas sources was essential to an efficient and successful project. The market assessment tour was followed by two publicly advertised workshops within Australia (QFVG building, Brisbane Markets, and Qld DPIF, South Johnstone), in which all the expertise regarding the crops was combined. The outcome of the tour and workshop was published, and the specific work to be completed in Stage determined.

Stage 2: Develop pre- and post-harvest supply

In the first season, varieties that have been sourced locally and / or imported through stage one of the project were trialled in seven production areas:

Atherton tablelands: Qld DPIF Southedge Research Station
Innisfail: Qld DPIF South Johnstone Research Station
Central Queensland: Rodney Wolfenden, Harvey Rich
Southern Qld: Qld DPIF Gatton Research Station
Northern NSW: Northern Rivers Agricultural Development Association, Murwillumbah region
Central NSW: NSW DPI Gosford Horticultural Institute
Northern Territory: NT DPIFM Coastal Plains Horticultural Research Farm, Darwin

- Produce was graded by hand according to the market specifications determined in stage one. Organoleptic and other bio-assays were conducted at Gosford. Some agronomic issues for production in each region were addressed. Minimal amounts of product were shipped for culinary and acceptance tests in Japan.
- In the second and third season, larger trials were placed in fewer locations NSW and Qld to simulate commercial production. Produce was used in a trial shipment to the proposed markets.
- The protocol for assessing risk of infection by *Radopholus similis* was established, in order to satisfy AQIS and Japanese quarantine directives for fresh taro corms
- Experiments for harvesting methodology were determined after completion of Stage 1.
- Germplasm collections were maintained *in situ* (yam bean at CQU Rockhampton, sweet potato at QDPI Gatton, and taro at NSW DPI Gosford, Qld DPI Gatton and at CQU Rockhampton). Some of the collection was genetically assessed using RAPD PCR.
- Post-harvest trials were conducted to determine the optimum shipping conditions for each product. Quality was assessed after storage under different temperature, humidity, controlled atmosphere, heat treatment and packaging.
- Trial samples were sent to the proposed markets, via commercial exporters. One investigator spent 3 days in Japan in November 2004 to obtain feedback of product from buyers and potential markets, and to re-establish previous contacts.

Communication/Adoption/Commercialisation Strategy

A market assessment tour report was produced from stage one of the project and made available to the public via RIRDC publication (http://www.rirdc.gov.au/reports/AFO/03-052.pdf). Public presentations of the findings were conducted in NSW and Qld and follow up trials were conducted by collaborating producers with assistance from research personnel. Material for trial shipment was produced on farms. There was direct involvement by a select group of producers, who were well positioned to continue developing the supply chain beyond the time frame of the project. Wider adoption was encouraged by bringing together producers with NORADA and Taro Growers Australia, however no new association was formed specifically for sato-imo or for Asian root crops.

3. Outcomes and Results

This section presents information along five fronts:

- Market assessment
- Germplasm and imports
- Field trials
- Post-harvest and quality trials
- Grower organisations and trial exports

Market assessment

An initial meeting was held at Queensland Fruit and Vegetable Growers (QFVG) on 28 February 2001 at which information available to date on production statistics and market requirements were presented.

Two separate trips were made to Japan (and one to USA) in June and July 2001. The first trip to Japan and USA followed up on desk-top research of taro, sweet potato and yam to identify regional and seasonal preferences and trends in varieties and markets. Yam bean was considered to be a low priority for Japan. The second trip to Japan established contacts for the acquisition of germplasm of desired varieties. Sample (7 x 5 kg boxes) were sent to four companies at the end of August 2001, and feed-back was excellent, with indications that current wholesale market prices were approx 3,500 yen (A$ 54.00) /10kg. Two meeting/workshops were held in September (one in Brisbane and one in South Johnstone) to present information from the trips. Business links were established which have led to the shipment of well-received samples of a taro variety, resembling Ishikawa wase, from Australia to Japan. One particular company immediately requested larger volumes. This same company was presented with samples of the 2002 taro crop in May, with the aim of negotiating a larger shipment to allow investigation of product integrity during transport. Based upon the feed-back from the market assessment studies, it was decided to proceed with development of small-corm taro exports to Japan as the main priority.

At a project meeting in April 2002 in Murwillumbah (it was decided that the market research report should also include sections on the Australian domestic markets of taro, sweet potato and yam. Following some research it was evident that there was no useful detailed information available for yam or yam bean.

The market assessment studies terminated with the production of a guide, in the form of an RIRDC report, with colour photos of the various varieties of taro, sweet potato and yam in demand in Japanese markets. (http://www.rirdc.gov.au/reports/AFO/03-052.pdf)

As follow-up, in November 2004, one co-principal investigator visited a sato-imo importer in Japan, with whom the project has maintained contact since 2001, and confirmed that there was still a market opportunity in Japan for Australian fresh produce during the Australian production season. The message received was that the second shipment was not as good quality as the first. Although the taste was considered as good, the product was similar to the Chinese product, of various colours sand shapes, reflecting the lack of proper grading and sorting by size. The best price for sato-imo in the Japanese wholesale market was A$2.50.kg (about 2/3 of the price in Table 3), and interest was expressed in importing 500 to 1000 t by Maru over the April to September period (the total demand over this period was estimated to be 5,000-6,000 t. This topic is discussed in more detail later in the report.

A new challenge for Australian producers has presented itself with a significant increase in imports of frozen sato-imo from China to Australia since April 2005. However, cleaned, peeled, blanched and packed fresh taro is still desired by Japanese importers.

Germplasm and imports

In 2001 all known available germplasm for sato-imo (Japanese taro – *Colocasia esculenta* var. *antiquorum*) was accessed in Australia, and genetic fingerprinting techniques using RAPD PCR and a more sensitive variation known as RAF PCR were developed by a student at CQU. Japanese material was used for comparative purposes in the biotechnology laboratory at CQU, which was AQIS recognised for import of material. For taro, the results revealed that Australian accessions identified as *Colocasia esculenta* var. *antiquorum*, based on morphological characters, were not readily genetically distinguishable from accessions identified as *Colocasia esculenta* var. *esculenta*. The RAPD and RAF results were based on a maximum of 6 RAPD primers and 49 polymorphisms (DNA fragment sizes used as characters). Using more primers and basing the analysis on more polymorphisms would give greater genetic "resolution". Australian small-corm taro accessions can be compared directly with the Japanese cultivars. RAPD and RAF techniques seem to be not the most suitable DNA fingerprinting techniques for taro, because of the small degree of genetic variation discovered by other researchers. In particular, Emma Mace and Ian Godwin (ACIAR project associated with TANSAO and TaroGen) of University of Queensland employed DNA fingerprinting techniques that detect variation in DNA sequences known as simple sequence repeats (SSR) or microsatellites. The SSR techniques are much more sensitive than RAPD and RAF in detecting genetic variation among closely related cultivars of taro.

Due to AQIS quarantine regulations, taro (*Colocasia esculenta*) germplasm cannot be imported to Australia for propagation. The project has therefore been limited to evaluating small-corm taro already available within Australia. One Australian-sourced cultivar (NORADA 1) appears to be physically similar to the Japanese cultivar "Ishikawa wase". This cultivar is available in large enough volume for much of the research work of the project. Several other small-corm taro cultivars sourced from within Australia also exhibit similarities to Japanese cultivars. Given the availability of taro germplasm in Australia, a variety that meets Japanese market demands, coordinated trials in Gosford, Northern Rivers (NSW) and Gatton, Rockhampton, S. Johnston and Atherton Tablelands (Qld) was used for establishing trials in November 2001.Results from earlier trials in 2000/2001 suggest that yield of this variety is sensitive to growing conditions, and needs to be investigated further. For vegetatively propagated crops freedom from viruses that might reduce yield potential is imperative. Virus testing was conducted by Dr Rob Harding at Queensland University of Technology on leaf samples of "NORADA 1" grown at Coastal Plains, South Johnstone, Southedge, Rockhampton, Gatton, Burringbar and Murwillumbah, and leaf samples of two other small corm taro cultivars grown at Burringbar. Results showed that all samples were free of known taro viruses, with the exception of one sample from Southedge DPI Research Station. The taro bacilliform badnavirus (TaBV) in the Southedge sample has been found in Australia before and is widespread in the Pacific. By itself, TaBV does not seem to cause significant symptoms. This positive result was probably due to infection at the research station rather than from the parental plant material. At this stage the virus indexing exercise has given an initial indication that the widely distributed "NORADA 1" planting stock appears to be free of important viruses.

Seven Japanese cultivars of sweet potato and two Japanese varieties of yam arrived in Australia in May 2002. While in quarantine, the yam tuber material (varieties Yamato Imo and Naga Imo) was found to be infected with viruses and subsequently destroyed. The sweet potato material was in quarantine for a long time; after undergoing heat therapy to eradicate known viruses and being sent back to AQIS for grafting to *Ipomoea* for final verification of the absence of viral symptoms and four lines (Beni Aka, Beni Komachi, Beni Kokei and Kanpachi) were released from quarantine in 2005, into the sweet potato program based at QDPI Gatton. The lines are maintained by QDPI as *in vitro* cultures, and are also available at NSWAg. Two lines (Beni Azuma and Kokei 14 – both very poplar in Japan) are still in quarantine, and once released will also be available for grower trials.

Discussions were undertaken to source pathogen-free tissue cultured plants of Japanese taro cultivars, for, as mentioned earlier, AQIS quarantine regulations prohibit taro (*Colocasia esculenta*) germplasm from being imported directly into Australia for propagation. Indeed, taro can only be imported as *in vitro* tissue cultured material via the Secretariat for the Pacific Commission (SPC) Tissue Culture Laboratory in Fiji or the University of the South Pacific (USP) Tissue Culture Unit in Western Samoa. One co-principal investigator undertook negotiations with Dr Mary Taylor (SPC, Fiji) and Dr John Cho (University of Hawaii) during a Taro Conference in Fiji in May 2003. In July 2003, Dr Taylor initiated the transfer to tissue culture of 47 taro accessions from Hawaii, including 10 cultivars originating from Japan (immediately relevant to this project) and 26 accessions from taro leaf blight (TLB) resistance breeding lines (which may be relevant to the Australian taro industry in the future). These accessions are currently in Fiji; the Japanese small-corm accessions underwent meristem culture before being sent to Dr Rob Harding (QUT) for pathogen testing. Once declared pathogen-free, these accessions can be imported into Australia. Currently Fiji sent 10 lines of Japanese taro on 9/9/05. Three lines were infected by Dasheen mosaic potyvirus so only 7 lines are available. The available lines are: MH01Tsuronoko, MH02 Wasehasuba-imo, MH04 Miyako, MH06 Shogatsu-imo, MH22 Akame, MH42 Takenoko-imo, MH44 Shiro-imo.

The three lines that were infected by Dasheen virus are: MH11 Dodare, MH31Tono-imo, MH46 Ebi-imo. We have requested re-importation of the three lines discarded by AQIS, 3 lines (5 tubes each) of Dodare, Tono-imo and Ebi-imo. These lines, if free from infection, should be available in Aug/Sep 2006 to Qld DPIF and NSW DPI for production trials.

The CQU student also ran similar genetic fingerprinting analyses with nine varieties of yam bean available in Australia, and was able to distinguish a yam bean variety sourced from Mexico apart from other varieties sourced from Asia.

Field trials

Initial plots of 50-100 plants of the taro cultivar tentatively named “NORADA 1” (similar to “Ishikawa wase”) were established in late 2001 at South Johnstone, Southedge, Rockhampton and Gatton in Queensland, at Burringbar and Gosford in NSW and at Coastal Plains near Darwin in NT and larger trials were conducted in NSW to investigate aspects such as variety, planting material, and nutrition and water management. Corms less than 20 g did not survive as planting material; the planting was late (Nov/Dec) due to late receipt of planting materials. Harvesting of these trials commenced in May 2002. The best quality corms resulted from the NT plot. It was concluded that:

- sowing/planting should be completed by the end of October in NSW and Queensland, to avoid the effects of high summer temperatures on young plants
- re-hilling of soil around plants is required throughout the growing season, to avoid exposure of corms to sunlight and to encourage maximum corm swelling.

Due to the inability to import identified desirable taro cultivars from Japan, and with the known acceptance of “NORADA 1” to Japanese companies (as a result of samples sent in 2001), further trials concentrated on this one cultivar. Six other small-corm cultivars were multiplied for establishment of multi-location trials in 2003. However, since the Japanese market accepted NORADA 1, these were not distributed. NORADA also maintained a collection of eight small-corm taro cultivars, which were multiplied at Burringbar NSW. The trials of “NORADA 1” were established in October 2002 at Cairns, Emerald, Gatton, Burringbar, Kyogle and Gosford to compare the effects of planting density, time of planting, “seed” corm size, nutrition and irrigation on yield and quality. Additional data were collected from commercial crops in some of these regions and in Gin Gin. At Gatton, cluster caterpillar was observed and controlled by insecticidal spray. Water management trials were conducted at Burringbar through collaboration between NORADA and Mr Stephen Anderson of Andersons Hydraulics, however, these were discontinued as the crop and the trial could not be maintained due to the grower's incapacitation through injury. The Kyogle trial was also abandoned due to lack of irrigation water supply. To replace the Kyogle trial, a nutrition trial was then set up in a commercial crop at Cudgen. Trials at the other sites proceeded, however, propagation material was of poor quality when planted, and particularly hot summer conditions were experienced at all sites. Yield data were collected from the Cairns, Emerald, Gatton, Burringbar and Cudgen trials. Yield data were collected from commercial crops in a number of locations in Qld and NSW, on seed corm size: small daughter corms, golf ball size corms, quarters of mother corms and whole mother corms – quarters of mother corms appear to be best yielding.

Trials of taro "NORADA 1" for the 2003-2004 season included irrigation trials (incorporating aspects from the abandoned 2002-2003 Burringbar trial) at Gosford, soil and nutrition trials at Alstonville, best management options trials (bed type, water delivery method, weed control) at Rockhampton, and planting/harvesting times in Emerald.

Results from 2001/2002 trial comparing mother corm to daughter corm seed material (see attached table) showed that mother corms were better for yield. The definition of mother corm in Table 4 is a corm that has five or more daughter corms. These data are presented for purposes of illustration of the types of data presented in the Growers' Guide to Japanese Small Corm Taro.

For harvesting, most growers used modified potato diggers to lift corms from the ground, followed by manual labour to pick up, clean and wash, then sort and pack corms. One northern NSW grower purchased a corm cleaner (for removal of roots) and size grader from Japan.

Table 4 Taro 2001-02, CQU-13A: Yield and Corm size of Ishikawa Wase grown at the Gosford Horticultural Institute, Central Coast, NSW, 2001/02.

	Daughter corms		Mother corms		Total		
	Corm #/plant	**FW/ Plant (g) (t/ha)**	**Corm #/ plant**	**FW/ Plant (g) (t/ha)**	**Corm #/ plant**	**FW/plant (g)**	**Yield (t/ha)**
G1: Mother corm >120g	42.4	1200.9 16	1.8	231.3 3.1	44.2	1432.2	19.1
G2: Mother corm 60-119g	42.7	1200.0 16	2.0	225.3 3.6	44.7	1468.00	19.6
G3: Mother corm < 59g	36.7	1160.7 15.5	1.4	133.2 1.8	38.1	1293.9	17.3
G4: Daughter corm 40-60g	34.3	908.5 12.1	1.6	129.0 1.7	35.9	1037.5	13.8
G5: Daughter corm 20-39g	36.8	975.6 13.0	1.6	190.1 2.5	38.4	1165.7	15.5
G6: Daughter corm < 19g	28.6	613.1 8.2	1.0	110.8 1.8t	29.6	752.5	10.0

Planting, harvesting and cleaning equipment has been investigated and developed by Mr Craig Lemin of Qld DPIF through his involvement with this project and through RIRDC project DAQ-291A. A number of NORADA growers also experimented with various mechanical systems. Information was gathered on taro harvesting and cleaning machinery used in Japan. This information was forwarded to Mr Lemin and several growers that are developing their own equipment.

A major issue is the lack of any registered pesticide for use on sato-imo (and on Pacific taro).

NORADA reported that a number of its growers have trialled a sweet potato variety obtained from Lester Loader (ex QDPI) as a result of this project, and have found that it is being well accepted in domestic markets with increasing demand. This variety, being marketed under the name "Tweed Sweet Potato" has white skin and white flesh with purple flecks.

Post-harvest and quality trials

To facilitate the development and maintenance of new export markets, the entire supply chain needs to be geared to meet consumer expectations. Sato-imo destined for the Japanese market must meet stringent quality requirements, both in external appearance and internal quality. The domestic market is less demanding on both accounts, but will not accept cut or misshapen or soft/flaccid corms. After harvesting, corms lose weight by transpiration (water loss) and continue to respire (use stored chemical energy reserves of starch); both result in some loss of fresh weight.

Much of the post-harvest research work at NSW DPI Gosford focussed on the determination of optimal storage and shipping conditions. In one experiment, taro corms were stored at 7°C, 12°C and 20°C for 4, 8 and 12 weeks. For each temperature, corms were stored at a relative humidity of 70% or 90-95%. Corms were assessed for weight loss and sprouting both immediately following storage and after a further 5 days at 20°C. At this final assessment corms were also evaluated in terms of disease incidence and severity, internal colour and textural quality. In a second experiment the effect of curing temperature and duration was also investigated.

Taro quality was acceptable following 4 and 8 weeks storage at either 7°C or 12°C. However storage at 20°C, particularly under high humidity conditions resulted in excessive sprouting. Corms should be stored under high relative humidity to ensure that weight loss is minimised, however care should be taken to exclude any diseased corms from storage. It is essential that corms be surface dry before storage to reduce the incidence of fungal infection. Disease incidence increased dramatically between 4 and 8 weeks at the higher temperatures. 5% and 23% of corms were affected by disease following 8 weeks storage at 7°C and 20°C respectively. Storage of corms is possible at 7–12°C in a dark well-ventilated room for up to eight weeks without quality compromise. Technologically, quality parameters for a product that must go via sea container are not yet resolved.

It is quite evident that appropriate storage conditions are required to maintain desired corm quality during distribution to consumers at the final point of sale, and to ensure sufficient maintenance of quality during household storage before preparation for consumption.

After contact with Food Science Australia product development scientist, Jayanthi Weerasinghe, during the RIRDC Asian Foods project leaders' workshop in Gosford in June 2003, samples of small-corm taro and sweet potato were sent to her for inclusion in trials of processed Asian vegetable products. Limited feedback indicated that the use of taro in a cold salad product for use in hotel food services had potential. We are seeking further detailed results from these trials.

In order to gain information of the organoleptic properties of taro produced in Australia, samples were sent from the trial plots at Darwin, South Johnstone, Southedge, Gatton, Burringbar, Cudgen, Kyogle and Gosford to be subjected to taste panels with a focus group of ten Japanese ladies from the Central Coast region of New South Wales. The main objective of using this untrained panel was to provide some information on the important quality attributes of Japanese taro. The panel was presented with samples from the different growing areas ranging from Darwin in the Northern Territory, to Gatton in southern Queensland and Gosford in central NSW. Representatives from a Japanese restaurant in Sydney were also asked to rate the samples. Although external quality (shape, size, colour) varied, all rated high for taste and internal appearance. A full detail of the parameters evaluated is contained in the Growers' Guide to Japanese Small Corm Taro.

Australian-produced Japanese taro, therefore, appears to be acceptable to Japanese consumers despite the considerable variability. However to maintain market access, quality specifications will need to be developed and adhered to by suppliers. The effect of climate and agronomic practices has been shown to have a large effect on quality and need to be studied further.

Grower organisations and trial exports

Support to the development of cohesive associations of growers, and to the achievement of trial export consignments was a major activity within this project. Throughout the project there was transparency between researchers and grower counterparts.

An initial meeting of researchers, producers and other industry representatives was held in Brisbane in February 2001. Desk-top studies of the Japanese and USA markets for the Asian root crops were planned, as were plans for group visits to both countries. Two Australian workshops were subsequently held (one in Brisbane with 15 attendees, and the other in South Johnston with 24 attendees) in September 2001 following the tour to present information to stakeholders and to decide which species/varieties should be selected for production, shipping and marketing trials. Business links were established which subsequently led to the shipment of well-received samples of a taro variety, resembling Ishikawa wase, from Australia to Japan. One particular company immediately requested larger volumes.

During 2002, interest in the export of taro to Japan increased thanks to four seminars held by Northern Rivers Agricultural Development Association (NORADA), two on taro and another two on New Asian Crops, plus an industry and project development meeting organised by CQU. The NORADA meetings for taro growers (current and potential) were held in Murwillumbah on 29th April and 25th November 2002. Both of these seminars included presentations from researchers involved with the RIRDC project.

A project and industry meeting was held on 29th July 2002 in Brisbane to present feedback about the taro sample sent to Japan, and to discuss taro industry development as well as the formation of a trading entity or arrangement. Overall, the quality was considered by the Japanese company as very good: external colour needs to be very light, excellent internal white colour, good starch content, but need to remove larger "hairs" (dried roots). They were particularly interested in L (60-80g) and 2L (80-100 g) sizes and oval/egg shape rather than spherical. Grant Vinning developed communications, negotiations and relationships with the Japanese company Maru. In May he presented sample corms from the 2002 harvest and reported that Maru was particularly interested in L (60-80g) and 2L (80-100g) sizes that were oval/egg shaped rather than spherical. For 2003 the NORADA associated growers had a verbal commitment to supply a minimum of 3 x 20' shipping containers. The seasonal windows of market opportunity had been identified for an Australian taro product that should be readily identifiable by brand name as a unique Australian product.

The Japanese company wanted to market the Australian taro as a premium product, suggesting shipping in 5 kg boxes rather than 10 kg boxes, and stressed that there must be consistent/uniform size and shape grading, to counter cheaper Chinese imports. Product should be shipped at 8°C. Price was discussed, and requires further discussion. If they were willing to take M (40-60g) and S (20-40g) sizes as well – i.e. they take more of the crop – then price could be decreased. A clear need for

Australian production to become more mechanised (particularly cleaning and grading) was evident to reduce costs and achieve a reasonable profit margin.

For 2003, NORADA-associated producers aimed to supply the minimum of three 20 ft shipping containers. Dennis Murphy, a trade development officer with the Qld DPI, stepped the 29th July meeting participants through the stages involved in developing an export trade and gave some options for business arrangements for producers to consider. Due to the commitment of sending three containers of taro in 2003 from May, at least a temporary arrangement needed to be made for the coordination of sourcing, grading, packing and transporting the produce, the communications and financial transactions with the Japanese company, and feedback. From planting in September 2002 to first shipment in May 2003 there was about nine months. The question as to who deals with the company in this time was raised? An inbound mission was recommended of the Japanese company representatives coming to Australia to enhance the relationship and inspect taro production, harvesting, grading, and packing. In the afternoon, the producers at the meeting discussed such issues among themselves, in the absence of researchers and industry development people.

With facilitation by Greg McMahon, participants discussed two main subjects:

1. Consideration of trading arrangements and/or entities for the “very short term” and for “long term” success; and
2. The Plan for 2002-2003 for the shipment of at least 3 containers to Japan, and setting up for ongoing trade.

In particular, it was decided that an umbrella “association” or alliance, “TGA-NORADA” (T-N), should be formed to drive activities leading up to and including the first shipments in 2003. The management committee included the presidents of TGA (Taro Growers’ Australia) and NORADA, and Philippe Petiniaud, Colin Foyster and Steve Pohlman would address technical aspects.

The prospective taro export business organisation considered product brand name(s). Grant Vinning pointed out that if we call the product “Australian sato-imo”, then it will only ever be considered another version of Japanese or Chinese sato-imo, rather than a product with its own identity. Grant also stressed that the quarantine inspection procedures for the larger volumes need to be established now, to ensure that quarantine paperwork is airtight and entry of product into Japan is not delayed. (A section on quarantine is to be found at the end of this section)

At the stage of the meeting there were about 40 producers growing or planting small-corm taro, and there was ever-increasing interest from prospective new growers and marketing agents. Key growers had committed at least 50% of their 2002 crop for the Japan 2003 export initiative. NORADA had proposals submitted for funding a central packing facility – this was primarily in response to the taro export initiative, but will be used for many other crops as well.

At a NORADA taro seminar in Murwillumbah on 25th November 2002, CQU research officers Dan White and Dee Reeve urged growers that they needed urgently to decide on how they would manage the export operations and further develop the industry – the suggestion was made that NORADA form a Taro Committee to involve growers in the decision-making for these processes, and to alleviate the workload on NORADA president Peter McLaughlin. At least five ‘taro dedicated’ people were required to meet regularly to share the tasks and make decisions for the export business. Some immediate issues for the sub-committee to address include:

- Determine the form of the business entity or choose an industry partner
- All issues concerned with the 2003 trial shipments, e.g. quarantine, grading, packaging, storage, transport insurance
- Inform all NORADA-associated growers of the production, post harvest and trade issues and all associated costs?
- Facilitate standardisation within the industry
- Frequent communication with growers.

The first taro committee meeting was held on 13th December 2002 in Murwillumbah and was attended by Dee Reeve. It was discussed that three parties expressed interest in export marketing of small-corm taro from NORADA growers. Various options for the establishment of a company to manage production/promotion/marketing of horticultural produce from the Northern Rivers were presented, with the bottom line of marketing all produce on a full commercial basis, with maximum prices to growers. One company, IHM Australia continued to show interest and IHM representatives attended a number of meetings with the NORADA Taro Committee members, taro growers and project team members over the following months. IHM was contracted to undertake the marketing role for NORADA taro.

On 29th April 2003 in Murwillumbah, a Japan Taro Export meeting was attended by project team members, NORADA Taro Committee members, taro growers and IHM Australia representative Frank Collins. Definitive action was decided upon to commence sending samples and trial shipment of the 2003 taro crop to Japan. Leo Burgoyne was appointed as the coordinator of five growers whom would be contributing to the initial export samples and trial shipments.

Towards the end of May a group of taro growers, including those contributing to initial exports, expressed dissatisfaction with information (as opposed to market information gathered by IHM Australia) and coordination from NORADA and the research project. At a previously unplanned NORADA Taro Committee meeting held on 2nd June, the majority of growers that attended expressed a desire to form a group separate from, but still associated with, NORADA. It should be noted that other growers present at this meeting and a number of others who did not attend the meeting did not agree with this course of action at that point in time. The response of the NORADA Board members present was to agree to hand over the development of the taro industry (except for information that is directly related to RIRDC project UCQ-13A) to the new taro group.
Dan White and Phil Wilk (NSW DPI officer) attended the packing of the first 1000 kg trial shipment to Japan on 7th June 2003 at Condong NSW. Some of the issues that led to the discontentment of the growers were discussed. Several of the growers admitted that the decision to form a taro group separate from NORADA was actually premature, as they did not have the time, resources and contacts to organise and maintain the new taro group.

A 1000 kg trial shipment was sent to Japan in early June 2003. Initial feedback was provided by the export grower coordinator. Five growers contributed to the trial shipment. Produce from two of the growers was grown in red soil, washed well and hand graded before being brought to the packing shed. The produce from the other three growers was grown in dark soil, required further washing at the packing shed in one case, and was graded using Leo Burgoyne's imported size grader. The feedback from Japan favoured the produce with lighter external colour (that grown in red soil) which was also more consistently size-graded than the produce from the other three growers. The produce that had been grown in dark soil and machine graded was considered less desirable because of the darker external colour and because the sizes of corms within each box were inconsistent. To avoid the inconsistency in the machine-graded product the corms should be pre-sorted according to shape. The machine that was used consists of a rotating cylinder with five sections of grills with increasing apertures. The smaller corms fall through first, and the largest corms fall out at the very end, thus giving six size grades. The inconsistency in weights arises when the corms are inconsistent in shape. The grader does not discriminate shapes and weights, so heavier elongated corms can fall into the same box as lighter spherical corms. The feedback from Japan also suggested that future shipments contain product with all the same external colour – i.e. all light-coloured product or all dark-coloured product, but not both.

The most significant issues were the price and the market timing. The Japanese importer has said that despite the high quality of the Australian product, the price paid (AUD$7.00/kg) was far too high, and particularly in the summer season, in which they claim that there is very low demand for sato-imo, which is traditionally a winter food. This is contradictory to market information, reported by Asian Markets Research for this project, which shows that although wholesale market and import throughput volume is lower in Japan in May to July/August, the prices are higher than in the Japanese autumn-winter period - this indicates that there is still significant demand during Japan's spring-summer period. Additionally, since representatives of the import company were first met in 2001 and product samples were sent in the period May to August, they were keen to trial imports during the May-August period. Only one trial shipment was sent to Japan in 2003, and although the importer offered to buy more product in September, the export growers decided not to send another shipment because there was no guaranteed minimum price. Although IHM Australia did not comment on whether they would continue to pursue business with this initial import company, they have explored opportunities with other contacts in Japan and the south east Asian region, but would not give more detailed comment (unless permitted by the export growers) due to the commercial nature of the information.

NORADA had achieved a high price on the domestic market through the harvest period (May to Aug) 2002 by selling to only one market outlet in Melbourne at a fixed price of $40 per 10kg box for three grades of large, medium and small. This collective marketing strategy also helped to maintain a higher price on the Sydney markets. High domestic prices in 2003 to some extent fuelled the lack of commitment from growers to further supply Japan in 2003. The higher returns on the domestic market (soon to be reduced due to oversupply of product) were more attractive to growers than a lower, but steadier, market for Japan. Prices of $4.50 CIF per kg to Japan were believed to lead to positive returns to growers. However, the issue of what to do with rejects from the Japanese market (i.e. those not sent to Japan) were not resolved. Overall, a break-even price of $2.02/kg was estimated for the average grower, as indicated in the Growers' Guide to Japanese Small Corm Taro.

The import company has suggested marketing Australian sato–imo during the traditional sato-imo eating season, to establish an identity of high quality, value-added (distinctly packaged and presented) Australian produce, then continue testing acceptance in the Japanese Spring and Summer. This would necessitate Australian production of sato-imo for harvest from September, or storage of winter crops until September/October. In all cases, current production cost in Australia is still a major limiting factor.

Of major concern for export success was the export growers' dislike of grading to strict specifications and the non-agreement of price that suited both importer and exporter. An independent source of information suggested that the quality of commodity was not bad but the problem was that because of the extremely high price of the purchase, the importers could not achieve a positive margin; in fact they incurred financial losses. The major competitor was China's product, which was much cheaper than that from Australia but their shipping season is from Oct-March. If shipped by sea from Australia perhaps a lower price could be asked for?

Another meeting was held involving as many northern NSW growers as possible to form a consensus view about the development of the small-corm taro industry. This meeting was held on 24th June 2003 in Murwillumbah, following a NORADA and NSW DPI taro quality workshop. Unfortunately, there were fewer growers present than at the 2nd June meeting. It was decided to leave organising of another meeting with growers, to discuss the issue of forming a new taro organization, until after the 2003 harvest period. It was also decided that the taro committee meetings needed to continue so that there was some momentum from growers, so the date was set as 24th July, and the meeting was to be organised by the remaining export growers with assistance from NORADA. This meeting did not occur, and no further grower meetings have been held except for a number of small meetings of the small group of export growers.

It was suggested numerous times to NORADA and to various northern NSW taro growers that all taro growers should become members of Taro Growers Australia Inc, and perhaps form a NSW branch based in the northern rivers region, rather than forming a completely new association. Some advantages of this are TGA's existing organisational structure and constitution, TGA's track record with obtaining R & D funding, contact with other Australian taro growers, and opportunity to coordinate Australian production windows and cooperate in the development of domestic and export market opportunities.

Quarantine/customs is an important issue for import of fresh taro corms into Japan. Japanese quarantine requires an AQIS phytosanitary certificate stating that corms are free of soil, and have been inspected for the presence of *Radopholus similis* (burrowing nematode) during the growing season, and that the soil in which they are grown has been inspected for the presence of *R. similis*. An AQIS-issued phytosanitary certificate declaring these conditions must accompany the corms. Assistance from NSW DPI and Qld DPIF was enlisted for infield sample collection prior to the first large consignment.

One research officer devoted considerable time to communicating with AQIS, NSW DPI and Qld DPIF personnel to initiate the nematode testing program required for phytosanitary certification of taro being exported to Japan. This activity was not foreseen at the initiation of the project. Further, this activity should be the responsibility of the business entity that is exporting to Japan. As the growers involved in the trial shipments had not decided upon the business arrangement by the time of the need for AQIS involvement, the urgent organisation of quarantine-related testing was conducted by the CQU researchers.

A risk assessment strategy was set-up, with input from Dr Graham Stirling (Biological Crop Protection) to rationalise the sampling procedure. High risk locations (those with or close to existing or prior banana crops – a co-host species) required two sampling times – just after planting (soil only) and pre-harvest (soil, root and corm) giving four samples in total. Other locations were considered as low risk – one sampling time at pre-harvest only (soil, root and corm) giving three samples in total.

There were no charges for sample collection for the 2003-2004 season, however the actual nematode testing cost $80 per sample. Phil Wilk (NSW DPI) collected NSW field samples then sent them to Graham Stirling (Biological Crop Protection) for nematode testing. About 10-20 growers were expected for the 2003-2004 season. Normal charges for sample collection applied after the 2003-2004 season. Graham Stirling also undertook the same service for Queensland growers. Eventually growers would prefer to be approved to do their own sample collection.

4. Discussion, Implications and Recommendations

Stage 1 of the project "…to assure confidence amongst Australian producers and export agents of the extent of market opportunity, and to determine product ideo types" was successful, and attendees at meetings in 2001 encouraged the team to continue with the research on pre- and post-harvest supply. Growers that contributed to the trial shipment and sold product domestically, believed that the main issues that needed addressing were reduction of production costs (through mechanisation, and generally more efficient practise), expansion of the domestic market for fresh and semi-processed /value-added products, and further exploration of export markets inside and outside of Japan for fresh and value-added products.

The discontinuation of exports was due to a number of factors, amongst which may be cited the inclement weather of 2003 (extremely dry and with fires, and new legislation regarding reduced entrainment of overland flows), the subsequent risk-aversion of most growers (growers were in the main not main-stream, but part-time, and or small-scale, with little cash backing, and more responsive to short term returns), the lack of attention to detail in quality standards for the Japanese market, the lack of continuity in negotiation over price between Maru and the project team, the raising of the asking price by the contracted marketing agent, and the possible influx of Chinese product beyond the normal seasonal supply identified during Stage I of the project. There may have been some confusion over the original asking and proposed selling prices, for sato-imo and Ishikawa wase names are used in various senses in the Japanese markets. Other major shortcomings of the project may have been the lack of specific hands-on experience in export to Japanese market, the inability of growers to join forces as a robust growers' group to take charge of opportunities to gain funding for technical and administrative support, the gross underestimate for labour requirements to ensure adequate grading, the inflexible nature of AQIS to provide support for development of protocols for nematode sampling.

Sato-imo production is currently very limited in Queensland and NSW, with only several commercial producers in northern NSW supplying to domestic markets. A new challenge for these producers has presented itself with a significant increase in imports of frozen sato-imo from China to Australia since April 2005. However, cleaned, peel, blanched and packed fresh taro is still desired by Japanese importers, and if the practices outlined in the companion Growers' Guide to Japanese Small Corm Taro are followed, and good links with importing companies are established, there is no reason why such a venture should not be profitable.

As with the potential export of other commodities (e.g. Chinese waterchestnut, Midmore and Gerstelling, 2004), small scale non-mechanised growers are unlikely to be able to reduce costs to the level necessary to export at a price that would allow for positive net returns.

5. Publications and communications arising from the project

Communications

- NORADA held 3 major seminars in 2001 with over 200 farmers attending overall.
- A Taro work-shop in Murwillumbah in November 2002 attracted over 50 taro growers.
- NBN Television (Channel 9)

- “Asian crops for Tweed”, Luis Feliu, Daily News (Tweed/Murwillumbah), 2 May 2001, p 2.
- “Tweed to put food on Asian tables”, Luis Feliu, Daily News, 9 May 2001.
- “Trade Minister inspects farms”, Peter Caton, Daily News, 1 June 2001, p 4.
- “Export push”, The Weekly (Northern Rivers, NSW), 15 July 2001.
- “To market, to market”, Kevin Elsley, The Land, 2 August 2001, p 19.
- “Farm business set to grow”, David Middleton, Daily News, 24 October 2001, p 1.
- “Big future for Tweed taro”, David Middleton, Daily News, 10 November 2001, p 21.
- “Tapping into taro market”, 2001.
- “Signs show good future for our taro”, Kevin Elsley, The Land, 2 May 2002, p 19.
- “Island crop takes root: taro growers take on Asia market”, Gold Coast Bulletin, 5 June 2002.
- “Taro comes to rescue: Aussie farmers find safety line in a common Japanese vegetable”, Belinda Lavis, Tweed Sun, 24 July 2002, p 18.
- “Water scheme a winner”, Luis Feliu, Daily News, 25 July 2002, p 3.
- “Rural Bonanza: farmers ready to cash in on new crops”, Shan Goodwin, The Northern Star (Lismore/Grafton), 1 August 2002, p 1,3.
- “Local Japanese give taro export nod”, National Marketplace News, August 2002, p 6.
- “Export taro push promises $50,000/ha”, Kevin Elsley, The Land, August/September 2002.
- “Root crop has export appeal”, David Austin, Small Farms Magazine, August 2002, p 56.
- “Taro market opening in Japan”, The Land – NSW Agriculture Today, August/September 2002.
- “Japanese taro: a new export crop”, Phillip Wilk, The Land – NSW Agriculture Today, 24 April 2003, p 11.
- “Tweed taro crop fails to bear financial fruit”, Daily News, 9 July 2004, p 3.
- “Work needed to market taro: Grower rejects claims sales to Japan have failed”, Daily News, 21 July 2004, p 14.
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- ABC Regional radio interviews with Peter McLaughlin.
- “New crops for export”, Tablelander (Atherton), 9 October 2001.
- “DNA to help gauge export potential”, Qld Fruit & Vegetable News, May 2001.
- Presentation by D. White: “RIRDC Project UCQ-13A: Development of taro, yam, yam bean and sweet potato exports to Japan and USA”, Agro-Trend Bundaberg Qld, 15 May 2002
- Presentation by Prof D. Midmore to Cane Growers in Maryborough on 20th July 2002
- D. Hicks to Third Taro Symposium, Fiji, 21-23 May 2003.
- ABC radio interview with Dan White (taro) and Eric Coleman (sweet potato), Cairns, 19 June 2003.
- D. White. “RIRDC Project UCQ-13A: Development of taro, yam, yam bean and sweet potato exports to Japan and USA” (Taro). DPI Production and Market Development Day, QDPI South Johnstone, 20th June 2003.

- E. Coleman. "RIRDC Project UCQ-13A: Development of taro, yam, yam bean and sweet potato exports to Japan and USA" (Sweet potato). DPI Production and Market Development Day, QDPI South Johnstone, 20th June 2003.
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7. APPENDICES

Appendix 1. NORADA/NSWAg Sato-imo experimental trial report

David J. Hicks, Peter McLaughlin, Phil Wilk, Vong Nguyen.

Introduction

Traditionally, the soils of the Northern Rivers region of NSW have supported dairy, beef-cattle, sugarcane and banana industries. In the past 30 years these industries have waned and have been surpassed by relatively new crops such as macadamia, avocado, mango and sweet-potato as the dominant rural industries for the region. Currently, as competition increases from new establishments for these crops in other Australian and international regions, producers in the Northern Rivers are seeking other crops required of previously un-explored market-places to give them a competitive edge (Hicks 2001).

Market opportunities reported for sato-imo (*Colocasia esculenta* var *antiquorum*) (Vinning 1995, 2003) catalysed the requirement to evaluate the factors necessary for optimal cropping in specific targeted areas. Knowledge for the production of *antiquorum* varieties of taro is limited (Purseglove 1992, Follet 1996) and undocumented in the Northern Rivers. Therefore, in order to assist the establishment of an industry in the Northern Rivers region it was necessary to challenge an *antiquorum* variety (resembling the Japanese variety *Ishekawa wase* with a suite of experimental trials designed to provide preliminary indications of the production requirements and yield potential.

The soils in the Northern Rivers vary considerably and have been adequately mapped and documented into 12 physiographic groups, with further sub-classification of soils using the Northcote system of classification (Northcote 1979, Morand 1994, 1996). The soils of use to horticulture are largely a function of the parent geology derived from tertiary Lamington volcanics, and quarternary alluvial deposits over river plains (Morand 1994). The complexity of classification of soils in the Northern Rivers is simplified through the Australian Soil Classification system (Isbell 1996) identifying the soils with horticultural potential as ferrosols (red krasnozems), dermosols (chocolate krasnozems), kurosols (red and yellow podzolics) and tenosols (alluvial deposits) (Lines-Kelly 2000). For the purpose of this project and ease of interpretation, these terms were adopted for clarity of distinction between major soil groups. The minutiae of further reducing classification was considered far too specific for undertaking comparative analysis between soil types and locations.

The weathered geology of the Lamington shield volcano which physically dominates the region, has imparted topographical features in the landscape which influence niche micro-climates (Morand 1996). Further, there are changes in climate in the region from coastal locations, through the ranges to those situated inland (Fig 1). The varying soil types coupled with the micro-climate niches provide the Northern Rivers region with an intensity of different cropping situations within a relatively small region of Australian land. This bestows a number of agricultural opportunities to the region. Most importantly, a diversity of crops can be grown specific to a particular requirement, and where more than one climate niche supports a specific crop then the harvest season may be extended within the region. Likewise, research information gleaned from conducting trials on any crop in one or more location types may be transferable to other regions outside the Northern Rivers which demonstrate similar environmental conditions.

These factors endow the Northern Rivers as the ideal new crop research template facility for assessing crops under a variety of Australian conditions in a relatively small area. The combined approach of researching sato-imo production and identified market requirement with industry involvement simultaneously provided opportunities for grower involvement, education, communication, experiential learning and swift research feedback. From a Northern Rivers Agricultural Development Association (NORADA) perspective, introducing sato-imo as a new crop to the Northern Rivers growers was intended to provide the template as the first of many potential crops.

Information on the culture of taro species in general is limited and often appears conflicting (Harwood and Plucknett 1981, Purseglove 1992, Onwueme and Charles 1994). Most available information relates to the C*olocasia esculenta* ssp *esculenta* varieties which have a single or few side corms, and are traditionally cropped in tropical regions of the world (Onwueme and Charles 1994). The *antiquorum* ssp types favoured in Japan are grown in temperate to sub-tropical climes (Honda 1987, Purseglove 1992). Planting and harvesting times for tropical taro crops are governed by rainfall seasonality (Onwueme and Charles 1994), whereas in temperate to sub-tropical climates the local seasonal temperatures will determine dates (Purseglove 1992).

Recommended propagation material and spacing between plants have been reported for *antiquorum* ssp under New Zealand (Follet 1996), Japanese conditions (Honda 1987) and generally (Purseglove 1992). Honda (1987) recommends 30 cm spacing for plants propagated with ‘daughter’ corms and 50 cm when propagating from ‘mother’ corms, whereas Follet (1996) gives a generic 30-50 cm spacing recommendation. The Honda (1987) recommendation suggests differences in outcome of yield due to mass of propagation materials, while Purseglove (1992) states 60 to 75 cm spacings are normal for the West Indies. *Esculenta* ssp varieties are generally restricted in propagation material potential due to the low number of corms produced per plant and the reliance of growers to recycle the main growing point for the next season’s crop (Onwueme and Charles 1994). *Antiquorum* ssp varieties produce a great number of corms of varying shapes and sizes which have potential as propagation material. It was not known which specific sized corm mass selected for propagation gives the greatest quantity and/or quality yield for the subsequent seasonal planting.

Spacing recommendations of 60 cm x 60 cm between plants for *esculenta* ssp varieties may be an economic compromise given the larger numbers of propagation material required for a closer plant spacing (Onwueme and Charles 1994). Further, Onwueme and Charles (1994) cite several studies which determine the influence of closer spacing on yield in terms of per plant (lower yield) and per hectare (greater yield). However, yield does not automatically translate to quality, and these estimates are based upon a distinct morphologically-different species. Therefore, the need to identify the correct propagation material size and address the spacing requirements for *antiquorum* ssp varieties under Australian production conditions and techniques is mandatory for industry success. These are high priorities for growers to calculate plant numbers per unit area and make estimates of yield, so that adequate equipment and labour for harvest and grading practices during the post-harvest operations can be provided for.

Sato-imo yields and corm quality responses to soil type, climate niche, fertilising and irrigation have been documented across a wide variety of tropical production centres (Jackson and Wagih 1996, Craswell *et al.* 1996) but in limited reports for temperate situations (Honda 1987, Follet 1996). The response of taro to nutrient applications have been positive (O’Sullivan *et al.* 1996) though fertilising of *Colocasia* sp. has not been a uniform science, a statement supported by Blamey (1996). Accurate fertiliser applications are also important to avoid residues which may affect quality in terms of taste (Poihega *et al.* 1996). Japanese practices reveal a dependence upon organic sources of nutrients of unknown composition in conjunction with inorganic fertiliser applications of N 100: P 180: K 100 kg ha^{-1} and 500 kg ha^{-1} of liming material (Honda 1987). Similarly, Follet (1996) reports the exact same fertiliser quantities. The levels of fertiliser application seem disproportionate to other root crop species in general especially for phosphate application (Lorenz and Maynard 1988), and to the diversity of nutrient application rates for *esculenta* cited by Onwueme and Charles (1994) for African, Indian and Hawaiian production centres and by Blamey (1996). All reports have not adequately identified the soil conditions of the fertilised crops. The divergence in requirement may be driven by cultivar, climate or soil type, hence the necessity of any potential production region to make independent evaluations and report for localised conditions.

Plant disorder responses to incorrect nutrient supply have been reported for *antiquorum* ssp (O'Sullivan *et al.* 1993, O'Sullivan *et al.* 1996) and for *esculenta* ssp (Cable 1996), though these reports are preliminary and require confirmation from secondary and tertiary evaluation before adoption. Critical nutrient concentrations in organs and corresponding adequate supply rates of all mineral nutrients are necessary for grower monitoring and possible reaction in response to nutrient disorder. Treatment estimates in trials investigating the effects of fertiliser application in any given region would be more accurate when working from an established calibrating reference point. Work to establish the critical tissue concentrations and the corresponding nutrient supply rates was beyond the mandate of the current obligation, although it should seriously be considered at stages where an industry could help support its application if required. Similarly, minor and trace elemental nutrient effects along with pest and weed control measures were considered advanced production research, reliant upon an established working industry.

The response of taro to irrigation has not been widely reported as most taro is grown under tropical conditions where adequate rainfall predominates. Purseglove (1992), notes that *antiquorum* varieties can withstand lower rainfall than *esculenta* varieties, while Brown (2000), describes a range of 1 750 to 2 000 mm requirement for upland grown taro. Root crops in general have been shown to have reduced yields when water is limited (Trebejo and Midmore 1990). Therefore, assessment of the water requirement requires attention.

The effects of treatment applications on yield as a function of crop scheduling, plant material, plant spacing, and nutrient and water applications were considered the most important aspects of the research trial focus for industry establishment purposes. Therefore, the following experiments were carried out in the Northern Rivers region. Experiment 1 evaluated the yield response to planting and harvest date, within particular seasons and over a number of seasons. The second experiment was designed to determine the optimal spacing between plants while Experiment 3 was meant to assess the irrigation needs. Experiments 4 and 5 were implemented to look at yield responses to early N and late K applications respectively while Experiment 6 was conducted to assess the effect on yield of initial corm size at planting. An audit of grower practices and yields was issued for Experiment 7 to gain a greater appreciation of sato-imo in the Northern Rivers while Experiment 8 was set up to evaluate the effect of high application rates of nutrient on yield parameters, especially applied late in the season. Finally, a dual soil type and phosphorous trial was conducted (Experiment 9), as was an irrigation trial concerned with volume and frequency of delivery (Experiment 10).

Experiment 1 Evaluation of planting and harvest date for sato-imo (*Colocasia esculenta* spp *antiquorum*) at different locations in the Northern Rivers region of NSW.

Rationale

If a sato-imo production industry is to be established in the Northern Rivers region of NSW then it was necessary to trial the growth and yield response of sato-imo in as many regional locations as possible. Firstly, a critical mass of propagation material was required before any comparative analysis was possible. Secondly, conditions for growth in differing areas had to encompass as wide a variation as possible, therefore, the following program of trialling sato-imo evolved in response to grower position and requirement of the crop as a greater understanding of need was presented.

Materials and Methods

Climate data for several locations were computed for visual comparison of seasonal trends for coastal, range and inland sites within the Northern Rivers region. Average minimum and maximum temperatures and precipitation data were provided by statistics posted on the website of the Australian Bureau of Meteorology. The exact climate data for each research site could not be obtained and the nearest localities with data were used (Anon. 2005). Coastal data was presented as Ballina, Byron Bay and Coolangatta, range data was presented as Murwillumbah and inland as Casino. Gosford data were also presented as a contrast between Northern NSW sites and the Central Coast of NSW.

During September of 1998, twenty sato-imo corms were provided to an inland located grower at Iron Pot Creek and to a coastal grower at Cudgen in the Northern Rivers region of NSW as part of the consolidating Asian vegetables project. The corms were planted in single raised mounds at a spacing of 50 cm and irrigation was requested. The soils at Iron Pot Creek were well structured heavy chocolate coloured silty clay (dermosols with pH 6.0) located on a slight slope and previously unused for crop purposes. At Cudgen, the soils were lighter clay with deep red colour (ferrosols with pH 4.5) and poor structure from over-cultivation for sweet-potato production. Growers were requested to apply a compound fertiliser in two split applications at a rate of approximately 200 to 300 kg N ha^{-1}. The timing and method of application of fertiliser was left to the growers' discretion. Requests were made to apply irrigation frequently in the absence of precipitation and to keep the crop-plot free of weed infestations. The objective was to propagate material for future trials; therefore only visual observations were made.

During September of 1999, the corms grown at Iron Pot Creek were dug and divided between growers at Eden Creek (Inland) and Burringbar (Range, kurosol soils pH 5.7) where they were planted for further propagation development and initial yield indicators. Cultivation remained at the discretion of the grower and their available resources. The plants at Cudgen (Coastal) were dug and all corms replanted on site for propagation material development. During June of 2000, four plants from each site were harvested for evaluation of total and marketable numbers and mass of corms (except Eden Creek where only totals were recorded).

During June of 2002, at the harvest of the first commercial crops 4 plants from each site were sampled for evaluation. The same actions were taken during July of 2003 except the inland site was from Whyralla (September planting data used in analysis) which had similar soil and climate conditions to Eden Creek, and the range values were taken from a planting at Clothiers Creek (reduced soil data used in analysis) which had similar soil conditions to Burringbar. Data for seasonal comparisons was analysed using ANOVA techniques for a two-factorial trial where season and location were the factors.

The July 2003 harvests from Whyralla were separate September and October planting samples of 4 plants each, Clothiers Creek supplied 4 plant samples from both waterlogged soils and non-waterlogged soil from higher ground. The data from the 2003 season were analysed as a single factor ANOVA situation.

In 2001, 15 corms per month were planted at Cudgen and Eden Creek in the second week of August, September, October, November and December. Corms were planted into sections of rows inside commercial plantings set aside for trial purposes. Harvest of three plants per monthly planting treatment, were made during the second weeks of March, May and July of 2002. The number and mass of total and export marketable corms were recorded. Data were analysed using ANOVA techniques for a three-factorial experiment using Statistica 6.0 software where location, planting date and harvest date provided factors. Presentation of data via graphs was separated into location for ease of expression and interpretation.

Results

The mean precipitation available to crops showed a pattern that is conducive to the requirements of the cropping of sato-imo (Figure 1a). Precipitation increases from the lowest means with the onset of spring planting in September and October and increases through to March before a downward trend was seen with the onset of autumn. The exception to the later stages is the high volumes of rainfall at coastal sites during autumn and early winter months.

The maximum monthly mean temperatures for all sites have been in a suitable range for sato-imo growth during the crop cycle periods between September and May (Figure 1b). The minimum temperature monthly means also indicate an adequate amount of time is available for each Northern Rivers site to achieve a critical growth mass to produce an economically viable crop of corms. An apparent period of average temperatures below 15^{o}C corresponding to the time of corm initiation and formation (Figure 1b) is of sufficient period to allow for corm development and harvest practices. The period of growth above 15^{o}C is longer for coastal sites than at inland sites by approximately 2 months. The inland sites however, have higher maximum averages during the growing months.

The time of planting ($P<0.000$), time of harvest ($<P0.000$) and location of planting site ($P<0.0.009$) all had significant effects on the export numbers of corms plant^{-1} produced. Similarly, the interactions between location and time of planting ($P<0.000$), location and time of harvest ($P<0.000$), time of planting and time of harvest ($P<0.002$), and location, time of planting and time of harvest ($P<0.000$) had an effect on the production of export corm numbers (Figures 2a & b). At Cudgen, the greatest yields were achieved with a September planting harvested during May. At Eden Creek, the yield was greatest for an August planting harvested between May to July. Cudgen had greater yields than Eden Creek.

The time of planting ($P<0.000$), time of harvest ($P<0.000$) but not location of planting site ($P<0.312$), had a significant effect on the total number of corms plant^{-1} produced. Similarly, the interactions between location and time of planting ($P<0.001$), time of planting and time of harvest ($P<0.014$), and location, time of planting and time of harvest ($P<0.008$) but not location and time of harvest ($P<0.055$) had an effect on the production of total corm numbers (Figures 2a & b). At Cudgen, the greatest yields were achieved with a September planting harvested during July. At Eden Creek, the yield was greatest for an August planting harvested during July. Cudgen had a greater yield than Eden Creek.

The time of planting ($P<0.000$), time of harvest ($P<0.000$) but not location of planting site ($P<0.628$) had significant effects on the export mass of corms plant^{-1} produced. Similarly, the interactions between location and time of planting ($P<0.000$), location and time of harvest ($P<0.002$), time of planting and time of harvest ($P<0.042$), and location, time of planting and time of harvest ($P<0.007$) had an effect on the production of export corm mass plant^{-1} (Figures 3a & b). At Cudgen, the greatest yields were achieved with a September planting harvested between May and July. At Eden Creek, the yield was greatest for an October planting harvested during July. Cudgen had a greater yield than Eden Creek.

The time of planting ($P<0.000$), time of harvest ($P<0.000$) and location of planting site ($P<0.018$), had a significant effect on the total mass of corms plant^{-1} produced. Similarly, the interactions between location and time of planting ($P<0.000$), location and time of harvest ($P<0.017$), and location, time of planting and time of harvest ($P<0.003$) but not time of planting and time of harvest ($P<0.198$) had an effect on the production of total corm mass plant^{-1} (Figures 3a-b). At Cudgen, the greatest yields were achieved with a September planting harvested during July. At Eden Creek, the yield was greatest for an October planting harvested during July. Cudgen had a greater yield than Eden Creek.

The site location ($P<0.001$), the year ($P<0.000$) and the interaction between site location and year ($P<0.000$) had significant effects on the production of export quality corms numbers plant^{-1} (Figure 4a-b). The site location ($P<0.027$), the year ($P<0.019$) and the interaction between site location and year ($P<0.002$) had significant effects on the total production of corms numbers plant^{-1} (Figure 4a-b). Corm numbers plant^{-1} both export and total tended to increase with the years at inland and range sites, though for the coastal site decreases were recorded. In 2003, the numbers of corms for range and inland sites had increased to a point of parity with the initial 2000 corm numbers of the coastal site.

The site location ($P<0.001$), the year ($P<0.000$) and the interaction between site location and year ($P<0.001$) had significant effects on the production of export quality corm mass plant^{-1} (Figure 4a-b). The site location ($P<0.007$) and the interaction between site location and year ($P<0.002$) but not the year ($P<0.272$) had significant effects on the total production of corm mass plant^{-1} (Figure 4a-b). Corm mass plant^{-1} total tended to increase with the years at inland and range sites, though for the coastal site decreases were recorded. Export quality mass decreased also for the 2002 before increasing the following year. In 2003, the numbers of corms for range and inland sites had increased to a point of parity with the initial 2000 corm numbers of the coastal site.

In 2003, the number of export corm numbers plant^{-1} ($P<0.048$) was significantly lower at Cudgen than for other sites sampled (Figure 5a). There were no differences between sites for total corm numbers plant^{-1} ($P<0.227$), export quality fresh mass plant^{-1} ($P<0.239$) and total fresh mass plant^{-1} ($P<0.863$) (Figure 5a-b).

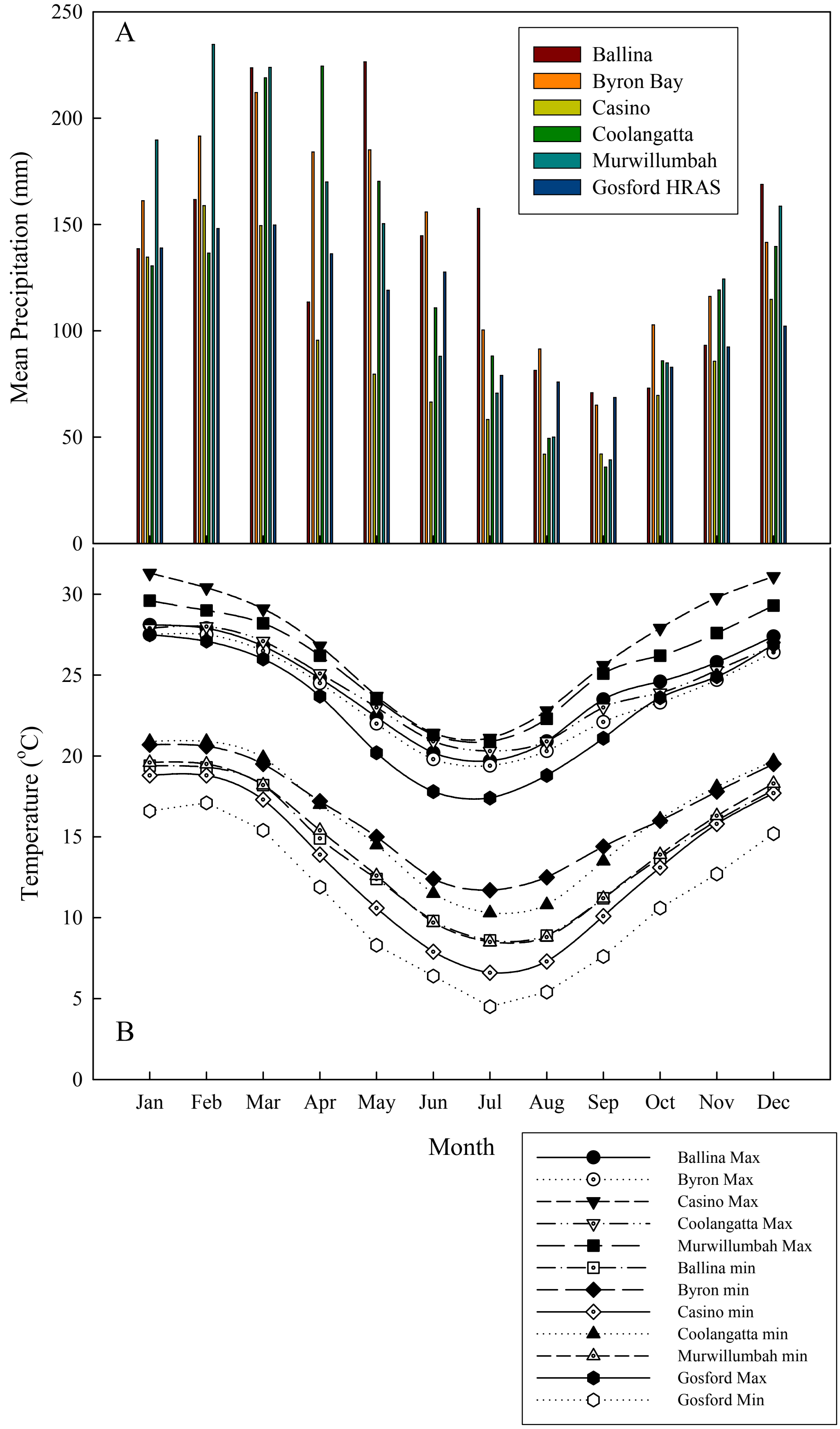

Figure 1 Seasonal climate of the Northern Rivers region of NSW: a) Average precipitation; b) Average maximum and minimum temperatures. (Source: Anon. 2005)

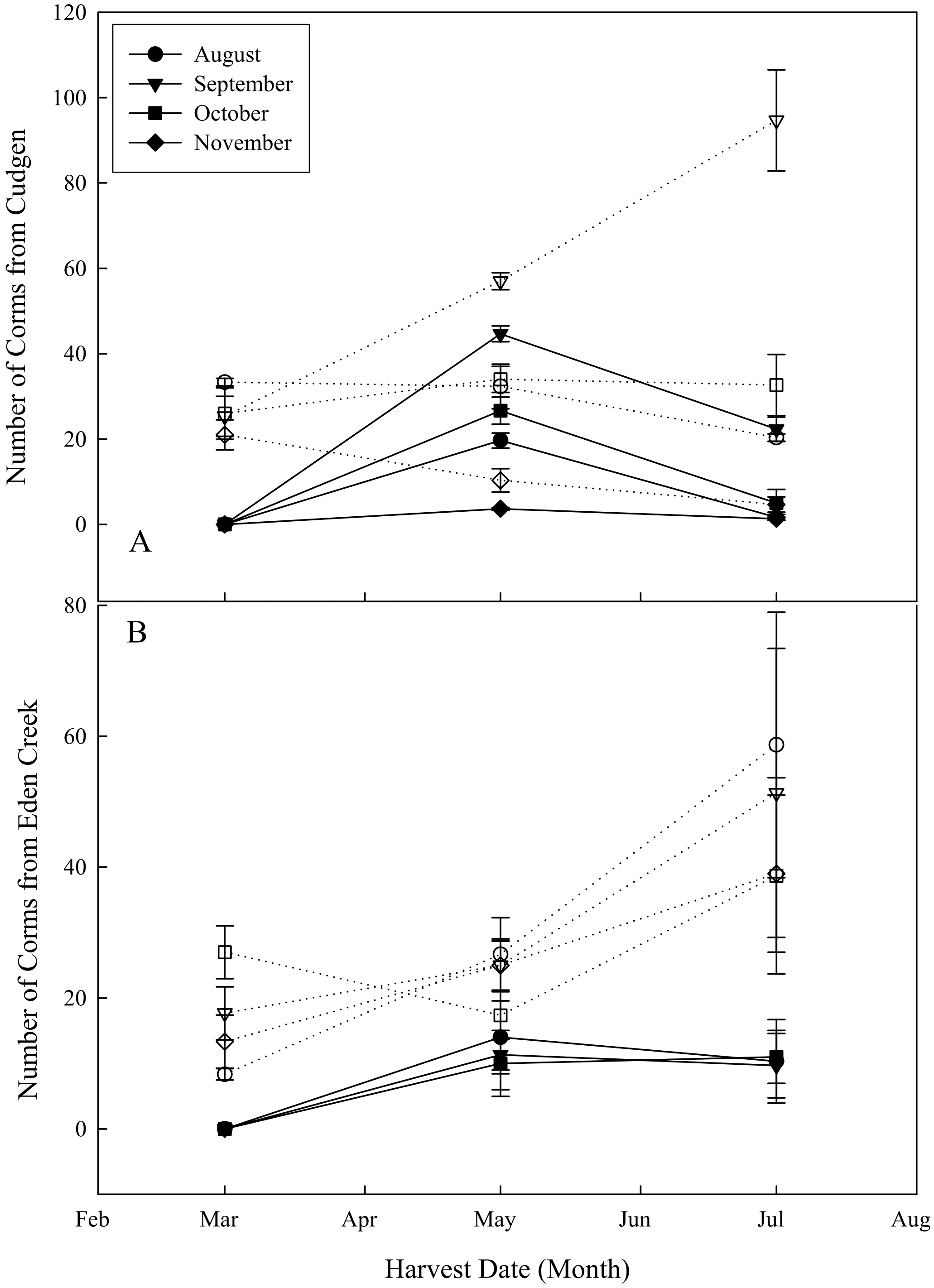

Figure 2 Number of corms per plant of sato-imo as a function of site location, planting date and harvest date for the 2001/2 season: a) Cudgen grown plants (coastal ferrosol site) and b) Eden Creek grown plants (inland dermosol site). Solid lines represent export quality per plant and dotted lines represent totals per plant. All values are means and bars represent S.E. (n=4).

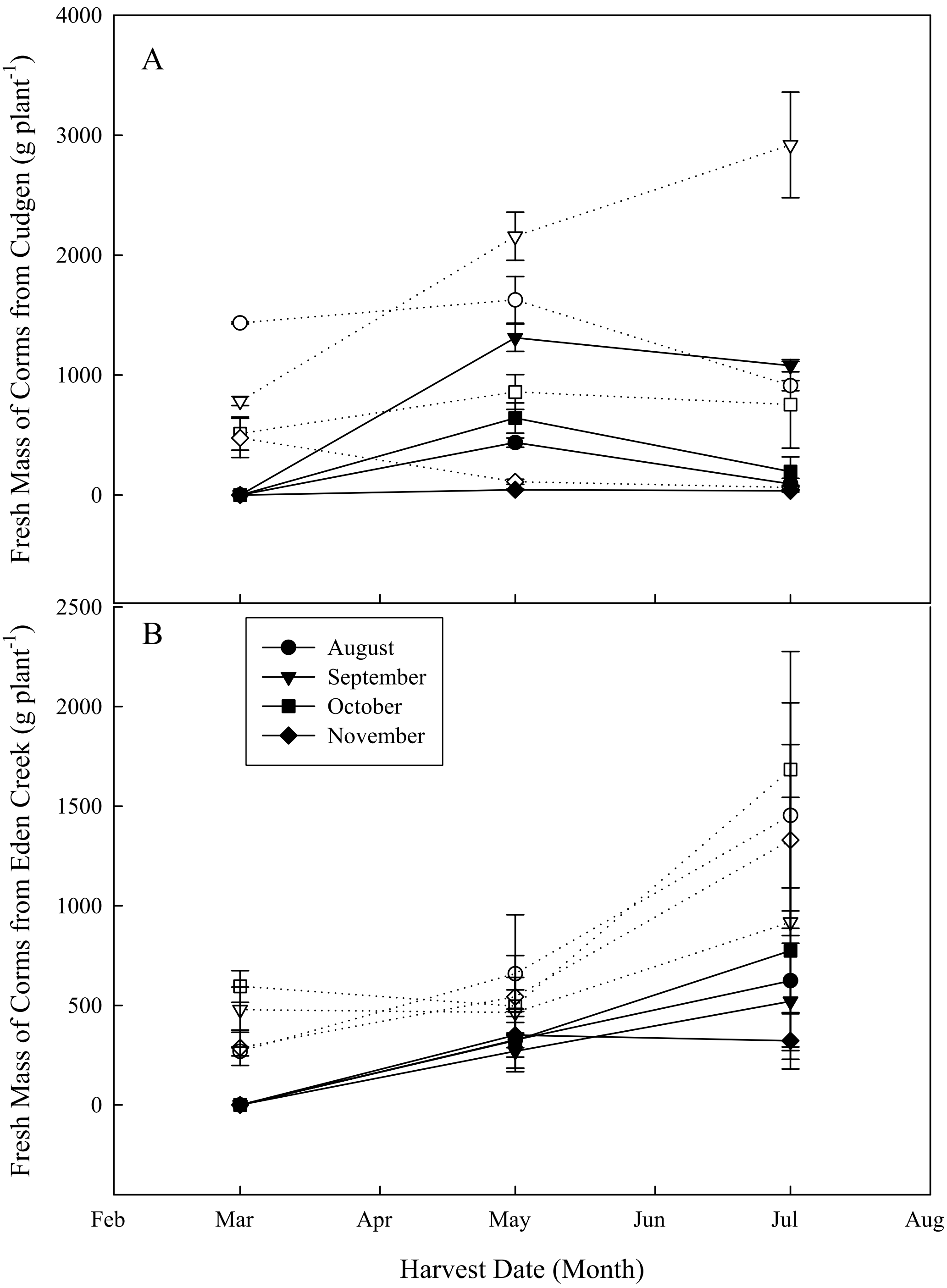

Figure 3 Fresh mass of corms per plant of sato-imo as a function of site location, planting date and harvest date for the 2001/2 season: a) Cudgen grown plants (coastal ferrosol site) and b) Eden Creek grown plants (inland dermosol site). Solid lines represent export quality per plant and dotted lines represent totals per plant. All values are means and bars represent S.E. (n=4).

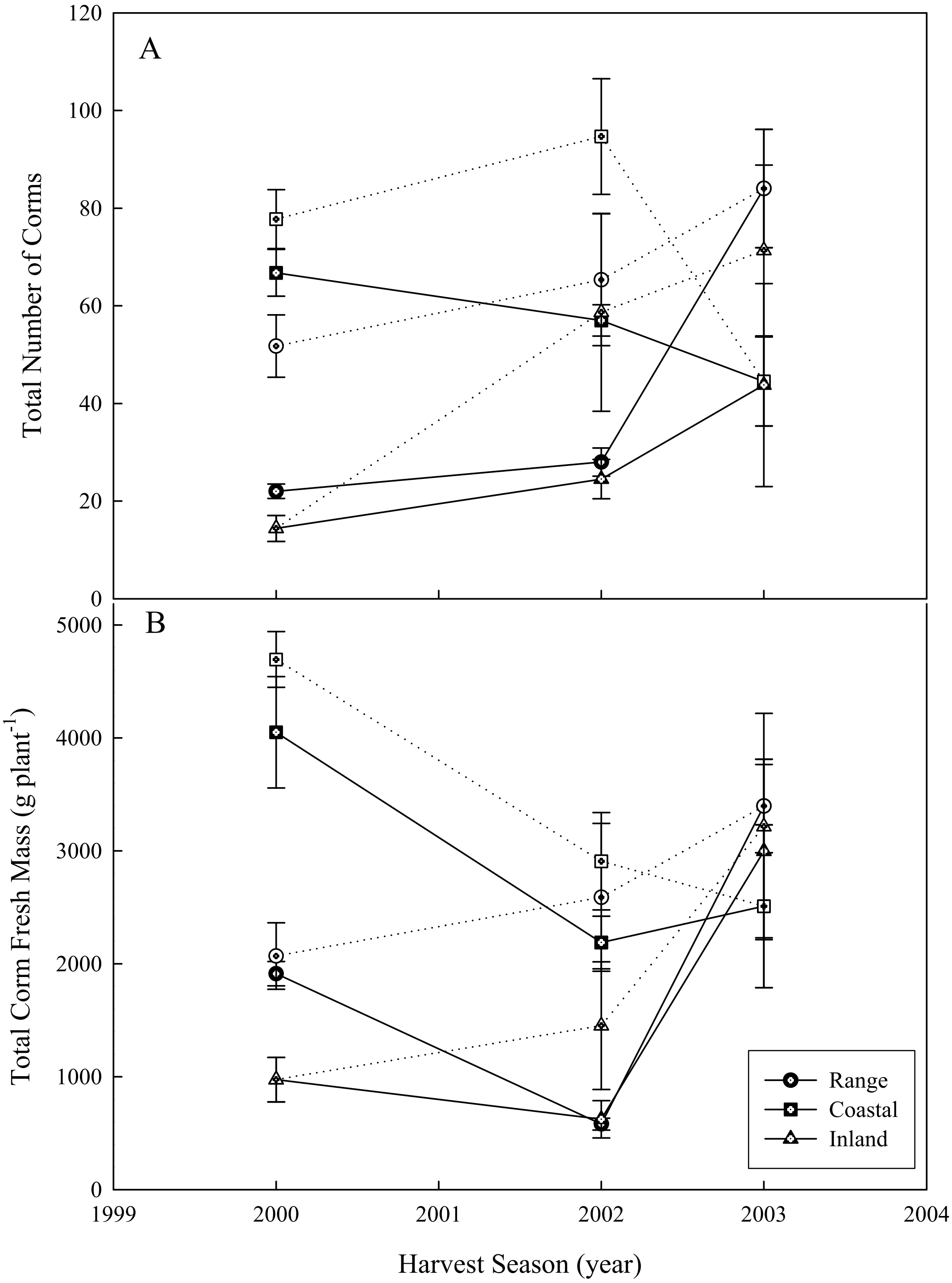

Figure 4 Sato-imo production in the Northern Rivers as a function of year. All values are means and bars represent S.E. (n=4).

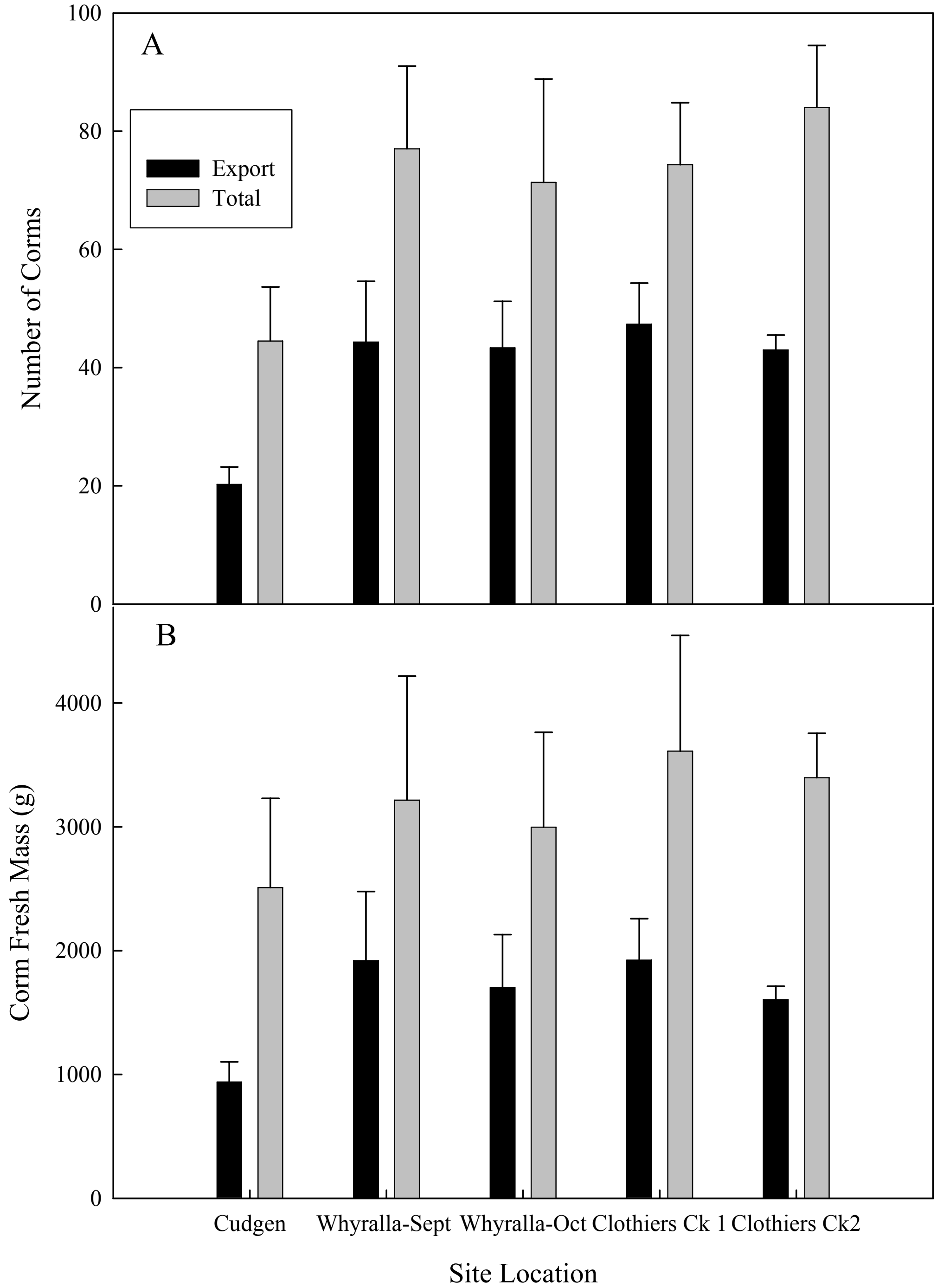

Figure 5 Total and export quality yield of sato-imo from locations in the Northern Rivers region of NSW harvested during July 2003: a) Number of Corms b) Corm Fresh Mass. All values are means and bars represent S.E. (n=3), Clothiers Creek 1- non waterlogged soil, Clothiers Creek 2 - waterlogged soil.

Experiment 2 Effect of plant spacing on sato-imo (*Colocasia esculenta* sp *antiquorum*) yield.

Materials and Methods

The trial was implemented at the Burringbar and Eden Creek sites during October. Three within row spacing's were implemented: 30, 50 and 70 cm.

Results and Discussion

The trial at Burringbar was abandoned due to grower incapacitation, the trial plot was over-grown with weeds and the irrigation scheduling was intermittent. The trial at Eden Creek was abandoned due to water-restrictions preventing cropping.

Experiment 3 Effect of irrigation frequency and volume on the yield of sato-imo (*Colocasia esculenta* spp *antiquorum*).

Rationale

Most Esculenta sp are grown in tropical regions with adequate rainfall and irrigation requirements are generally not considered in the various recommendations. Therefore, under temperate Australian conditions where rainfall is not delivered regularly or in predictable volumes, trials to determine the best water regimes for optimum yields are necessary.

Materials and Methods

A trial to investigate the amounts and frequencies of delivery of water for sato-imo was implemented at the Burringbar site during September of 2000. Sections within 3 rows of a commercial crop were pegged out in four by 5 m lengths per row for 3 rows. Each row planted by the grower was stagger planted in double rows in an equilateral triangular pattern with a spacing of 30 by 30 cm between plants. Double rows were centred at approximately 1.2 m. Corms of indeterminate size were used as propagation material. Treatment rows were separated by a non-treatment row and treatment sections were separated by a 2 m section of the row.

Irrigation treatments included frequencies of daily, 5 day and 10 day intervals for a duration of 1 hour, and volumes of 2 ml, 4 ml and 8 ml per hour per emitter. Frequency treatments were in dedicated rows containing each of the volume treatments. Frequencies were imposed via a battery operated irrigation solenoid controller while volume treatments were via regulated emitters. The delivery of the water to the point of application was via the grower operating a positive displacement pump from an on site reservoir.

Results and Discussion

The trial was abandoned due to grower incapacitation, disabling the ability to start the manually cranked reservoir pump. The trial plot was over-grown with weeds and the irrigation scheduling was intermittent, many plants failed to grow.

Experiment 4 The effect of early nitrogen applications on growth of sato-imo (*Colocasia esculenta* spp *antiquorum* Schott).

Rationale

Nitrogen comprises the greatest proportion of mineral nutrients in plants (Mengel and Kirkby 1987) and is well known to promote growth in plants (Marschner 1988). The amount and the timing of availability of N required for crop plants varies widely amongst species (Lorenz and Maynard 1988). The reports for N applications for taros reflect total amounts and do not discriminate between crop stages of development (Honda 1987, Purseglove 1992, Onwueme and Charles 1994). Therefore, it was a priority to investigate the N supply requirement and type for the initial growth stage of sato-imo.

Materials and Methods

Plant Culture

During September 2001, 3 rows situated within in a commercial crop of sato-imo grown at Burringbar in the Northern Rivers region of NSW were selected for applications of nitrogen during the initial stages of growth. Each row was single planted with a space of 40 cm between plants and 1.2 m between rows. The rows with treatment were separated by a non-treatment row. Treatments were segregated into 5 m sections beginning 2 m from a treatment row edge and 2 m between treatments within rows.

Irrigation was delivered on a regular basis via monsoon overhead sprinklers at the growers' discretion. Weeds were manually removed while pests such as heliothis budworms (*Helicoverpa armigera*) and cluster caterpillars (*Spodoptera litura*) were controlled by the grower with carbaryl. Nutrition was provided through evenly-spread applications of an unspecified amount of composted fowl manure worked into the soil. The site nutrient and liming activities were conducted 1 month prior to planting.

Experimental Design

Nitrogen treatments included KNO_3, $Ca(NO_3)_2$, NH_4NO_3, $(NH_4)_2SO_4$ and DAP at supply rates of 50, 100 and 150 kg N ha^{-1}. The treatments were randomly ascribed to a row, each row containing five treatments. Treatments were applied as crystallised fertiliser salts hand-spread around target plants in split applications, the first during September 2001 and the second during November 2001.

Plants were harvested during July 2002 by hand, washed free of residual soil and assessed for the number of corms and the corm mass. Data was analysed using ANOVA techniques for a two-factorial experiment using Statistica 6.0 software.

Results

Nitrogen fertiliser type ($P < 0.004$) and the interaction between N rate and fertiliser type ($P < 0.001$) but not N supply rate ($P < 0.175$) had significant effects on the export number plant^{-1} of sato-imo corms (Figure 6a). Similarly, total corm numbers plant^{-1} were influenced by N fertiliser type ($P < 0.001$) and the interaction between N supply fertiliser type ($P < 0.009$) but not N supply rate ($P < 0.154$) (Figure 6a). Corm number plant^{-1} was generally greater with N supplied as nitrate, especially Ca_2NO_3, rather than ammonia based fertilisers.

Nitrogen fertiliser type ($P < 0.002$) and the interaction between N rate and fertiliser type ($P < 0.003$) but not N supply rate ($P < 0.077$) had significant effects on the export fresh mass plant^{-1} of sato-imo corms (Figure 6b). Total corm mass plant^{-1} was influenced by N fertiliser type ($P < 0.000$), N supply rate ($P < 0.025$) and the interaction between N supply and fertiliser type ($P < 0.001$) (Figure 6b). Corm mass plant^{-1} was generally greater with a supply rate of 150 kg ha^{-1} of N and N supplied as nitrate, especially $Ca_2NO_{3,}$ rather than ammonia based fertilisers.

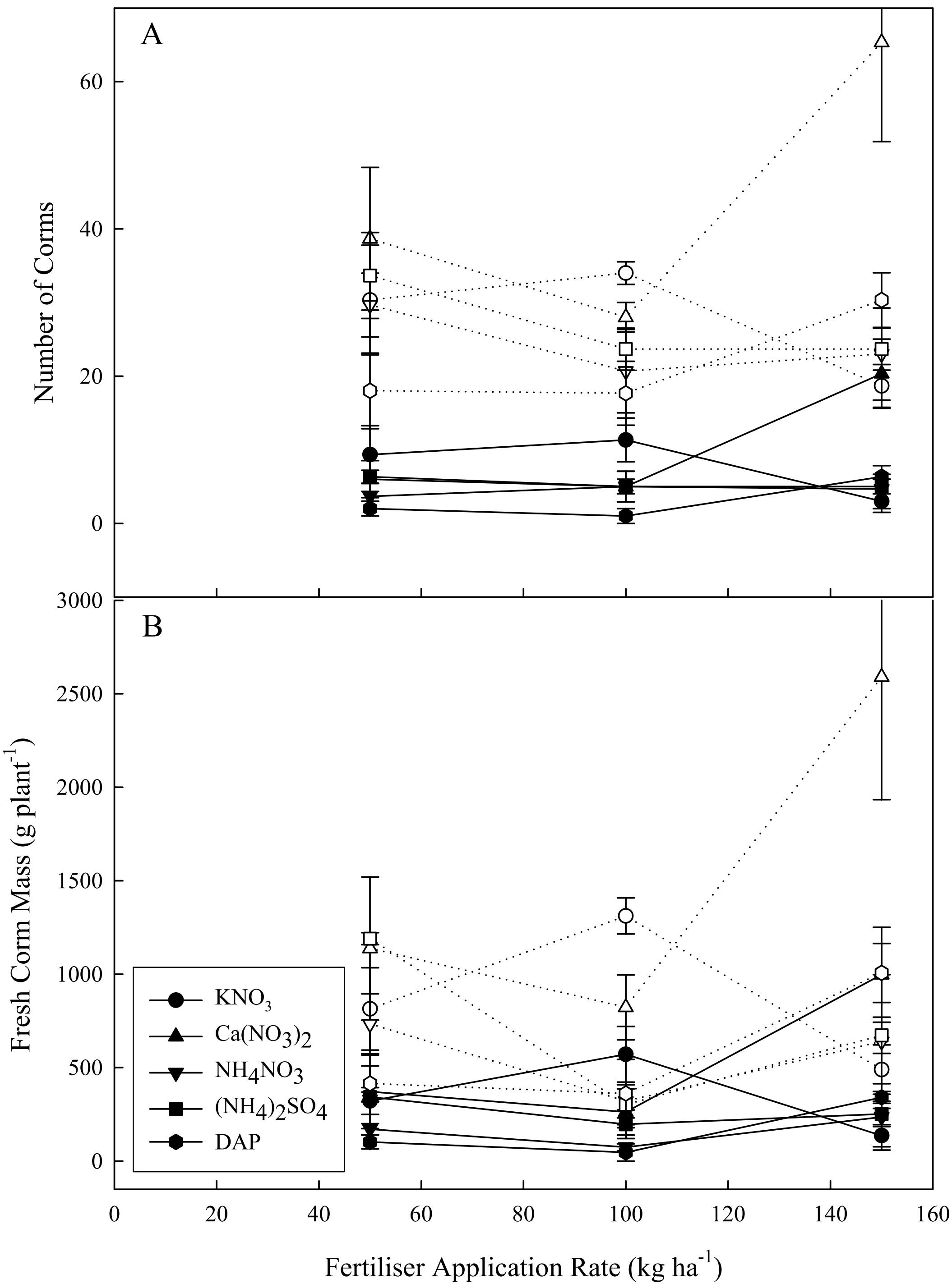

Figure 6 Total and export quality yield of sato-imo (*Colocasia esculenta* var. *antiquorum*) as a function of different nitrogen sources with varying supply rates, grown at Burringbar in the Northern Rivers region of NSW and harvested during July 2002: a) number of corms per plant; b) fresh corm mass per plant. Dotted lines represent totals and solid lines represent export quality, all values are means and bars represent S.E. (n=3).

Experiment 5 Effect of potassium applied late in the crop cycle of sato-imo (*Colocasia esculenta* spp *antiquorum*) on yield.

Materials and Methods

Plant Culture

During September 2001, three rows situated within in a commercial crop of sato-imo grown at Cudgen in the Northern Rivers region of NSW were selected for applications of potassium during the initial stages of growth. Each row was single planted with a space of 30 cm between plants and 1.0 m between rows. The rows with treatment were separated by a non-treatment row. Treatments were segregated into 5 m sections beginning 2 m from a treatment row edge and 2 m between treatments within rows.

Irrigation was delivered on a regular basis via monsoon overhead sprinklers at the growers' discretion. Weeds were controlled by mounding soil around plants and Fusilade 500 during the first 3 months of growth. Paraquat was using between rows during the remainder of the crop cycle. Soil larval pests such as African black beetle (*Heteronchyus arator*), field crickets (*Gryllidae* sp.), mole crickets (*Gryllotalpa* sp.), (false) wireworms (Elateridae; *Gonocephalum spp., Pterohelaeus* spp.) and sweetpotato weevils (*Cylas formicarius elegantulus*) were controlled by the grower with chlorpyriphos at a rate of 0.1 L per 10 kg bran bait per ha. Foliar pests such as heliothis budworms (*Helicoverpa armigera*) and cluster caterpillars (*Spodoptera litura*) were controlled by the grower with dimethoate at 75 ml 100 L^{-1} of spray. Nutrition was provided through evenly spread applications of Crop King 44* at four by 50 kg bags ha^{-1} worked into the soil. The site nutrient and liming activities were conducted 2 weeks prior to planting.
* Brand name.

Experimental Design

Potassium treatments included KNO_3, K_2SO_4 and $KHPO_4$ at supply rates of 50, 100 and 150 kg K ha^{-1}. The treatments were randomly ascribed to a row, each row containing 5 treatments. Treatments were applied as 5 L solutions on two separate occasions, February and April 2002. Controls received water only

Three replicate plants were harvested per treatment during July 2002 by hand, washed free of residual soil, roots and petiole material before assessment. A control sample was taken from within Corms were separated into export marketable and non-export corms and reported as export and total numbers and mass. Data were analysed using ANOVA techniques for a two-factorial experiment using Statistica 6.0 software and presented as graphs constructed using Sigmaplot 8.0.

Results

Potassium supply rates (P< 0.006) and the interaction between K rate and fertiliser type (P<0.023) but not fertiliser type (P<0.915) had significant effects on the export number of sato-imo corms plant^{-1} (Figure 7a). Export numbers of corms plant^{-1} generally increased with increasing rate of K. Anomalies included the K_2SO_4-100 treatment and the control treatments; these were assumed to be a function of unknown size and quality of propagation material, imprecise applications of initial fertilisers and use of over-head irrigation giving uneven water coverage. Total corm numbers were influenced by K supply (P< 0.000) but not fertiliser type (P< 0.373) or the interaction between K supply and fertiliser type (P< 0.051) (Figure 7a). The trends for totals were similar to those for export numbers of corms plant^{-1}.

Potassium supply rates (P< 0.001) and the interaction between K rate and soil type (P<0.016) fertiliser type (P<0.004) had significant effects on the export mass plant^{-1} of sato-imo corms (Figure 7b). Export mass of corms plant^{-1} generally increased with increasing rate of K. Total corm mass plant^{-1} was influenced by K supply (P< 0.000) but not fertiliser type (P< 0.238) or the interaction between K rate and fertiliser type (P< 0.086) (Figure 7b). The trends for total fresh mass plant^{-1} were similar to that of export mass except for the KNO_3-150 treatment which was almost 1 kg greater plant^{-1}.

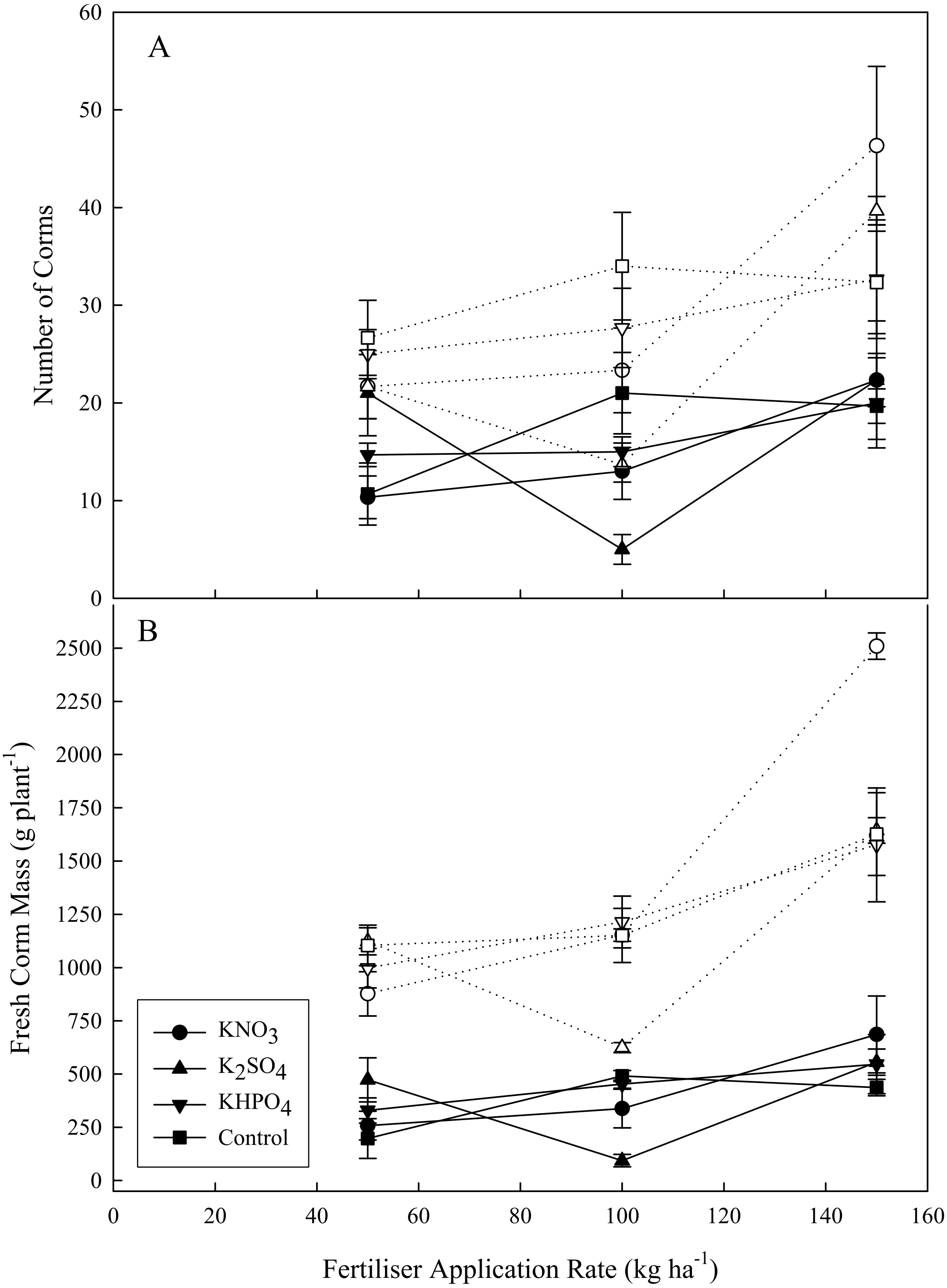

Figure 7 Total and export quality yield of sato-imo (*Colocasia esculenta* var. *antiquorum*) from different potassium sources with varying supply rates, grown at Cudgen in the Northern Rivers region of NSW and harvested during July 2002: a) number of corms; b) fresh mass of corms. Dotted lines represent totals and solid lines represent export quality, all values are means and bars represent S.E. (n=3).

Experiment 6 Effect of propagation corm size on yield of sato-imo (*Colocasia esculenta* spp *antiquorum*).

Materials and Methods

An extra treatment excising the apical meristem from 50 g propagation corms was also included, in addition to the treatments mentioned in the report on corm propagation size in the other sites. The apical meristem was removed with approximately 1 g of corm tissue from corms using a budding knife and the cut surface allowed to dry before planting. The trial was installed at Burringbar and Eden Creek during the 01/02 season and at Clothiers Creek (without the apical meristem removal treatment) during the 02/03 growing season.

Results and Discussion

The trial at Burringbar was abandoned due to grower incapacitation, the trial plot was over-grown with weeds and the irrigation scheduling was intermittent. The trial at Eden Creek was abandoned due to drought and water-restrictions that prevented irrigation of crops.

The effect of apical meristem removal to investigate the manipulation of the side shoot growth remains unresolved. The rationale was to remove any potential of auxins produced in the apical meristem from distribution into the corm mass and inhibiting side shoot growth. Promotion of side shoot growth may have closed over the canopy quicker than with a single main shoot. A closed canopy has been observed in previous trials to reduce weed growth and decrease irrigation inputs through lower ground evaporation by reducing the incidence of solar radiation on exposed ground surfaces.

The trial at Clothiers Creek showed no differences in the export ($P<0.685$) or total ($P<0.217$) numbers of corms plant^{-1} as a function of propagation corm size which were approximately 40 to 50 export-sized corms plant^{-1} and 70 to 110 for total, respectively (Figure 8a). Similarly, no differences in the export ($P<0.119$) or total ($P<0.254$) mass plant^{-1} as a function of propagation corm size were found, which were approximately 1 500 to 2 500 g and 3 000 to 5 500 g for export and total, respectively (Figure 8b). There was, however, a slight tendency for quarter-sized propagules to result in greater total number and weight of corms

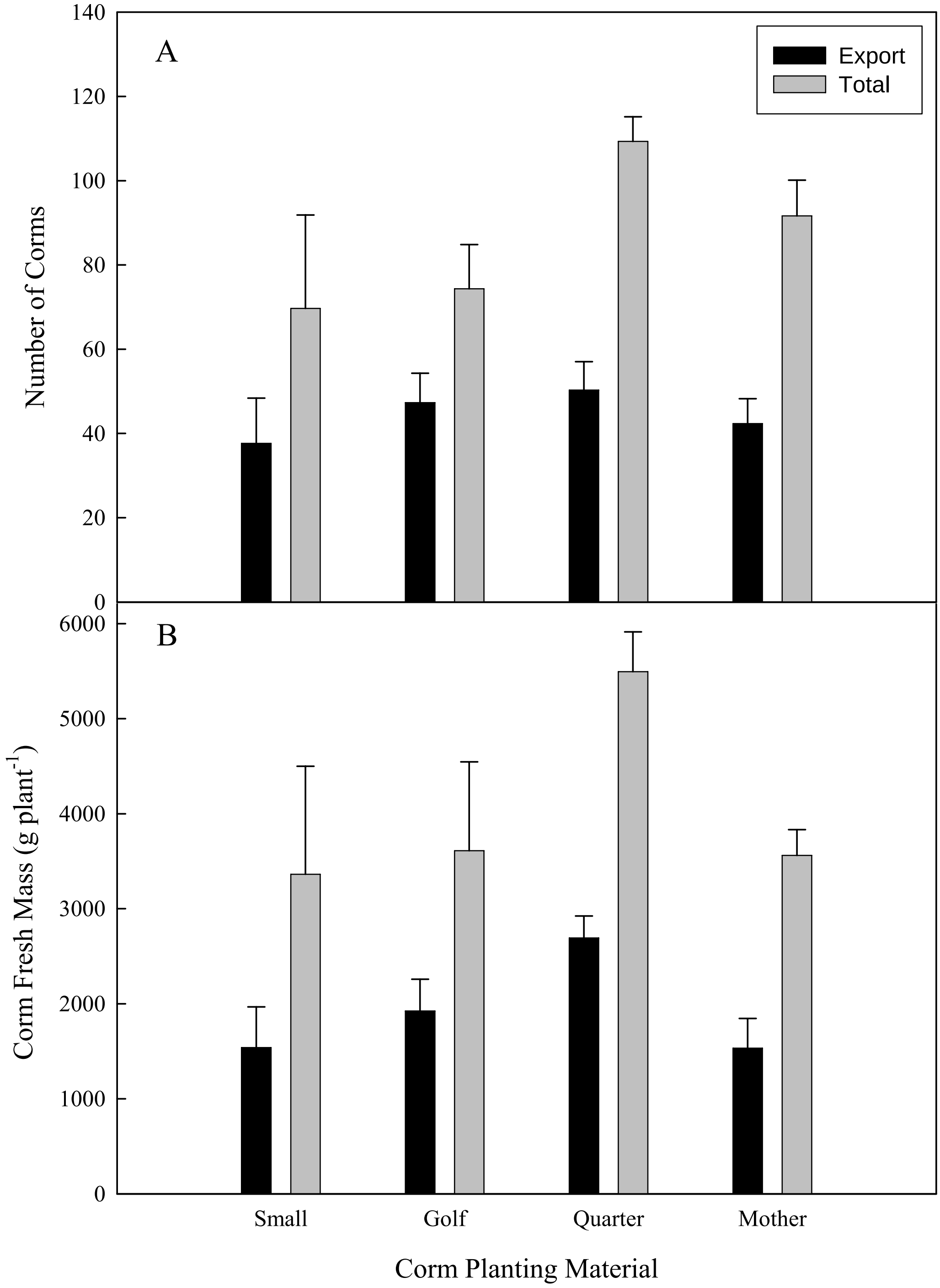

Figure 8 Total and export quality yield of sato-imo as a function of differently sized propagation material grown at Clothiers Creek in the Northern rivers region of NSW, harvested during July 2003: a) Number of Corms per plant b) Corm Fresh Mass per plant. All values are means and bars represent S.E. (n=3).

Experiment 7 Audit of yield and growth conditions for sato-imo (*Colocasia esculenta* spp *antiquorum*) grown during 2002 to 2003 in the Northern Rivers region of NSW.

Introduction, Materials and Methods

During September 2003, a questionnaire was distributed to growers at a group meeting in Murwillumbah. The questionnaire (see attached) comprised of predominantly tick-a-box responses to questions over planting volumes, yields and environmental conditions for the individual sato-imo growing operations. The objectives were to:

a) determine the productivity of different areas,
b) develop an information base from which to plan marketing activities and other events,
c) identify the major factors which growers are finding limit their activities,
d) provide a wider comparison index for all growers' crops and for trials.

Sixty questionnaires were distributed with a stamped return-addressed envelope, conditions of anonymity and discretion of sensitive commercial information were assured.

Results and Discussion

The number of questionnaires returned from growers was nil. This result prevented any wider comparative assessment of sato-imo producing operations and prevented any effectual market planning directives from being implemented.

Experiment 8 Effect of late applications of high rates of nitrogen and potassium on sato-imo (*Colocasia esculenta* spp *antiquorum*) yield.

Rationale

The effect of high rates of applications of nitrogen and potassium fertilisers on corm yields during the period of corm formation may be necessary. Root crops in general are known to require higher available potassium concentrations during root formation to assimilate CO_2 (Mengel and Kirkby 1987). It was shown in Experiment 5 that the higher applications of K during corm formation increased total numbers and mass of corms. Conversely, high nitrogen availability at storage root formation has been demonstrated to encourage further shoot growth at the expense of root development in some crops (Mengel and Kirkby 1987). Therefore, a working ratio between N and K for grower estimates of fertiliser application during corm formation for sato-imo was essential.

Materials and Methods

During February 2003, three rows in the middle of a commercial crop of sato-imo growing at Cudgen in the Northern Rivers region of NSW were selected for treatment applications, each treatment row was separated by a non-treatment row. Treatment sections containing 10 plant replicates were pegged with wooden stakes beginning 10 m from the row edge. A 2 m space of non-treatment plants separated treatments within rows. Plants in the main body of the crop served as control plants for comparison.

Cultivation of the sato-imo crop by the grower was as single mounded rows planted during August 2002. Irrigation was supplied every 14 days using two inch hand-line with monsoon over-head sprinklers. Fertiliser was applied at the rate of 8 bags of CK 44 per hectare (providing x, y and z kg ha^{-1} of N, P and K). Control of weeds was accomplished by first mounding when plants were small enough to pass over with a tractor then Fusilade 500 for grass weeds and Paraquat between rows for broad-leafed weeds.

Treatments included K_2SO_4 at supply rates of 150, 300, and 500 kg K ha^{-1}, KNO_3 at supply rates of 150, 300, and 500 kg K ha^{-1}, and NH_4NO_3 at supply rates of 150, 300, and 500 kg N ha^{-1}. Treatments were applied as pre-prepared solutions in 5 L aliquots and delivered in two separate applications during February and March 2003.

Harvest of plants was undertaken during July 2003 at the behest of the grower, each treatment had three replicates taken for analysis. A pitch-fork was used to unearth the corm mass of the selected plants. Plants selected had to be at least one plant from the treatment edges and separated by a non-harvested plant from another harvested plant. Plants which did not conform to an observable treatment average were not selected. Control plants were taken at random from the crop in rows separate from treatment rows.

Each treatment replicate was washed free of soil, roots and spent petiole residues were removed by hand before dividing corms into marketable (export quality) and unmarketable fractions. Corms were allowed to surface dry before grading, counting and weighing.

Data were tested for homogeneity and ANOVA techniques using Statistica 6.0 software to distinguish any significant differences between treatment means of corm numbers and mass. A confidence level of 95% was used and where ANOVA differences were found, Tukey's honestly significant difference protocol was used to estimate the differences between means.

Results

Fertiliser type ($P<0.655$), fertiliser rate ($P<0.163$) and the interaction between type and rate ($P<0.783$) had no significant effect on export numbers of corms which were stable at between 20 to 30 corms plant^{-1} (Figure 9a). Fertiliser type ($P<0.616$) and the interaction between type and rate ($P<0.937$) had no significant effect on total numbers of corms though fertiliser rate ($P<0.163$) 150 to 300 kg ha^{-1} favoured higher total corm numbers which ranged from 50 to 70 corms plant^{-1} compared to the zero control (43 corms) and 500 kg ha^{-1} treatment (range between 42 to 56 corms plant^{-1}).

Fertiliser type ($P<0.724$), fertiliser rate ($P<0.444$) and the interaction between type and rate ($P<0.948$) had no significant effect on export mass of corms which were stable at between 940 to 1411 g plant^{-1} (Figure 9b). Similarly, fertiliser type ($P<0.329$), fertiliser rate ($P<0.869$) and the interaction between type and rate ($P<0.169$) had no significant effect on export numbers of corms which were stable at between 2 500 to 4040 g plant^{-1}.

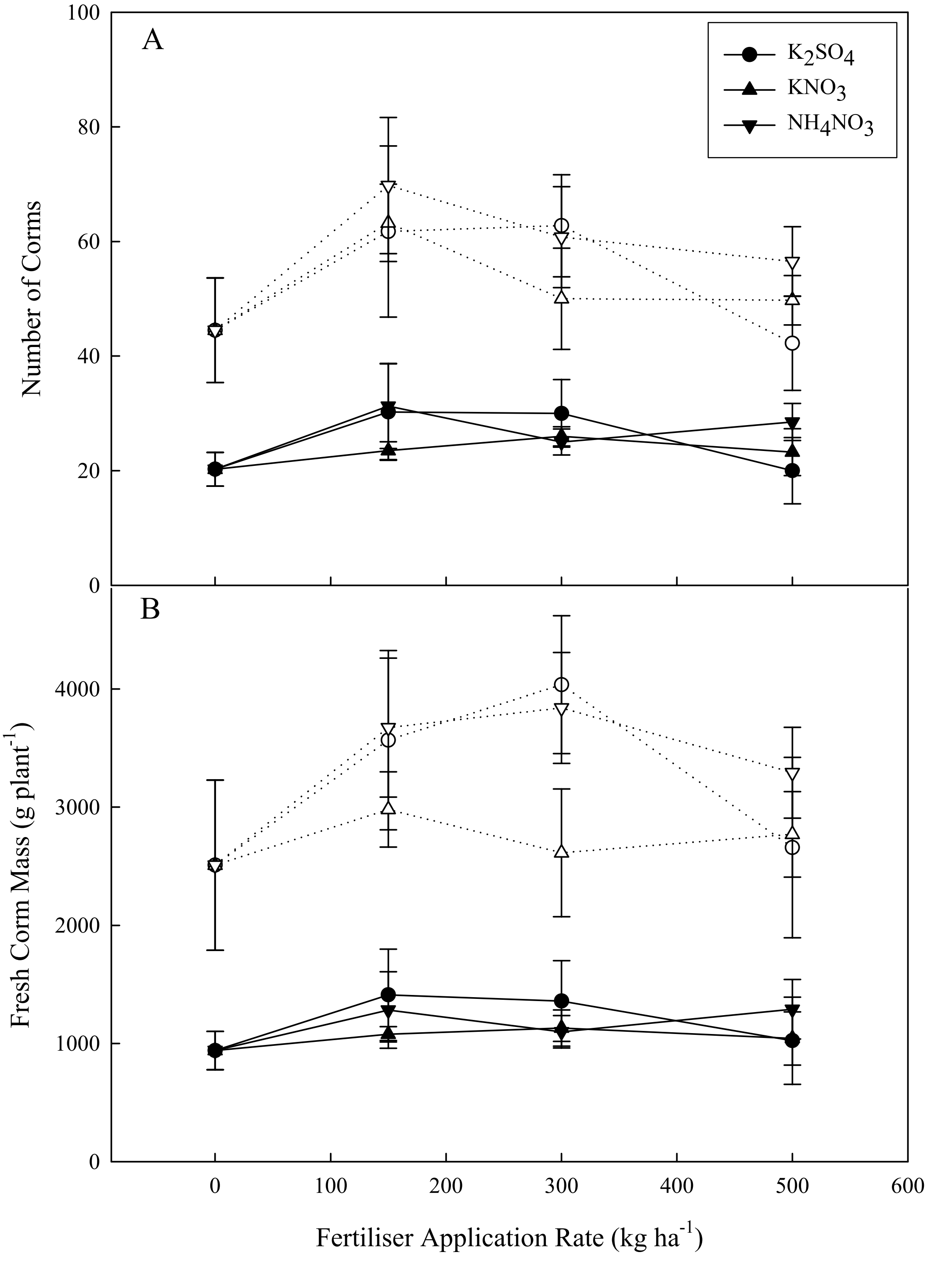

Figure 9 Total and export quality yield of sato-imo (*Colocasia esculenta* var. *antiquorum*) from different nitrogen and potassium sources with varying supply rates, grown at Cudgen in the Northern Rivers region of NSW and harvested during July 2003: a) number of corms per plant ; b) fresh corm mass per plant. All values are means and bars represent S.E. (n=3), solid symbols and lines represent exports, and open dotted symbols and lines represent totals.

Experiment 9 Effect of soil type and phosphorous concentration on sato-imo (*Colocasia esculenta* spp *antiquorum*) yield.

Rationale

The discrepancy between yields achieved from sites in the Northern Rivers could not be solely attributed to climate or soil type. Further, it was necessary to evaluate the soils of use to sato-imo growers in response to phosphorous applications. Therefore, a trial comparing the two major soil groups used for growing sato-imo in the Northern Rivers was set up at a single location with a second factor incorporated into the experiment evaluating the effect of phosphorous on sato-imo yields.

Materials and Methods

Plant Culture

Three spherically shaped corms of 20 to 25g mass were planted 10 cm deep in an equilateral triangle pattern in twelve 200 L concrete lysimeters. Each lysimeter was submerged into surrounding soil and situated in a full sun aspect. The lysimeters contained 50% sand at the bottom and 50% treatment media in the top, the depth of treatment media (>60 cm) ensuring all roots of the plants were completely encased in treatment media.

Each plant was provided with 4 ml hr^{-1} of water delivered twice daily for 1 hour on each occasion through regulated emitting drippers controlled by a programmed irrigation unit with a solenoid on a central pipe inlet. Any weed proliferation was controlled by hand and pests, monitored on a daily basis were physically removed.

Nutrients were applied at four separate intervals. An initial application prior to planting and coinciding with the soil preparations comprised 25 kg ha^{-1} KNO_3, 50 kg ha^{-1} Ca_2NO_3, 25 kg ha^{-1} $MgSO_4$, and the recommended rate of a standard trace element mix. The first side dressing applied during the first week of December 2003 was composed of 25 kg ha^{-1} KNO_3 and 50 kg ha^{-1} Ca_2NO_3. The second side dressing applied during the first week of February 2004 comprised 25 kg ha^{-1} KNO_3 and 25 kg ha^{-1} $MgSO_4$. The third side dressing applied during the first week of March 2004 comprised 25 kg ha^{-1} KNO_3 and 150 kg ha^{-1} K_2SO_4.

Harvest of plants was undertaken during June 2004 after the first major frost killed plant above-ground organs. Each treatment replicate was washed free of soil, roots and spent petiole residues were removed by hand before dividing corms into marketable (export quality) and unmarketable fractions. Corms were allowed to surface dry before weighing.

Experimental Design

A two-factorial trial evaluating the yield responses to soil type and P supply treatments was commissioned on 7th of October 2003. Soil treatments included red volcanic soil typical of the Cudgen and Alstonville plateaux (ferrosols), the dark chocolate soils found at inland sites around the Kyogle and Lismore areas (dermosols), and a sand control. Phosphorous supply treatments were 25, 50, 75, and 100 kg ha^{-1} of P as triple superphosphate, applied as an initial application at soil preparation. There were 3 replicates per treatment totalling 36 plants. The trial was located at the NSW DPI Horticultural Station at Alstonville, situated midway between coastal and inland sato-imo evaluation sites. Plants were monitored for obvious expressions of nutrient disorder.

Total and export corm numbers and mass for each treatment were recorded. Data was tested for homogeneity and ANOVA techniques using Statistica 6.0 software to distinguish any significant differences between treatment means of corm numbers and mass. The mass fraction of the soil water at harvest was calculated by weighing soil at harvest, drying at 80°C, reweighed and tested with ANOVA techniques for differences. The mass fraction of the soil water was then correlated against the number and mass of corms both export and total. A confidence level of 95% was used and where ANOVA differences were found, Tukey's honestly significant difference protocol was used to estimate the differences between means.

Results

Phosphorous supply rates ($P< 0.039$) and soil type ($P<0.000$) but not the interaction between P supply and soil type ($P<0.146$) had significant effects on the export number of sato-imo corms (Figure 10a). Export numbers of corms generally decreased with increasing supply of P from approximately 26 corms at P_{25} to 3 corms at P_{100} for sand and from 36 corms at P_{25} to 23 corms at P_{75} corms for dermosols. Ferrosol yield ranged between a high of 40 corms at P_{50} and a low of 24 corms at P_{75}, and was higher than dermosol or sand.

Total corm numbers were influenced by P supply ($P< 0.001$), soil type ($P< 0.000$) and the interaction between P supply and soil type ($P< 0.001$) (Figure 10a). Plants grown in ferrosols yielded a total of 67 corms at P_{25} increasing to 137 corms at P_{50} before decreasing to 97 and 77 corms for P_{75} to P_{100}. Dermosols yielded a total of 63 to 77 corms between P_{25} and P_{75} before rising to 95 corms at P_{100}. The sand treatment yielded between 84 and 95 corms for P_{25} to P_{50} before rapidly decreasing to 34 and 27 corms at P_{75} and P_{100}.

Phosphorous supply rates ($P< 0.000$), soil type ($P<0.004$) and the interaction between P supply and soil type ($P<0.036$) had significant effects on the export mass of sato-imo corms (Figure 10b). Export mass of corms generally decreased with increasing supply of P from approximately 1.10 kg $plant^{-1}$ at P_{25} to 0.03 kg $plant^{-1}$ at P_{100} for sand and from 1.50 kg $plant^{-1}$ at P_{25} to between 0.96 and 1.07 kg $plant^{-1}$ at P_{50} to P_{100} for dermosols. Ferrosols yielded between a high of 1.56 kg $plant^{-1}$ at P_{50} and a low of 1.00 kg $plant^{-1}$ at P_{75}.

Total corm mass was influenced by P supply ($P< 0.000$), soil type ($P< 0.003$) and the interaction between P supply and soil type ($P< 0.007$) (Figure 10b). Plants grown in ferrosols yielded a total of 3.23 kg $plant^{-1}$ at P_{25} increasing to 5.84 kg $plant^{-1}$ at P_{50} before decreasing to 3.78 and 2.38 kg $plant^{-1}$ for P_{100} and P_{75}. Dermosols yielded a total of 2.64 to 2.09 kg $plant^{-1}$ between P_{25} and P_{75} before rising to 2.83 kg $plant^{-1}$ at P_{100}. The sand treatment decreased mass dramatically from 2.41 and 0.40 kg $plant^{-1}$ between P_{25} to P_{100}.

The soil water fraction held within ferrosols and dermosols was found to be similar to each other though greater than that held in the sand soil ($P<0.000$). Significant correlations ($P<0.05$) between soil water mass fraction and export number ($r = 0.73$), export mass ($r = 0.74$) and total mass ($r = 0.64$) were found (Figures 11a-b), but not total corm numbers ($r = 0.43$) (Figure 11a). This revealed a possible alternative explanation for the differences between soil influences other than an interaction with P supply or the inherent benefit of either soil treatment.

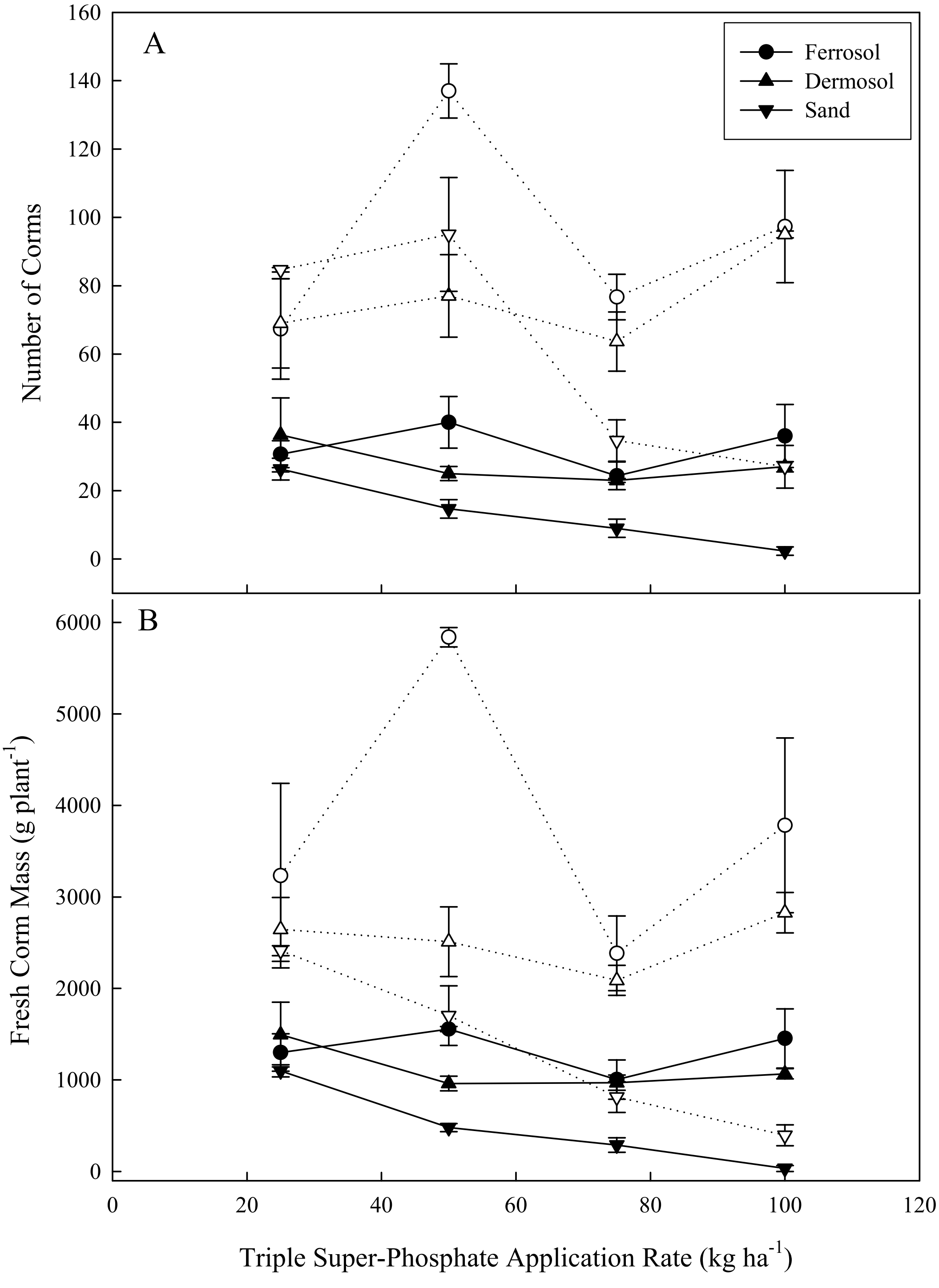

Figure 10 Total and export quality yield of sato-imo (*Colocasia esculenta* var. *antiquorum*) grown in containers with differing soil types and with varying phosphorous supply rates: a) number of corms per plant; b) fresh corm mass per plant. All values are means and bars represent S.E. (n=3), solid symbols and lines represent exports, and open dotted symbols and lines represent totals.

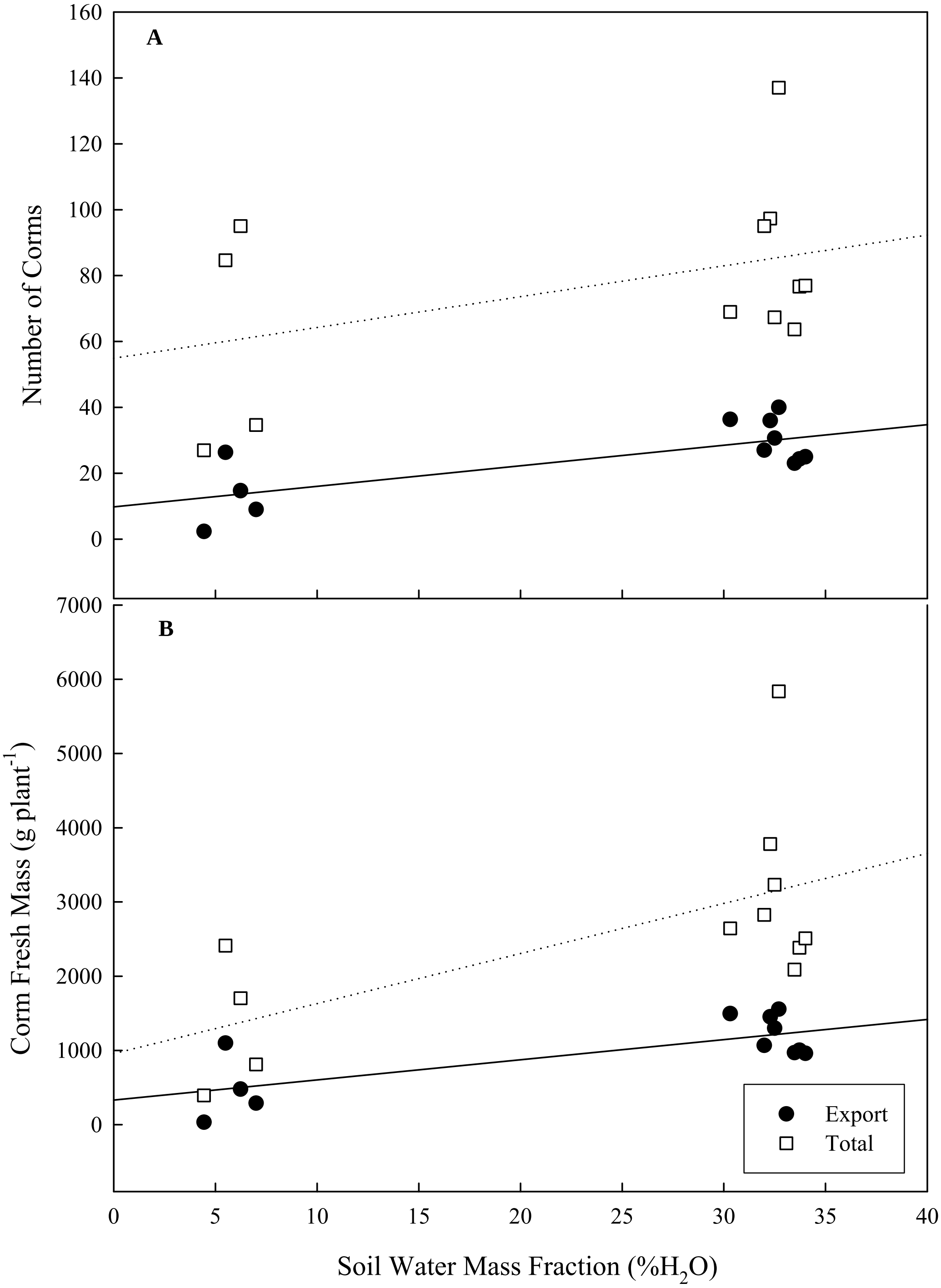

Figure 11 Correlation of total and export quality yield of sato-imo (*Colocasia esculenta* var. *antiquorum*) grown in containers with differing soil types under varying phosphorous supply rates with soil water mass fraction: a) number of corms per plant [export (r = 0.73), total (r = 0.43)]; b) fresh corm mass per plant [export (r = 0.74), total (r = 0.64)]. All values are means and bars represent S.E. (n=3), solid lines represent exports and dotted lines represent totals.

Experiment 10 Effect of irrigation frequency and volume on yield of sato-imo (*Colocasia esculenta* spp *antiquorum*).

Rationale

Observations from the previous trials have shown the availability of water to plants to be the most important limiting factor that constrains maximum expression of sato-imo growth and development. The volume of available water, the frequency of delivery, and the interaction of these two factors have not been adequately evaluated (see Experiment 3) with respect to the effects on sato-imo yield parameters. Therefore, a trial was implemented to challenge sato-imo with a brace of irrigation volumes delivered at different frequencies.

Materials and Methods

Plant Culture

During the first week of December 2003, the trial was set-up at Gosford HRAS. Corms of mass 20 to 30 g were planted 10 cm deep in a staggered double spacing 40 cm by 40 cm planting per row over five rows. Each row was a raised bed 1 m wide and 20 m long. Bed preparation was conducted by rotary hoe and fertilisers were incorporated during this process. The soil was a dark sandy loam of pH 5.7 after liming prior to soil work.

Nutrients were applied on four separate occasions. An initial application prior to planting and coinciding with the soil preparations comprised 25 kg ha^{-1} KNO_3, 50 kg ha^{-1} Ca_2NO_3, 25 kg ha^{-1} triple super-phosphate, 25 kg ha^{-1} $MgSO_4$, and the recommended rate of a standard trace element mix. The first side dressing applied during the first week of December 2003 comprised 25 kg ha^{-1} KNO_3 and 50 kg ha^{-1} Ca_2NO_3. The second side dressing applied during the first week of February 2004 comprised 25 kg ha^{-1} KNO_3 and 25 kg ha^{-1} $MgSO_4$. The third side dressing applied during the first week of March 2004 comprised 25 kg ha^{-1} KNO_3 and 150 kg ha^{-1} K_2SO_4

Water for irrigation was supplied through a 50 mm black poly-pipe fed by a permanently primed pressure activated pump from an on-site reservoir. Supplied water was controlled via an isolation valve, disc-filtration, and a back pressure regulator. A 20 mm poly-pipe was used for each row to supply regulated drip emitters. Each row was controlled by an isolation valve and a solenoid valve. Straw mulch was applied for weed control and water retention purposes. Weeds and pests were monitored on a regular basis and dealt with manually as required.

Experimental Design

The trial was set-up as a two-factorial investigation of frequency of water delivery and volume of water delivery per application. Frequency treatments included daily, 5 day and 10 day intervals with a 1 hr flow controlled by a battery powered programmable irrigation unit operating the solenoid valves. Volume treatments were 0, 2, 4, 8 and 12 L hr^{-1} controlled by regulated drippers. Frequency treatments were in dedicated rows containing each of the volume treatments. Volume treatments were randomly allocated within a frequency row and comprised 2 m row length separated by 1 m with row end buffer zones of 3.5 m. Non-treatment plants received 2 L H_2O hr^{-1} in non-treatment rows with the 5 day frequency of delivery and 2 L H_2O hr^{-1} volume drippers. The zero treatment contained no drip emitters and relied solely on rainfall. Irrigation treatments were terminated in April of 2004 to allow for the corm formation stage and discourage new shoots from plants.

Harvest of plants was undertaken during June 2004 after frost had killed the shoots. Plants were dug manually and three samples from each treatment taken for analysis. Soil and plant detritus was removed from corms before assessment.

Total and export corm numbers and mass for each treatment were recorded. Data was tested for homogeneity and ANOVA techniques for a two-factorial situation using Statistica 6.0 software to distinguish any significant differences between treatment means of corm numbers and mass. A confidence level of 95% was used and where ANOVA differences were found, Tukey's honestly significant difference protocol was used to estimate the differences between means

Results

Irrigation frequency ($P< 0.002$) but not volume ($P<0.523$) or the interaction between frequency and volume ($P<0.526$) had significant effects on the export number of sato-imo corms (Figure 12a). Export numbers of corms generally were similar with daily and five day treatments at approximately 15 to 30 corms per plant. The range for 10 daily frequency was between 10 to 15 corms per plant. Total corm numbers were similarly influenced by irrigation frequency ($P< 0.009$) but not volume ($P< 0.377$) or the interaction between frequency and volume ($P< 0.792$) (Figure 12a).

Irrigation frequency ($P< 0.002$) but not volume ($P<0.796$) or the interaction between frequency and volume ($P<0.562$) had significant effects on the export mass of sato-imo corms (Figure 12b). Export mass of corms generally were similar with daily and five day treatments at approximately 647 to 1 051 g $plant^{-1}$. The range for 10 daily frequency was between 261 to 597 g $plant^{-1}$. Total corm mass was similarly influenced by irrigation frequency ($P< 0.001$) but not volume ($P< 0.503$) or the interaction between frequency and volume ($P< 0.631$) (Figure 12b). Total yields ranged between 833 g $plant^{-1}$ to 1 611 g $plant^{-1}$ for daily and 5 day treatments, and 512 to 819 g $plant^{-1}$ for 10 day frequency treatments.

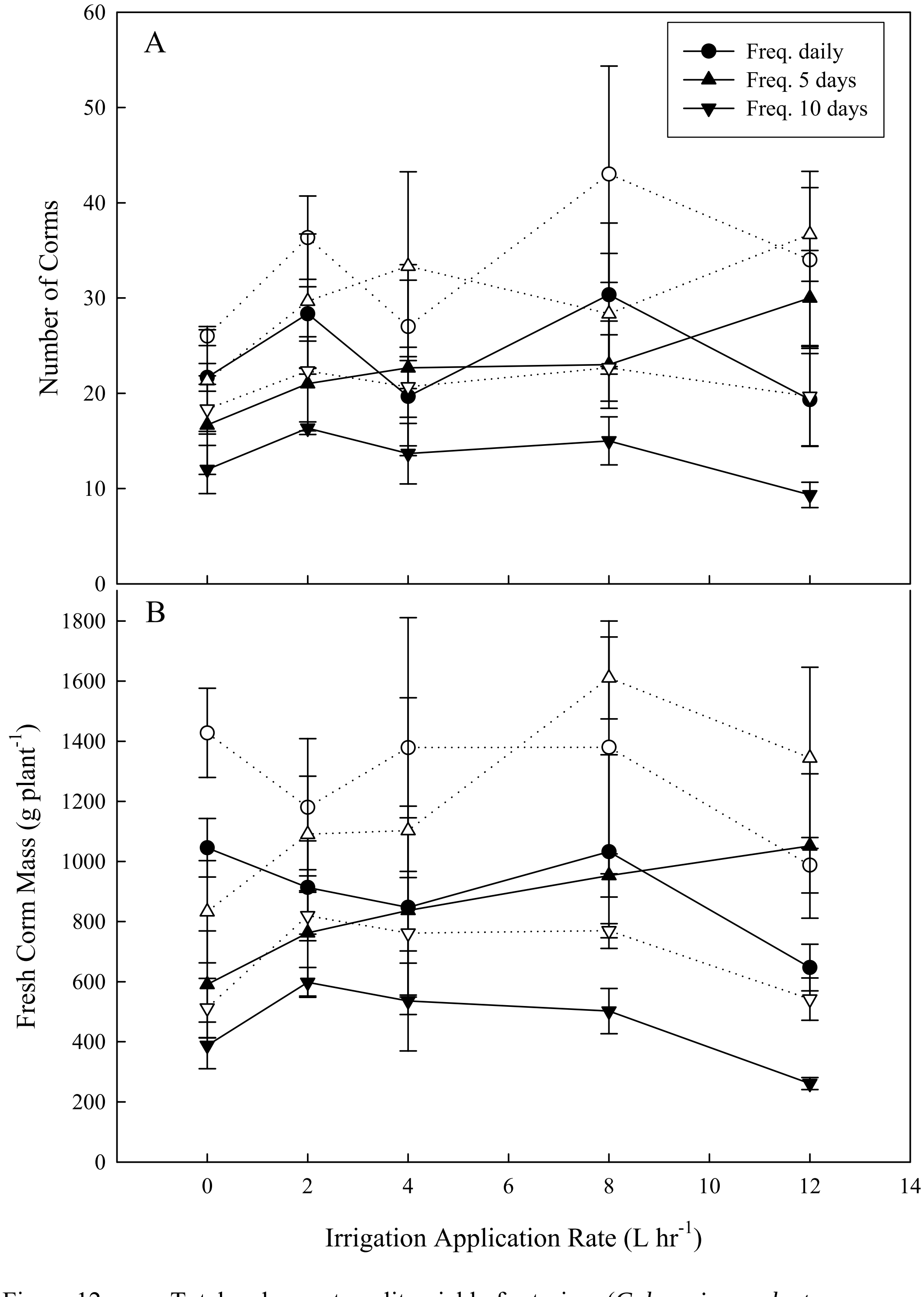

Figure 12 Total and export quality yield of sato-imo (*Colocasia esculenta* var. *antiquorum*) as a function of irrigation frequency and volume, grown at Gosford NSW and harvested during July 2004: a) number of corms per plant; b) fresh corm mass per plant. All values are means and bars represent S.E. (n=3), solid symbols and lines represent exports, open dotted symbols and lines represent totals.

General Discussion

The results found in Experiment 1 show that correct planting and harvest timing is essential to maximising the potential yield according to site location. Inland planting is best performed in October while coastal planting should be undertaken during September. Harvest at all sites is best achieved during the months of May to July inclusive. Prior harvest may not be mature and after this period the risk of corms initiating shoot production becomes higher, especially at coastal locations where temperatures and rainfall are higher than inland sites. The results from Experiment 1 also demonstrate the increase of yields as greater experience, information and knowledge of the crop is accumulated with time. The purpose of the on-going site evaluation was to observe the effects of adjustments in cultural applications based upon prior results interpretation. The decrease in yield parameters at Cudgen where consecutive crops were planted, suggest the need to not only rotate different crops over the same site but to re-locate subsequent planting of sato-imo from one season to the next to separate sites.

Experiments 2 and 3 while not achieving the specified goals demonstrated the importance of cultural control of the crop during the growing period. The heavy reliance the crop has on water applications became pronounced when drought reduced precipitation and curbed the ability of some growers to irrigate from local creek water sources. The control of weeds before the closing of the canopy was also seen to be essential. Un-controlled weeds compete for resources, available light and space to develop effectively smothering the crop plants and inhibiting crop growth (Gurnah 1985).

The size of propagation material was a concern of many growers who reported inconsistencies they attributed to planting material. Experiment 6 showed that corm size at planting does not influence yield. This has implications on selection of material for storage for the subsequent season. Smaller un-marketable corms are favoured for storage as more corms can be kept in a smaller storage space. Further, un-marketable larger corms may be useful in secondary value added processes such as peeled frozen product, chipping or starch production. Differences in yield experienced by growers may be a function of poor corm condition at the time of planting rather than corm size.

The application of nitrogen fertilisers were best in the nitrate form as $Ca(NO_3)_2$. The lowest yields due to N treatment from Experiment 4 were delivered as NH_4. The greater yield attributed to $Ca(NO_3)_2$ over KNO_3 may be due to the incorrect timing of K during the crop cycle. Imbalances of the N:K ratio in favour of K during vegetative growth may inhibit shoot production. Jacobs and Clarke (1993) found that increasing N supply increased N content, shoot number, leaf area but not corm mass and Gourlay (1999) reports K excesses can depress yields in some crops. While significant differences were not recorded for N supply rate, the highest yield for corm numbers and mass was consistently attributable to 150 kg ha^{-1} of $Ca(NO_3)_2$. Comparisons of yields with other N trials conducted with *esculenta* varieties in different regions of the world have little or no value due to the wide disparity of environmental conditions between production regions. Comparisons of the amounts of N supplied and their trends influencing yield have far greater meaning under these circumstances. However, due to the wide range of N supply and the effect on yield reported to date, the results of this trial should be considered within it own context. That is, the results suggest that applications of N supplied during the initial stages of vegetative growth for sato-imo in the Northern Rivers are best delivered as nitrate at a rate of 150 kg ha^{-1}. Further trials during the later stages of vegetative growth, leading up to corm initiation and formation may indicate a requirement for additional applications of N to improve yield.

Potassium applications prior and during corm formation were shown to be conducive to increasing yield at supplies up to 150 kg ha^{-1} (Experiment 5). Higher applications of N and K during the later stages of the crop cycle in Experiment 8 did not have an effect on yield. While no improvements in yield were recorded, neither were any decreases, signifying sato-imo as a crop with a high tolerance to nutrient application. Quality of the subsequent corms produced remains unknown. The mechanisms for increased yield may be attributed to an increased tolerance of water deficit and/or an increased leaf area, as reported by Sivan *et al.* (1996). The results from these experiments suggest that N applications should be greater during vegetative stages and decrease towards corm initiation while K applications should be lower at planting and increasing with plant age and development. This necessitates several split applications, a practice which would also minimise the loss of nutrients.

Sato-imo tolerated excessive amounts of N and K but in Experiment 9 displayed sensitivity to higher supplies of 75 to 100 kg ha^{-1} P, a feature consistent with most terrestrial plants (Marschner 1987). In contrast Poihega *et al.* (1996) report an increased taro yield with applications of P up to 90 kg ha^{-1} with lime and mulch, although they suggest limitations at 135 kg ha^{-1} without the additional treatments. Lime and mulch may bind excessive P. The greatest yields from Experiment 9 in all parameters were found for ferrosols at P_{50}. In sand and dermosols, P_{25} provided the highest yields within their media treatment class. Ferrosol high yield may have been an indirect function of the inherent high Fe in the soil binding P and acting as a reservoir regulating P availability (Moody and Boland 1999). Alternatively, the amounts of P in the trial soils were not known and could have been initially high, as were the soils at Gosford and Kyogle. Indeed, the amount of P in these soils at Kyogle was 175 mg/kg and Gosford 200 mg/kg (Colwell), Therefore it was difficult to ascribe any particular mechanism to the result which must be taken at face value. The discrepancy between export and total corm numbers and mass for this treatment in comparison to other treatments raises the question of the value of producing greater amounts of mass and numbers of corms when a greater amount of work is required for grading between export and total quality. Generally, P supplied at 50 kg ha^{-1} is an adequate reference point which growers should base their application, subject to soil analysis.

The similar amounts of water held in the ferrosol and dermosol type soils (Experiment 9) may be a more accurate account of the increased yields observed for both of these soils. The high sand component in the soil at Gosford (Experiment 10) suggest a greater application of water was necessary to achieve maximum yield, and soils with greater clay and organic matter composition which hold more water would require lower application rates. Therefore, there is a need to evaluate water volumes and frequency in different soil types. Support from the results of Expt 9, where greater water retention in the heavier soils correlated to greater yield. Pot trials in controlled atmospheres at a number of sites around the country could be evaluated simultaneously, reducing the logistical problems of transporting soils to one site and spreading the labour of trialling. This approach could generate a larger picture of the sato-imo soil-water relationship in a shorter period of time than a single experiment at one location.

Results from Experiment 10 indicate judicious applications of regular irrigation water influence the potential returns to the growers in terms of gross increases in yield and increased quality per yield. Carefully implemented irrigation schedules will increase overall yield and returns, and minimise the resources required for postharvest processes. For example an equivalent export yield for 12 L hr^{-1} plant^{-1} every 5 days (576 L in 240 days growing season, or 19 ML ha^{-1}) and 8 L hr^{-1} plant^{-1} delivered daily (1 920 L plant^{-1} in 240 days growing season or 63.4 ML ha^{-1}) is a vast difference in overall water use. Further, total corm product handling volume during postharvest is approximately 300 g plant^{-1} less for the 5 day frequency application than for the daily application. This extrapolates to approximately 11.8 tonnes ha^{-1} of extra handling of non-marketable product.

The questionnaire from Experiment 7 was intended as the first in a sequence of yearly anonymous feedback inputs. The absence of response from growers has many ramifications. Growers would have been able to assess their own production performance against a reflective average from season-to-season production statistics. Effectively, growers would be able to know whether their production practices needed adjustment or were sound in relative terms. Overseas companies who were target export clients have no reliable production statistics with which to make future estimates of commercial activity. Hence, commercial agents have no confidence or trust in unco-operative growers and would not seek to engage in commercial activity without assurances of known production volumes. Finally, production statistics from an established or new industry situation for any crop provide a greater suite of data (than individual trials) for the researcher to evaluate current situations and advance positions for the improvement of techniques and hopefully yield quality and quantity.

The approach sought by NORADA was a reversal of the traditional approach for the promotion of new crops where the crop is scientifically scrutinised before release to the growing community. For sato-imo the crop propagation material was released to the growing community without prior scientific analysis and the expectation was that preliminary data could be generated via rudimentary field trials and sampling from commercial crops. This would lead to the identification of the most important questions science needs to address and to an industry which could fund the appropriate in-depth scientific investigations. Under the auspices of this mandate there were not enough resources to address all the necessary requirements for industry establishment or apply a variety of techniques during the trials that were conducted. Furthermore, secondary considerations were only ever going to be identified. However, the results achieved have contributed to a moderately successful fledgling industry in the Northern Rivers. Continued success relies upon fine-tuning the production process through in-depth research efforts in concert with developing marketing issues (such as branding of product and reciprocated reliability of export market contacts), and addressing post-harvest storage and transport factors.

Future research on sato-imo production should concentrate on maximising the efficiencies of water delivery. Water applications should receive the highest priority due to the relatively high water requirement of the crop and the ongoing and predicted future drought around the country.
Other research topics to be addressed include:
- determine effective time conscious weed control techniques that require reduced labour inputs. Investigate responses to all nutrients in terms of yield, growth and tissue nutrient concentration to establish a plant/soil analysis index under the contexts of water availability and soil type applications for the crop.
- development of mechanical devices to reduce labour inputs allowing weeding, harvest and post-harvest processes to become efficient.
- look at viable options for waste disposal of un-marketable non-propagation corms which potentially pose an environmental catastrophe.

The measurement parameters for data collection in such trials should include leaf area, canopy cover, plant height, number of shoots, water use and regular plant and soil analyses. All of these components require specialist consideration, large amounts of funding and a co-operative industry to support the efforts of science.

The suite of trials conducted was useful as production information for industry establishment. The growth and development of any crop is a complex of factors with a delicate balance within a wide range of production practices which achieve acceptable yield outcomes. The results found here are not considered definitive values for sato-imo and must be confirmed with further trials and data support. The true picture of any crop is continually evolving with changes in environment, technological improvement and market requirement.

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Appendix 2. Sato-imo Field Trials in Queensland, Northern Territory, Western Australia and NSW

Acknowledgments

Report prepared by Dan White, David Midmore Vong Nguyen and Vynka McVeigh, with trial support by Eric Coleman (QDPI Gatton and Rockhampton) Craig Lemin (QDPI South Johnstone), Mike Hughes (QDPI Southedge), Mark Traynor (NT DPIF), and the following growers:

NSW
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Greg Sparks

QLD
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Harvey Rich
Peter Foxwell
Bill O'Donnell
Bill Pumper
Michael Seeney
Rodney Wolfenden

1 Field trials

All production field trials used the cultivar tentatively named NORADA-1, which is thought to be the same as or similar to the Japanese cultivar "Ishikawa-wase". This particular cultivar was sourced from within Australia.

2001/2002

Trials conducted in NSW during the 2001-2002 season included some replicated field trials and some observation trials. Those conducted by NORADA are included in a separate companion report.

Due to a limited supply of planting material, trials conducted in Queensland and Northern Territory during the 2001-2002 season were small-scale observational trials only, to provide some basic indications of performance in different geographical locations.

These trials were set up with the following objectives

- Compile tentative yield and quality data under local conditions.
- Compare the yields of different sized corm propagules.
- Provide a sample of harvested corms to the project co-ordinator for quality assessment.
- Identify any crop management issues that may need addressing.

1.1 New South Wales – NSW Agriculture Gosford HRA Station

One replicated trial was conducted at NSW Agriculture's Gosford Horticultural Research and Advisory Station, to measure yield of corms and cormels from different size propagule corms and cormels.

Propagule corms (mother corms) were sorted into three grades according to weight (≤59 g, 60-119 g, ≥120 g) and cormels (daughter corms) were also separated into three size grades (≤19 g, 20-39 g, 40-60 g). Propagules were planted in single rows, with an inter-row distance of 1.5 m and an intra-row plant spacing of 0.50 m. Five replicate plots of each size grade were planted, with three plants per replicate plot.

Plants were fertilised with G5 (N:P:K = 125:125:125 kg/ha), planted on 25 September 2001 and harvested on 25 July 2002 (10 month crop cycle).

Table 1 shows corm yield in terms of number and fresh weight of corms (mother) and cormels (daughter) per plant according to type and size of original propagules. Quite evidently mother corms gave greater total corm weight, and daughter corm weight than did daughter corms as planting material, and there was little difference between the effects of mother corms size on yield whereas daughter corms <19 g consistently gave less yield than did larger daughter corm planting material (Table 1).

Table 2 shows the yield distribution of cormels (daughter corm) within the export size grades, according to type and size of propagule. Daughter corm planting material gave on average a greater proportion of small-sized corms at harvest (Table 2).

Table 1. Taro 2001-2002: Yield and corm size of cultivar (NORADA-1) Ishikawa wase grown at the Gosford HRAS, Central Coast, NSW, 2001/2002.
Planting: 25.9.2001. Harvesting: 25.7.2002, 10 months

	Daughter corms		Mother corms		Total		
	Corm Number/plant	FW/plant g (t/ha)	Corm Number/plant	FW/plant g (t/ha)	Corm No/plant	FW/plant g	Yield t/ha
G1: Mother corm ≥120 g	42.4	1200.9 (16)	1.8	231.3 (3.1)	44.2	1432.2	19.1
G2: Mother corm 60-119 g	42.7	1200.0 (16)	2.0	225.3 (3.6)	44.7	1468.00	19.6
G3: Mother corm ≤ 59 g	36.7	1160.7 (15.5)	1.4	133.2 (1.8)	38.1	1293.9	17.3
G4: Daughter corm 40-60 g	34.3	908.5 (12.1)	1.6	129.0 (1.7)	35.9	1037.5	13.8
G5: Daughter corm 20-39g	36.8	975.6 (13.0)	1.6	190.1 (2.5)	38.4	1165.7	15.5
G6: Daughter corm ≤ 19g	28.6	613.1 (8.2)	1.0	110.8 (1.8)	29.6	752.5	10.0

Table 2. Taro 2001-2002: Corm size distribution of cultivar (NORADA-1) Ishikawa wase grown at the Gosford HRAS, Central Coast, NSW, 2001/2002.

	Corm size distribution				
	% Small (≤ 29 g)	% Medium (30-59 g)	% Large (60-90 g)	% 2Large (≥ 90 g)	Total %
G1:Mother ≥120 g	65	26	5	4	100
G2:Mother 60-119 g	67	25	5	3	100
G3:Mother ≤ 59 g	59	32	3	6	100
G4:Daughter 40-60 g	77	15	5	3	100
G5:Daughter 20-39g	67	21	7	5	100
G6:Daughter ≤ 19g	78	17	5	0	100

1.2 Queensland - DPI Southedge Research Station

An observation trial was established at DPI Southedge Research Station, north of Mareeba.

Fifty-five propagule corms and cormels were provided to Mike Hughes to plant an observational trial. Propagules in the following weight ranges were provided: 38 x 10-19 g; 14 x 20-29 g; 2 x 30-59 g; 1 x 100-299 g. Planting date was January 8th 2001 and harvest was on 5th June 2002.

Growth tended to be poor (cool climate) and yield ranges from 95 to 250 g per plant, not bearing any relation to corm size at planting and not meriting further research.

1.3 Queensland - DPI South Johnstone Research Station

An observation trial was established at DPI South Johnstone Research Station (Centre for Tropical Horticulture), south of Innisfail. Fifty-five propagule corms and cormels (the total number available) were planted in a single 1.0 m row at 0.45 m with-in row spacing and at a depth of 5-10 cm in non-replicated plots according to weight (38 x 10-19 g; 14 x 20-29 g; 2 x 30-59 g; 1 x 100-299 g).

Irrigation was by drip line with emitters every 0.50 m. Soil was kept moist but not wet, with up to two waterings per week if there was no rainfall. The planting date was 18 December 2001 and harvest dates were 21 and 26 July 2002.

Most propagules had already germinated before planting and almost all plants emerged from the soil within a week of planting. Hot and relatively dry weather was experienced following planting to the end of January 2002. By mid-January five losses due to non-emergence or wallaby damage were evident with 50 plants still growing well. Estimated average height at that time was about 12 cm.

In early May plants were about 120 -150 cm tall and leaves did not yet show any signs of dying back. A noticeable number of cormels had emerged or were growing above the soil surface.

According to Craig Lemin planting was later than desirable and was followed by 3-4 months of abnormally hot weather and low rainfall. However the taro grew very well with no observed effect of different sized corms used for planting. No pest problems were experienced and virus testing produced nil result however rots damaged some corms. Also failure to hill-up during the growing phase presumably led to development of poorly-shaped aerial corms that should otherwise have developed properly beneath the soil surface. This resulted in a low yield of marketable corms (on average 49%, Table 3) despite an apparently good total yield (computed to be *c*. 115 t/ha).

Table 3

Single plant yields at South Johnstone, harvested July 21 and 26 July 2002															
Corm No.	Marketable Round				Marketable Elongate				Marketable Mother		Marketable Reject		Unmarketable		Total
	25-45 mm		>45 mm		50-70 mm		>70 mm		>80 mm						
	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	No.	Wt.	Wt.
1	19	449	7	391	14	513	4	258	3	701	5	138	43	995	3445
2	17	409	10	493	21	902	1	83	2	875	3	157	110	3570	6489
3	13	325	12	637	9	422	1	67	1	405	2	30	76	2040	3926
4	17	488	6	376	9	451	7	661	1	517	5	153	113	3797	6443
5	17	434	4	236	11	508	2	143	1	576	2	112	69	2180	4189
6	22	473	21	1095	28	1207	6	582	4	1250	2	88	74	2432	7127
7	13	291	6	399	18	746	1	84	2	947	7	259	80	1721	4447
8	23	522	9	422	20	859	0	0	4	1025	17	1498	95	2560	6886
9	12	286	17	1162	10	389	1	110	3	886	9	378	63	1490	4701
10	20	344	22	1271	12	492	4	328	3	703	5	268	41	678	4084
11	11	221	12	742	15	729	4	359	5	1509	5	188	92	2715	6463
12	25	479	12	554	8	375	1	85	3	944	4	176	70	1252	3865
13	20	406	20	1046	10	634	1	95	5	1692	2	121	76	2686	6680
14	24	434	11	516	13	688	2	186	3	1071	3	179	80	2391	5465
15	15	316	19	844	13	755	2	158	3	1070	3	145	124	4076	7364
16	5	134	19	960	1	99	1	89	1	260	4	206	74	2171	3919
17	11	229	10	601	1	55	0	0	2	696	1	56	90	2618	4255
18	6	152	4	214	0	0	0	0	2	665	5	249	92	2870	4150
19	29	640	18	932	4	247	0	0	3	1012	7	301	120	3634	6766
20	14	285	14	822	2	116	0	0	2	762	0	0	104	2994	4979
Average	17	366	13	686	11	509	2	164	3	878	5	235	84	2444	5282.15

Marketable Reject = corms that were marketable except for having damage/rot etc, Unmarketable = corms that were too small or misshapen

1.4 Queensland - CQU Rockhampton

An observation trial was established at Central Queensland University Rockhampton campus. Raised beds were approximately 1.40 m wide at the base and 0.30 m high. Corms and cormels were planted on 3rd December 2001in double rows, with 0.70 m between paired rows, and intra-row plant spacing of 0.45 m. One hundred propagule corms and cormels were planted at 5-10 cm below the soil surface in non-replicated plots according to weight (19 x <10 g; 55 x 10-19 g; 15 x 20-29 g; 4 x 30-59 g; 4 x 60-99 g; 1 x 100-299 g; 2 x >300 g). Basal fertilizer application was CK55 (13.5 N : 15 P : 12.5 K %w/w) at 52 g/m^2 of bed. First shoot emergence was observed on 16 December 2001.

Irrigation was by mini-sprinklers placed at 50 cm above the bed surface. Irrigation time was 20 min twice per day, then decreasing to 20 min once per day when plants began to exhibit signs of winter leaf dieback/senescence in May (after 5 months). Harvest dates were 7th and 14 th August 2002. Pest and disease control was not required.

Plants that grew from propagule corms of weight less than 20 g did not survive. A total of eight surviving plants were harvested, irrespective of initial propagule size class above 19 g, to record yield data, and growth and development was poor.

Planting quite clearly occurred later than was considered desirable. Although the soil, a heavy clay-loam, was kept moist, temperatures between December 2001 to March 2002 were higher than average and humidity was very low, and this likely resulted in poor germination and growth by causing water stress to the plants and providing conditions favourable to pathogenic soil microorganisms. Many of the propagule cormels rotted before there was notable shoot or root growth, and leaves of plants that did grow were often observed to exhibit wilting despite the soil being moist. Over-watering at times may also have had detrimental effects in the hot conditions. Most corms (75%) were less that 20 g in weight, and total yield was computed at *c.* 14 t/ha.

Table 4. Yield and components for eight plants harvested at CQU, Rockhampton in August 2002.

	mother corm	< 20 g	< 20 g	20-40 g	20-40 g	40-60 g	40-60 g	Total
plant	weight	number	weight (g)	number	weight (g)	number	weight (g)	weight (g)
1. 7-08-2002	129.0	49	346.4	1	28.3			374.7
2. 7-08-2002	53.6	33	279.9	4	99.4			379.3
3. 7-08-2002	76.4	37	175.7	5	138.1			313.8
4. 7-08-2002	94.0	26	209	2	53.5	1	41.2	303.7
5. 7-08-2002	77.7	21	267.6					267.6
6. 7-08-2002	28.6	14	129.7					129.7
7. 14-08-2002	73.3	72	563.1	11	244.1	1	48.5	855.7
8. 14-08-2002	80.5	67	623.5	8	180.0			803.5
Total	613.1	319.0	2594.9	31.0	743.4	2	89.7	3428
Average (per no of plant)	76.6	39.9	324.4	5.2	123.9	1	44.85	428.5

1.5 Queensland - Rossmoya Rockhampton

An observation trial was established on the property of R and R Wolfenden at Rossmoya near Rockhampton. Raised beds were approximately 1.20 m wide at the base and 0.15 m high. Corms and cormels were planted in double rows, with 0.75 m between paired rows and 1.7 m between row pairs, and intra-row plant spacing of 0.42 m. Ninety propagule corms and cormels were planted at 5-10 cm below the soil surface in non-replicated plots according to weight (30 x <10 g; 43 x 10-19 g; 14 x 20-29 g; 2 x 30-59 g; 1 x 100-299 g).

Irrigation was by sprinklers at approximately 50 cm above bed surface. The beds were irrigated daily until soil was wet.

Planting dates were 27 and 29 November 2001

Planting occurred later than was considered desirable. Germination and growth were poor. Although irrigation water was supplied regularly, the abnormally hot and dry weather conditions from November 2001 through February 2002 seemed to dry the surface soil quickly, likely contributing to desiccation of smaller propagules closer to the soil surface and the high temperatures likely contributed to rotting of the larger propagules deeper in the soil The trial was abandoned within in February 2002, with no plants surviving.

1.6 Queensland - DPI Gatton Research Station

An observation trial was established at DPI Gatton Research Station in late 2001. Fifty-five propagule corms and cormels were planted in two single rows, with inter-row distance of approximately 1.0 m, intra-row plant spacing of 0.45 m spacing, and at a depth of 5-10 cm in non-replicated plots according to weight (38 x 10-19 g; 14 x 20-29 g; 2 x 30-59 g; 1 x 100-299 g).

Drip irrigation was used via T-Tape, one line per row on the soil surface.

Germination was slow to get going but survival was been good. Only four corms did not grow.
By the end of April the taro was looking good but did not seem suited to the earlier hot weather. A lot of off-shoots i.e. (cormels converting into shoots) were evident. Many of these shoots were stunted and with green colouring, much as observed at South Johnstone. This could be avoided by hilling up the soil to ensure that cormels are not exposed to sunlight or are fully exposed to the air.

Photos showing the trial at Gatton (April 2002) with cormel converting into a shoot, and the leaf margin burn.

1.7 Northern Territory - Coastal Plains Horticultural Research Farm

An observation trial was established on 1st December 2001 by NT DPIF at Coastal Plains Horticultural Research Farm (CPHRF) near Darwin (soils are sandy loams (10-15 % clay, 45% coarse sand and 28 % fine sand) at 0-to-20-cm soil depth). Raised beds that were 0.50 m wide and 0.30 m high were established with distance between beds of 1.0 m and intra-row plant spacing of 0.30 m. Fifty-one propagule corms and cormels were planted at a depth of 10-20 cm and were planted in non-replicated plots according to weight (34 x 10-19 g; 14 x 20-29 g; 2 x 30-59 g; 1 x 100-299 g). Beds were mulched with hay for soil moisture retention and weed control. Basal fertilizer application was CK55 at 100 g/m of row, superphosphate at 100 g/m of row, and gypsum at 200 g/m of row.

Drip irrigation was via 20 mm high flow T-Tape, one line per bed. Irrigation time was 30 min per day for early growth (first 4 months, to April), increasing to 30 min twice per day after corm initiation (after 4 months, from April, which was also the time of transition from wet season to dry season in the region).

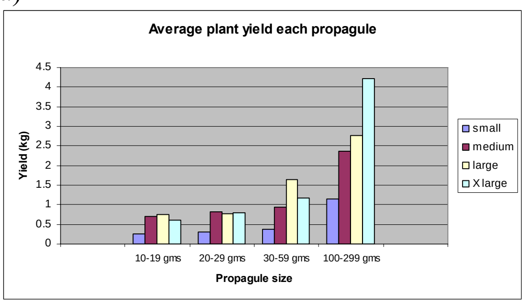
Weekly fertilizer injection was applied through the irrigation line was as follows:
0-1 month – no injection during shoot emergence;
1-4 months – 320 kg of N /ha, 213 kg of K /ha, 100 kg of P /ha;
4-6 months – 80 kg of N /ha, 120 kg K /ha, 48 kg Ca /ha.

Pest and disease control was not required. Harvest dates were from 28 May to 2 July 2002 at one week intervals.

The trial was planted and grown during the hot and humid conditions of the wet season with fairly regular monsoon rainfall from January through to March. With weekly injections of fertilizer, growth was fast and vigourous. The peak in vegetative growth was in early April, about 4 months from planting. In early May, plant leaves turned a paler colour and leaf petioles started to bend over. These may be visual signs that corm development was complete. By mid-May, leaves had died back and progressive harvests commenced in late May. Grading was done on corm weight only, not on other external characteristics.

Figure 1 shows the average corm number and weight for each propagule size. Although the sample plant numbers were low, the increase in total yield with larger propagules was evident. The very high yield for the plant from the 100-299 g propagule size was most likely due to lack of competition from neighbouring plants. The percentage of unmarketable yield for each propagule size was not significantly different. If only medium and large grades are suitable for export, approximately 40% of harvested yield was unmarketable.

a)



b)

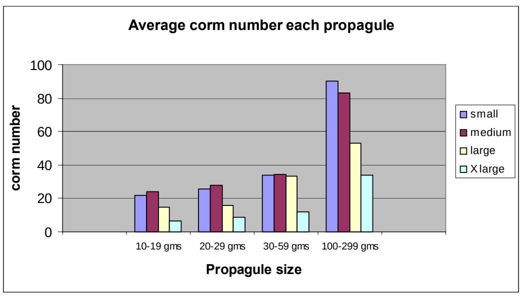


Figure 1 (a) Corm weight and (b) corm number per plant for each propagule size, averaged across all harvest dates.

Table 5 shows that delay of harvest after early June did not influence yield. This suggests that optimum harvest maturity for a December planting is at 6 months.

Table 5. Yield per plant on four harvest dates. (Average from 7 plants per harvest, for plants germinated from 10-19 g propagule size only)

Harvest Date	GRADES								
	Small (<20 g)		Medium (20 – 40 g)		Large (40 – 60 g)		Extra large (>60 g)		Mother corm
	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Number	Weight (kg)	Weight (kg)
4/06/2002	16	0.20	20	0.64	14	0.73	8	0.75	0.22
11/06/2002	24	0.30	21	0.63	15	0.74	7	0.58	0.24
18/06/2002	21	0.23	23	0.67	14	0.69	4	0.38	0.21
25/06/2002	19	0.22	19	0.57	14	0.70	7	0.60	0.21

2 2002/2003

Field experiments were conducted at fewer sites than in the 2001-2002 season, due to limited funds and planting material.

An attempt was made to establish three different experiments (one on plant spacing, one on nutrition and one on corm size at plating) in a number of locations in NSW, Queensland (and originally NT and WA as well). The idea was to have each standardised experiment occurring in more than one geographic region at a time to compare production performance.

The following Materials and Methods guidelines were sent to research collaborators for implementation.

Materials and methods

The corms were obtained from northern NSW (Eden Creek, near Kyogle) for distribution for the multilocation experiments. Before they were sent to CQU Rockhampton, they were dipped in copper oxychloride (4 g/L) fungicide and Rogor (recommended concentration for cabbage) insecticide. At CQU they were stored between 10-12°C and further dipped in a mixture of copper oxychloride (4 g/L) and Mancozeb (4 g/L) as a fungicide treatment. The corms were distributed from CQU Rockhampton to the collaborators.

Cultivation and fertiliser recommendations are based on those in the NORADA HORTFact on Sato-imo (HF2002si) by David Hicks.

Preparation & Planting

Soil test (0-30 cm depth) should be performed before ground preparation to determine fertiliser requirements. Sample from cores to 30 cm depth, from representative positions in the planting area. Combine sub-samples to be sent (approximately 1 kg) to Plant Sciences, Central Queensland University.

Plots were 4.5 m in length, and consisted of two rows. Rows could be single or paired.

Distance between single rows should be 90 cm, and distance between centres of paired rows should be 1.8 m. Single rows should be mounded 30 cm high and 50-60 cm wide (i.e., 25-30 cm both sides of plants). Soil should be mounded around plants at 1 month and 4 months after sowing to encourage corm swelling (or as required to prevent exposure of corms).

Half of the planned fertiliser should be incorporated into the rows pre-planting. See fertiliser section below.

Plot layouts are shown in each experiment section below. The shaded table cells represent the actual plots. The treatment plots should be randomised within each block (replicate). Additional corms (of various sizes) will be provided to plant a border (hopefully enough for 2-row border) around the outside of the entire experiment. The inter-row and interplant spacing of border plants should be the same/similar to nearby experimental plants. Hopefully there will be enough corms to prepare a border consisting of two rows of plants.

Fertiliser
Applications to be based on the shortfall identified by the soil test.

The definitions for Low, Medium and High levels of N, K, and P shown in the table below will be used for the trials.

	Nitrogen (N) kg/ha			Potassium (K) kg/ha			Phosphorous (P) kg/ha		
	Low	Med.	High	Low	Med.	High	Low	Med.	High
HortFact recommended range	50	100	150	100	200	300	50	75	100

Unless specified, as in Experiment 2 (nitrogen-potassium trial), macro elements should be at the following levels:

N: 150 kg/ha (high)
K: 300 kg/ha (high)
P: 100 kg/ha (high)

As the soil test results are not likely to be known before planting, half of the total target N, P & K should be incorporated with the soil, pre-planting (eg. for High N level, apply 75kg/ha, regardless of soil test result).

The remaining amount of N, K, & P (based on soil test results) should be applied in equal amounts at 2, 3, 4 & 5 months after planting.

Currently there are no recommendations for micro and trace elements, however they should be incorporated at pre-planting.

Sowing/planting Date
First planting: first week September, or as soon as possible thereafter, but not later than 21 Sept.
Second planting (Experiment 1): 6-8 weeks after first planting.

Sowing/Planting
If you usually sprout all corms before planting, then do so, otherwise plant corms >30g weight directly in the soil at 10 cm depth.

All corms <30 g weight should be sprouted prior to planting. Sprout in moist propagation beds at 25-30°C temperature.

Mulch

Only mulch if it is likely to be considered for commercial production in your region. Northern NSW commercial growers do not mulch (organic mulching is labour intensive and plastic mulching is damaged by emerging shoots arising from lateral corms).

Water management
Quote from sato-imo HortFact:
Water is essential for growth. Adequate amounts should be delivered on a regular basis to prevent wilting of the oldest leaves. Restricting water may promote corm formation and could be a management tool, provided that the plant is large enough to provide the energy for correct sized corms. Plants which are not watered will 'feed' upon their oldest growth before wilting.

Soil should be kept moist, applying water at a rate to compensate evaporation and transpiration, but avoid waterlogging of soil. Particularly maintain surface soil moisture in early growth of crop, especially for small corms.

EXPERIMENT 1 Spacing and Planting Date trial

Experiment locations. (originally to be 8 locations, including one in NT)

Queensland:

- Gordonvale (Cairns) (commercial farm)
- CQU Emerald (commercial farm)
- Gatton (commercial farm)

NSW:

- Northern Rivers 2 Commercial farms (Burringbar and Eden Creek – see D. Hicks report)
- Gosford (NSWAg res. station)

WA:

- Medina (AgWA res. station)

Each plot:

- 4.5m length
- Two rows (paired or single)

Treatments:

- Two Planting Dates × Three intra-row (interplant) Spacing Distances (30, 50, 70 cm) (6 treatments)
- Planting dates: 1st week in September (ideally, but no later than 3rd week in Sept.) & 6-8 weeks after first planting.

"Seed" corms:

- Size: 10-20 g
- Sprout/germinate all corms prior to planting in field. (Eg. sprout in moist propagation bed, at 25-30°C temperature)

Corm numbers and spacing:

Interplant (intra-row) spacing (cm)	No. of corms per 4.5 m plot [distance from first to last plant]	No. of corms per 3 blocks (ie. each sowing date)	No. of corms per site (ie. both sowing dates)
30	30 (15/row) [420 cm]	90	180
50	18 (9/row) [400 cm]	54	108
70	14 (7/row) [420 cm]	42	84
	Total for each sowing date	186	
	Total for each site		372

Inter-row spacing:

- Distance between single rows should be 90 cm, and distance between centres of paired rows should be 1.8 m.
- Single rows should be mounded 30 cm high and 50-60 cm wide (ie. 25-30cm both sides of plants).

Plan/Layout:

- 3 spacing treatments × 2 planting dates × 3 blocks

Border plants:

- Corms will be provided to plant around the outside of the entire experiment as a border (two rows).

EXPERIMENT 2 Nitrogen & Potassium trial

Experiment locations. (originally to be 4 locations, one each in NSW, Qld, NT & WA)

Queensland:

- Gatton (commercial farm)

NSW:

- Gosford (NSWAg res. station)

Each plot (block):

- 4.5 m length
- Two rows (paired or single)

Treatments:

- Two levels of N (med. & high) fertiliser × Two levels of K (med. & high) fertiliser (4 treatments)

"Seed" corms:

- 20-30 g only
- Sprout/germinate all corms prior to planting in field. (Eg. sprout in moist propagation bed, at 25-30°C temperature)

Interplant (intra-row) spacing:

- 50 cm

Inter-row spacing:

- Distance between single rows should be 90 cm, and distance between centres of paired rows should be 1.8 m.
- Single rows should be mounded 30 cm high and 50-60 cm wide (ie. 25-30cm both sides of plants).

Plan/Layout:

- 18 (9/row) corms/plot × 2 N treatments × 2 K treatments × 3 blocks = 216 corms per site

Border plants: Corms will be provided to plant around the outside of the entire experiment as a border (two rows).

EXPERIMENT 3 Seed corm size trial

Experiment locations. (originally to be one location in Qld as well)

Qld: Gordonvale (Cairns) (commercial farm)

NSW: Northern Rivers 2 Commercial farms (Burringbar and Eden Creek – see D. Hicks report)

Each plot (block):
- 4.5m length
- Two rows (paired or single)

Treatments:
- Three corm size classes: Small: 30-50 g
Medium: 50-100 g
Large: > 100 g (3 treatments)

- Sow corms directly in soil (10 cm depth).

Interplant (intra-row) spacing:
- 50 cm

Inter-row spacing:

- Distance between single rows should be 90 cm, and distance between centres of paired rows should be 1.8 m.

- Single rows should be mounded 30 cm high and 50-60 cm wide (ie. 25-30cm both sides of plants).

Plan/Layout:
- 18 (9/row) corms/plot × 3 corm size treatments × 3 blocks = 162 corms per site
- Per site: 54 × each of S, M, L size corms

Border plants:
- Corms will be provided to plant around the outside of the entire experiment as a border (two rows).

Information and Data to record

Soil type

Soil test results (pH, nutrients, organic matter, salinity, etc)

Rainfall (daily)

Temperature:
- Daily max. and min. air temperature (measured at least one day per week)
- If possible, daily max. and min. soil temperature at planting depth (measured at least one day per week)

Time of 50% emergence in field (not applicable to transplanted plants)

Fortnightly canopy cover estimation

Biomass (above- & below-ground fresh weight and, ideally, dry weight as well) from corner plants at one month intervals after planting

Harvest dates

Above- and below-ground biomass (fresh) of two rows (3m long) at final harvest

Yield & size distribution (number and weight of corms in each predetermined category: cull and marketable; S, M, L, 2L)

Soil Analysis

One kilogram soil samples from proposed experiment sites were sent to CQU Rockhampton for chemical and physical analysis to assist with soil amendment recommendations.

The results are shown in the following table:

Site	Gordonvale (Cairns) Qld	Emerald Qld	Gatton Qld	Burringbar NSW	Kyogle NSW	NARARA (Gosford) NSW	Peats Ridge (Gosford) NSW
Soil Colour (Munsell)	Pale Brown	Dark Grey	Dark Grey	Yellow Brown	Dark Grey	Greyish Brown	Grey
Soil texture	Silty Loam	Light Clay	Medium Clay	Silty Loam	Silty Clay Loam	Fine Sandy Loam	Fine Sandy Loam
pH (water)	4.9	7.8	7.8	5.7	6	5.7	5.1
pH (CaCl2)	4.3	7.1	7.3	4.8	5.4	4.7	4.3
Buffer pH	5.6			5.6	5.6	5.9	5.7
Org. %C	1.2	1.6	1.2	2.7	3.8	1	1.6
Nitrate mg/kg	24.3	45.2	80	10.5	39.2	9.9	23.5
S (MCP) mg/kg	34	15	53	28	17	10	9
P (BSES) mg/kg	70	88	>200	149	>200	>200	78
P (Colwell) mg/kg	51	41	210	97	175	200	59
K (Nitric) meq/100g	2.85	3.9	4	0.66	2.9	0.95	0.45
K (Amm.Ac)meq/100g	0.23	1.38	1.32	0.14	1.64	0.25	0.07
Ca (Amm.Ac.)meq/100g	1.28	13.36	24.26	3.67	18.45	1.95	1.71
Mg (Amm.Ac.)meq/100g	0.61	3.26	18.35	1.26	11.55	0.4	0.5

The following comments were made:

P	All adequate or excess (~20 mg/kg Colwell OK)
K	All OK (Peats Ridge & Burringbar marginal)
Ca	Low at Cairns site - ad 2 t/ha lime (too late for effect)
Mg	
Ca:Mg	OK, bit high in Narara - can limit Mg uptake
Al	Saturation of CEC in Cairns, add lime
Na	No problem with ESP
Cu	Very high in most? Low in Cairns & Peats Ridge
Zn	Deficient in Cairns.
Mn	Deficient in Cairns, Narara, Peats Ridge
Fe	Possibly a problem in Gatton, Narara & Peats Ridge
B	Preferably 0.5 mg/kg, so 3 sites limiting

Fertiliser Recommendations:

For N-K experiment at Gatton & NSW Ag (Narara or Peats Ridge) ADD the Medium and High rates of N (100 kg/ha, 150 kg/ha) & K (200 kg/ha, 300 kg/ha) instead of balancing according to soil analysis, as originally planned.

For other experiments the following was recommended:

-NITROGEN: Cairns add 200 kg/ha
Emerald add 150 kg/ha
Gatton add 50 kg/ha
Burringbar add 300 kg/ha
Kyogle add 200 kg/ha
Narara add 300 kg/ha
Peats Ridge add 250 kg/ha

-POTASSIUM: Burringbar add 300 kg/ha
Narara add 300 kg/ha
Peats Ridge add 300 kg/ha
All other sites add 150 kg/ha

-PHOSPHORUS: No P added at any site.

-Foliar micronutrient application of 2-5 kg/ha at all sites.

-Lime to be added to Cairns site.

2.1 New South Wales – NSW Agriculture Gosford HRA Station

Planted in early October, this trial was harvested in August 2003. Treatments were imposed upon single rows, 1.5 m between rows, with three replications receiving N:P:K at 300:100:300kg/ha.three within-row spacings of 30, 50 and 70 cm were trialled.

Closer within-row spacing led to markedly greater total and mother corm yields (Table 6), but the intermediate within-row spacing (50 cm) gave yield of daughter corms similar to that of the narrowest (30 cm) within-row spacing. However, there was a notable trend for wider spacing to give a greater proportion by weight of larger daughter corms. However, on a per unit area basis there was little difference between treatments (e.g. 10.3 to 11.5 t/ha for > 100 g corms).

Table 6. Taro 2002-03, CQU-13A: Corm yield of NORADA 1 grown at the Gosford HRAS, Central Coast, NSW, 2002/03.

Plant spacing		Too small	Marketable (g/plant)						Mother corms	Grand Total g/plant
		< 19g	20-39g	40-59g	60-79g	80-99g	> 100g	Total daughter corms	Total mother corms	
30cm	Y	300.8(19.8) 6.7t/ha	376.7(11)	290.4(5)	301.4(4.2)	370.8(3.9)	464.9(3.3) 10.3 t/ha	2105(47.2) 46.8 t/ha	2388.7(5) 53.1 t/ha	4493.7(52.2) 99.9 t/ha
	%	6.7	8.4	6.5	6.7	8.3	10.3	46.9	53.1	100
50cm	Y	373.6(22.6) 5.0t/ha	504(14.2)	485.8 (8.4)	365.8(6.1)	510.8(5.2 0	859.4(5.3) 11.5 t/ha	3099.4(61.9) 41.3 t/ha	2419.4(4.9) 32.3 t/ha	5518.8(66.8) 73.6 t/ha
	%	6.8	9.1	8.8	6.6	9.3	15.6	56.2	43.8	100
70cm	Y	520.1(32.7) 5.0t/ha	498(14.4)	423.6 (8.0)	468.2(7.1)	512.7(5.6)	1129.8 10.7 t/ha	3552.4(74.9) 33.8 t/ha	3132.1(6.1) 29.8 t/ha	6684.5(81) 63.7 t/ha
	%	7.8	7.5	6.3	7.0	7.7	16.9	53.2	46.8	100

2.2 North Queensland – Gordonvale (Cairns)

Both trials were planted on a commercial farm.

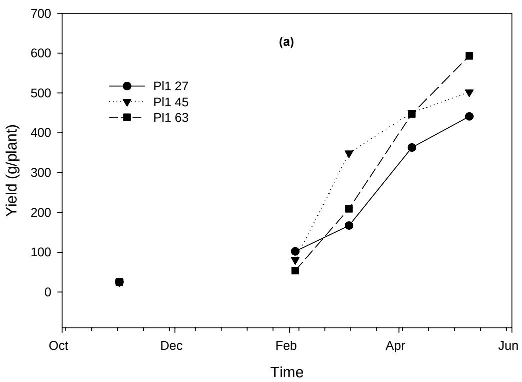
For the trial on plant spacing and planting date, the source of planting material was DPI South Johnstone Research Station – the harvest from the previous season's observational trial planting. This trial was planted on 1st November 2002 and on 5th December, with harvest of the former on 14/15th May and the latter on 19th June. Planting density was 1.6, 2.2 and 3.7 plants/m^2. Lime was applied to all plots on 5th December, and in mid-January all plots were hilled-up.

For the trial on the effect of propagation corm size on yield, planting corms were those sourced from Eden Creek NSW and distributed via CQU Rockhampton. Most of these corms failed to germinate or did not survive long. This may have been due to poor quality corms (tending to rot). This experiment was abandoned at this site.

In the spacing trial corm initiation began by the beginning of February for the November planting but not for the December planting (Figure 2). For the latter, corms were evident by the early March sampling. On a per plant basis, corm yield increased faster over time for the wider than the narrower spaced plants (Figure 2).

Total corm yield for both planting dates was greater at the closer spacing (Table 8) but commercial yield showed no obvious trend with respect to plant spacing. A high proportion of corms were tapered, or hooked, and considered as non-commercial. Differences in yield between planting dates were not conclusive (Table 7).

Figure 2. Spacing by planting date trial at Gordonvale, a) planted on 1st November, and b) on 5th December. Average of six plants.



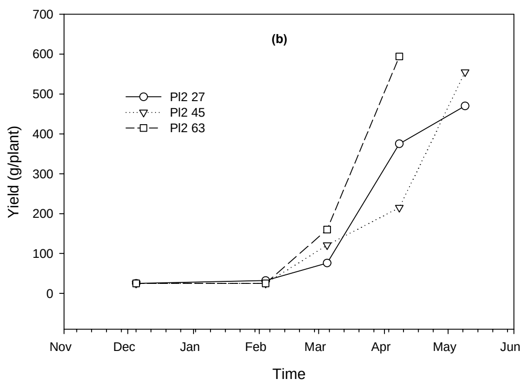


Table 8. Total and commercial (> 30 g corm weight) corm yields at Gordonvale, planted on 1st November and 5th December at three within-row plant spacings.

Sowing time	Spacing	Total yield		Commercial yield	
		Mean	Se	Mean	Se
1st November	27 cm	46.17a	0.636	6.60	0.115
	45 cm	41.57ab	1.790	7.87	2.541
	63 cm	38.33b	1.093	5.77	0.517
	P	0.043		0.678	
5th December	27 cm	58.55a	7.550	7.05a	1.450
	45 cm	29.20b#	5.600	2.35c	0.950
	63 cm	32.50ab	2.100	4.60b	0.800
	P	0.152		0.021	

#Significance level was set at $P < 0.1$; For others $P < 0.05$.

2.3 Queensland – Emerald

Good planting material was sufficient only for the first planting of the spacing trial. Propagule corms were sprouted in a mist house (about 2 weeks), then transferred to potting mix (1:1 peat:coarse sand) in small square tube pots (5 cm × 5 cm × 10 cm) outdoors for hardening for 2 weeks prior to planting on 31st October in the field at Emerald.

Three replicate blocks of within-row plant spacing treatments 30 cm, 50 cm 70 cm were set up; the experiment blocks were bordered by two rows of guard plants, with four guard plants at the each end of the double rows of treatment blocks.

Mounded beds were about 20 cm high, 80-90 cm across tops, and 1.8 m between centres. Experimental plots were 4.5 m long. Plantlets were placed in double rows within each plot, 50 cm between rows within a plot. Within each plot, plants were planted at treatment spacings of 30 cm (28 plants per plot), 50 cm (18 plants per plot) or 70 cm (14 plants per plot), and plant positions in one row within each plot were staggered (50% of treatment spacing) with positions in the other row within the plot (i.e. to give a triangular positioning of plants).

Total N was 150 kg/ha as was total K. One quarter of total N&K ("Poly Feed", N:P:K: = 19:8.3:15.8 % w/w plus trace elements. Based application on K:15.8% w/w) was applied at planting. One quarter was of total N&K (Nitram N=14%w/w& Muriate of Potash K=39%w/w) was applied on 10th December, one eighth (Nitram & Muriate of Potash) on 15th January, one quarter on 21st March 2003 and one eighth on 2nd May 2003. Hand weeding and hilling was done on 15th January 2003 and on 2nd May numerous corms, but all quite small, were visible. Hilling-up was not done then because the area was flooded/mud. Some hand weeding was also done each visit throughout the crop life.

Harvests were made on 2nd July 2003 and 12th August 2003:

While for both harvest dates the yield per plant was greater at the wider plant spacing (Table 9) the total yield on a per unit area basis did not differ between treatments (although the intermediate spacing led to a greater total corm yield, at $P< 0.09$, that the wider or narrower spacings). In the first harvest there was a greater proportion of corms > 30 g at the closest spacing, but in the second harvest all treatments recorded 20% of total corm yield as > 30 g. The longer period for growth to the latter harvest presumably allowed for more bulking up of the smaller corms at the wider spacing.

Table 9. Effects of harvest date and within-row plant spacing on corm yield at Emerald, 2002/3 season.

Harvest date	Treatment	Total Wt (g/per plant)		Yield (g/m^2)		>30g (%)	
2 July 2003		Mean	se	Mean	se	Mean	se
	30	1356.0b	317.59	5022.2	1176.24	18.2a	2.25
	50	2813.7a	226.68	6252.0	503.68	11.1b*	2.68
	70	3479.7a	402.20	5522.2	638.29	9.73b	1.86
	P	0.028		0.647		0.088	
12 August 2003	30	1474.3b	323.95	4541.8b	1120.37	20.4	2.86
	50	2906.7a	263.41	6270.1a*	889.91	20.0	1.85
	70	2813.3a	181.78	4464.8b	288.49	20.9	2.22
	P	0.002		0.093		0.984	

*significance level was set at $P < 0.1$; *others:* $P < 0.05$

2.4 Queensland – Gatton

(Eric Coleman and Bill O'Donnell)

Both trials were planted on commercial farms near Gatton. The plant spacing and planting date trial was planted on 2nd and 16th October 2002 with seed corms of questionable quality. Treatments comprised the two planting dates, and between-plant spacings of 30, 50 and 70 cm on 1 m spaced single row beds. Heat, dry air and weeds were major problems. Poor plant survival and performance were evident; therefore the data (harvest was on 28th May 2003) should be treated with some caution.

A browning damage to leaf margins (reaction to heat/dry air - also observed at Emerald and Gin Gin) was evident, as observed in the 2001/2 trial.

The nitrogen and potassium fertiliser levels was planted on a different farm on 2nd October 2002 and harvested on 28th May 2003. Treatments comprised N application at 100 and 150 kg/ha, and k at 200 and 300 kg/ha.

In the planting date by spacing trial yields were low (Table 9), and per plant did not differ between treatments, implying that canopies of adjacent plants barely touched each other (i.e. that there was minimal inter-plant within-row competition for light). Consequently, on a per unit area basis yield was greater at the closer spacing, but for neither planting date did it reach 10 t/ha. Yields were somewhat greater with the earlier planting (most likely a consequence of the longer growing season – harvest date was the same for both planting dates) and reject corms (< 20 g) slightly less.

The nutrition trial also had low yields, (Table 10) and there was a tendency for the higher N treatment to increase yields, while higher K reduced total yield and increased the proportion of rejects (< 20 g).

Table 9. Corm yields for two planting dates (both harvested on 28th May 2003) at three within-row spacings, Gatton.

Planting date	Spacing	Total Wt (per plant)		Yield (g/m^2)		Reject < 20 g (%)	
		Mean	se	Mean	se	Mean	se
2 Oct 2002	30	233.3	3.40	803.3a	11.35	38.1	3.15
	50	229.9	37.25	459.8b	74.54	43.5	4.74
	70	266.3	4.03	380.9b	5.77	37.1	5.07
	P	0.495		0.019		0.199	
16 Oct 2002	30	184.2	73.03	588.4a	243.16	47.2a	3.04
	50	193.4	30.35	567.5a	59.67	46.0a	3.33
	70	233.3	80.44	333.6b	115.02	33.1b	4.37
	P	0.867		0.047		0.038	

Table 10. Effect of nitrogen and potassium on taro corms yields at Gatton, harvested on 28th May 2003.

Planting date	Treatment	Total Wt (per plant)		Yield (g/m^2)		Reject < 20 g (%)	
		Mean	se	Mean	se	Mean	se
2 Oct 2002	N100	209.7b	41.01	698.3b	136.57	26.2b	1.66
	N150	282.0ab	99.37	938.9ab	330.89	28.1ab	4.81
	K200	318.9a	41.47	1061.8a	138.07	20.3b	2.64
	K300	181.0b	31.11	602.7b	103.58	32.7a	3.01
	P	0.038		0.038		0.027	

2.5 Western Australia – Agriculture WA Medina Research Station

The trial was planted at the Medina Research Station. The planting material came from Central Queensland University which was grown in southern Queensland. The taro corms were sprouted in a hot house before being transplanted on 15 October 2002. Unfortunately, more than half the corms began to breakdown and rot during sprouting.
The conditions of the hot house located at the Manjimup Horticultural Research Institute was not maintained at a high enough temperature (should be 30^{o}C or higher) to get the corms to sprout quickly. The corms were left in the hot house for over two weeks at temperatures of 18-22^{o}C which resulted in many of the corms rotting.

The site was sprayed with glyphosate at the recommended rate for weed control and Nemacur® at 24 L/ha was applied and incorporated one week before planting. Double superphosphate at 1200 kg/ha were broadcast and incorporated using rotary hoe. The sprouted corms were transplanted at depth of 5 cm with the tip of the shoot just above ground level. The beds were 1.5 m. wide and flat. The beds were not hilled during growth as suggested by Hicks (2002) because the developing secondary corms were not exposed above the ground. The variety of Japanese taro planted was *Ishikawa wase.*

Those corms that had sprouted without breakdown were transplanted into three double row plots. The plots were seven metres long and the rows were 75 cm apart. There were double rows of three intra-row spacings at 30 cm, 50 cm and 70 cm.

The small trial was surrounded by shade cloth (about one metre high) to protect the small plants from wind damage. During the first month, birds began digging the corms out of the ground. The plot with 30 cm. between the plants lost the most plants with 16 plants pulled out of the ground. The 70 cm spacing plot was also affected with only about four plants left in one row.

The trial was top-dressed for 26 weeks beginning the week of transplanting. Total amounts of potassium sulphate at 19 kg/ha and ammonium nitrate at 41 kg/ha were fertilised weekly using a watering can.

Irrigation was kept at 100-120% replacement evaporation during the months of October to March. It was then reduced to 35-40% in April and by week 29, the irrigation was withheld as the plants began to senesce.

The trial was harvested on 28 May 2003 (week 33). Total yield was calculated for each of the different spacings. Number of corms per plant, and corm yield (kg/plant) were recorded as well as a grading system used by the Japanese to grade each corm based on weight (Table 67).

The taro plants grew well and responded to the fertiliser applied with large leaves and many stems for each plant (Figure 43). Small corms began to form at approximately week 24.

A slasher was used to cut the leaves from the corm clump of the plant. The corm clumps of each plant were then dug up by hand using a fork. Each individual corm was then separated from other corms and roots were pulled off. The separated corms from each plant were put into onion bags ready for grading and weighing.
The yields achieved from all three intra-row spacings were comparable with yields achieved in northern New South Wales and Queensland. The total yield ranged from 41.84 t/ha at 70 cm intra-row spacing to 48.26 t/ha for a 50 cm. spacing. At 30 cm spacing the total yield was 45.52 t/ha. The 70 cm. spacing plot was severely affected by birds that pulled the sprouted corms out of the ground which reduced yield.

Marketable yields were not recorded due to the lack of information on quality grade standards. However, most of the corms that recorded a 3L grading were considered the primary corms and therefore unmarketable because of shape and the thick green stem coming out of the corm.

Table 11 shows the average number of corms per plant and the cormel yield (kg/plant) to each spacing. As to be expected the wider the intra-row spacing, the greater the number of corms and cormel yield per plant.

Table 11. Average number of corms per plant and cormel yield for each spacing

Intra-row spacing (cm)	Average no. corms per plant	Average corms yield (kg/plant)
30	50.8	1.5
50	62.0	2.0
70	81.4	2.6

The percentage of total yield that fell into each size grade category for each spacing spacings showed similar patterns in that the majority of corms weighed less than 40 g. Also, the majority of corms grown at Medina were not of a rounded shape but had pointed ends. Japanese markets prefer egg-shaped, rounded corms with a weight of 41-60 grams. Further information needs to be sought and further agronomic trials need to be conducted to fine tune the management of growing taro in the Perth area or further north to achieve better quality.

2.6 Western Australia – Agriculture WA Manjimup Horticultural Research Institute

Twenty four taro plants were transplanted at the Manjimup Horticultural Research Institute (350 km southwest of Perth) on the 29 October 2002, in one double row plot of Research Institute due to the lack of planting material.

During the growing period it soon became apparent that the taro plants were not growing as quickly as the plants grown at Medina, despite the plants at Manjimup being planted two weeks later. Thirty one weeks after transplanting, no corms had developed and the plants were still very small. It is likely that the cooler climate in Manjimup is not suited to growing Japanese taro at this time.

Medina Research Station

Location:
35 km south of Perth
Lat: 32° 22” S Long: 115° 81” E

Weather: (17 year averages)

	JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
Mean daily max temp (°C)	30.4	31.3	28.9	25.8	21.7	19.2	18.1	18.7	20.4	22.5	25.6	28.2
Highest max temp (°C)	44.9	45.8	42.0	35.5	31.2	26.2	25.8	27.8	30.9	35.8	39.0	42.5
Mean daily min temp (°C)	16.5	17.2	15.7	13.4	10.4	9.4	8.2	8.1	8.8	9.9	12.9	15.0
Lowest min temp (°C)	4.8	6.4	4.6	2.4	2.0	-2.0	-1.0	-0.8	0.9	0.7	3.1	4.4
Mean Rainfall (mm)	11.1	25.6	22.3	34.7	104.5	161.9	159.8	120.5	79.3	43.3	36.8	9.3

Soil Characteristics and type:

pH (1:5 $CaCl_2$)	6.2
Extractable phosphorus[A]	15 mg/kg
Phosphorus Retention Index	1.1 mL/g
Extractable potassium	<10 mg/kg
Organic carbon[B]	0.55%
Ammonium-N	4 mg/kg
Nitrate-N	1 mg/kg
Electrical conductivity	6 mS/m

[A] 0.5M sodium bicarbonate (after Colwell 1963)
[B] After Walkley and Black (1947)

2003/2004

Trials in 2003/4 conducted by NORADA are reported in another Appendix. Herein we report on two experiments conducted in Queensland, one on a suite of 'best practices' and the other on a range of planting dates.

3.1 Queensland – Alton Downs, Rockhampton

A "Best Management Options" trial was planted on 17th December 2003. Treatments compared bed vs. single row planting, overheads vs. drip irrigation, comer size at planting and herbicides. The trial set-up is presented in Figure 3.

Hand weeding of beds and single row mounding was done on 16th February 2004. Nut grass is a severe problem. Nut grass and other weeds in between beds and single rows were sprayed with roundup.

Hilling up with tractor (shoes for single rows, discs for beds) was done on 2nd April 2004. Some mechanical damage to plants was evident from the tractor passing over them, mainly on double-row beds, as beds were higher than row mounds. Neither was very effective at throwing soil up around plants, even at increased speed. The soil was probably too moist, forming large clods and sticking to discs.

Plants were harvested on 11th August 2004.

Drip irrigation and planting formation resulted in significant differences in yields (Table 12). Drip irrigation gave a 25% yield increase above overhead irrigation, and single rows plus mechanical weeding was superior to bed planting plus herbicides. The number of daughter corms and their weight was affected by herbicides (greatest yield with.Stomp) although the effects of herbicide on total and mother corms weight were not significant. The type of planting material affected yields (Table 12); mother corms gave greater yields than did daughter corms. As a proportion of total yields none of the treatments influenced the % of corms > 20 g.

Table 12. Yield data from trial at Alton Downs as affected by various agronomic treatments, 2003/4 season. Figures in bracket are standard errors of each mean.

Irrigation

Treatment	All Corms Fresh Weight	Mother corms Fresh Weight	Daughter corm number	Daughter corm Fresh Weight
Overhead	0.485b (0.042)*	0.084b (0.005)	20.5b (1.582)	0.384b (0.037)
Drip	0.606a (0.035)	0.105a (0.004)	23.9a (1.170)	0.483a (0.028)

Planting

Treatment	All Com FW	Mc FW	Dc number	Dc FW
Bed + herbicide	0.427b (0.028)	0.085b (0.004)	18.2b (1.187)	0.342b (0.026)
Row + mechanical	0.664a (0.043)	0.104a (0.005)	26.2a (1.418)	0.524a (0.035)

Corms size at planting

Corm size	All Com FW	Mc FW	Dc number	Dc FW
Daughter 30-60 g	0.427b (0.028)	0.085b (0.004)	18.2b (1.187)	0.343b (0.026)
Daughter 60-100 g	0.711a (0.057)	0.108a (0.006)	28.2a (2.018)	0.563a (0.048)
Mother *c.* 100g	0.616a (0.063)	0.100a (0.007)	24.2a (1.955)	0.485a (0.050)
P	<0.0001	0.007	<0.0001	<0.0001

Herbicide (within the bed)

Herbicide	All Com FW	Mc FW	Dc number	Dc FW
1 Stomp	0.502 (0.601)	0.094 (0.007)	23.5a (2.384)	0.448a (0.052)
2 Dual	0.365 (0.027)	0.078 (0.005)	14.2b (1.219)	0.273b (0.025)
3 Gramoxone	0.418 (0.051)	0.085 (0.007)	16.9b (1.885)	0.306b (0.046)
P	0.138	0.193	0.003	0.012

Figure 3. Plot set-up at Best Management Options trial

Best Management Options trial at Alton Downs, Rockhampton 2003-2004.

General layout plan and treatments

		Overhead irrigation Double-row beds *Herbicides	Overhead irrigation Single rows Mechanical weed control	Trickle irrigation Single rows Mechanical weed control	Trickle irrigation Double-row beds *Herbicides
		Buffer - Sorghum			
		Buffer - Sorghum			
Taro rows	1	Taro Bed 1 Stomp 2 l/ha	Taro	Taro	Taro Bed 1 Stomp 2 l/ha
	2	Taro Bed 1	Taro	Taro	Taro Bed 1
	3	Taro Bed 2 Dual 1.5 l/ha	Taro	Taro	Taro Bed 2 Dual 1.5 l/ha
	4	Taro Bed 2	Taro	Taro	Taro Bed 2
	5	Taro Bed 3 Gramoxone	Taro	Taro	Taro Bed 3 Gramoxone
	6	Taro Bed 3 after emerge	Taro	Taro	Taro Bed 3 after weed emerge
		Buffer - Sorghum			
		Buffer - Sorghum			

4 m	15 m	4 m	15 m	4 m	15 m	4 m	15 m	4 m

Corms and plants

Taro rows	1	Taro Bed 1	Taro	Taro	Taro Bed 1
	2	Taro Bed 1	Taro	Taro	Taro Bed 1
	3	Taro Bed 2	Taro	Taro	Taro Bed 2
	4	Taro Bed 2	Taro	Taro	Taro Bed 2
	5	Taro Bed 3	Taro	Taro	Taro Bed 3
	6	Taro Bed 3	Taro	Taro	Taro Bed 3

Propagation corms were from 2002-2003 Emerald trial:

Daughter corms - approx. 30-60 g

Mother corms - approx. 60-100 g

Mother corms - approx. >100 g

Plant intra-row spacing is 50 cm.

Double-row beds had 60 plants in staggered positions.

Single rows had 31 plants, slightly staggered positions in relation to adjacent single rows.

Planting date: 17 December 2003

3.2 Queensland – Emerald

Monthly plantings were done by farmer Harvey Rich from September 2003 to December 2003, then 7/12/2003, 21/12/2003; between 25-50 plants were established each time at 50 cm spacing in single 1 m spaced rows with drip irrigation. The final planting (30/3/2004) comprised 23 daughter corms and 24 mother corms. Tops of corms were 10-15 cm below soil surface at planting.

All plots were harvested on 11th August 2004.

There was a tendency for total yields to decline with planting date (Figure 4), with a marked downturn in yields when planted after November. The same trend was evident for mother and daughter corm weights and daughter corm numbers. There was a significant difference in all parameters measured in the comparison between planting of mother and daughter corms (Table 13); mother corms outperformed daughter corms by doubling yields and corm numbers, however, yields were low due to the late (March) planting.

Figure 4. Yields per plant as a response to planting date at Emerald, 2003/4. A) all corms, B) mother corms, C) daughter corms, and D) number of daughter corms per plant.

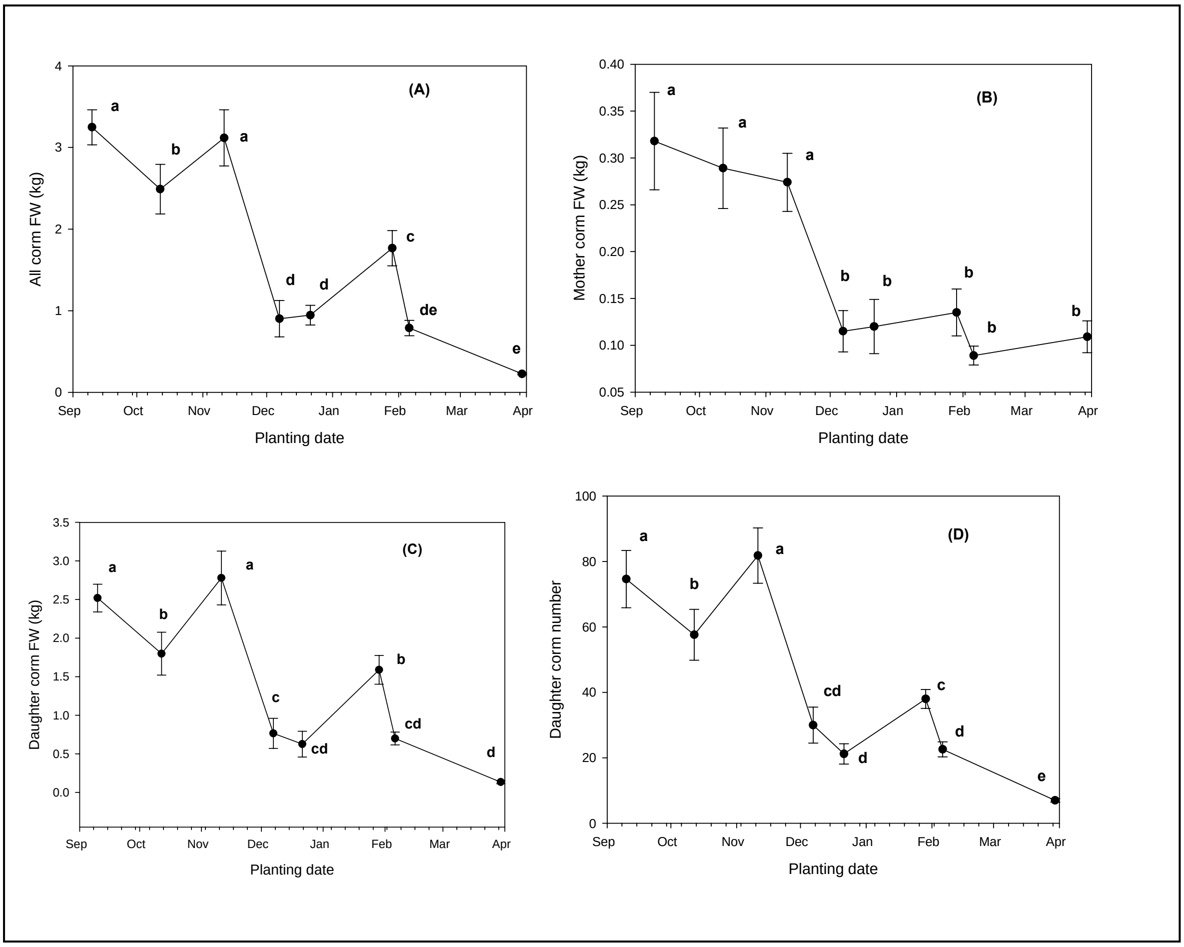


Table 13. Comparison of effects of mother vs. daughter corm planting material at Emerald, planted in late March, 2004.

Treatment	All corms weight	Mother corms weight	Daughter corms number	Daughter corms weight
Mother	0.453 (0.045)	0.193 (0.010)	12.4 (0.927)	0.282 (0.044)
Daughter	0.226 (0.011)	0.109 (0.017)	7.0 (0.548)	0.134 (0.010)
P	0.001	0.003	0.001	0.011

Observations and comments on all field trials

Planting date

Quite clearly in central and SE Queensland planting should be done to avoid emergence and early growth during the hot (and especially if dry) conditions surrounding November to January. Earlier planting led to yields three times those of December plantings, however, plantings in February and March, although avoiding the inclement heat, did not allow sufficient growth and corm bulking before cessation of growth in the cooler winter. Growth at Southedge, in the cool climate of the Atherton Tablelands, was also not successful. In contrast to the negative effects of a dry summer in central Queensland, planting in mid-December in the wet climate of South Johnstone resulted in 2001/2 in total yields of on average 5.2 kg/plant. In the following year there was no difference between early November and early December plantings for total corm yield there, with yields of *c.* 1.5 kg/plant at 3.7 plants/m^2.

In the Northern Territory, with suitable irrigation, as with Pacific taro all year production should be possible under local tropical conditions. This should allow any export market window to be targeted.

Size of planting propagule

Quite clearly the planting of mother corms was superior to that of similarly-sized daughter corms, for total corm yield and for yield of commercial-sized (larger) corms. This was evident in NSW and central Queensland. Small (<19 g) sized daughter corms either did not survive (under hot plantings) or resulted in less yield that larger sized daughter corms. This was evident even in the comparison between 30-60 g vs. 60-100 g; the latter gave 65% more yield.

Under conditions that were less unfavourable for survival during germination and establishment, and that favour a long growing season (e.g. north Queensland) there was less noticeable difference in performance of different-sized planting propagules, although in the Northern Territory yields from 30-59 g corms were double those from 10-19 g corms.

Plant population (between-plant spacing)

Higher population (closer between-plant spacing) led to higher total yields, and at times of particular interest commercial yields. In some sites where growth was poor, interplant competition between the canopy was negligible, yields per plant were not constrained by having neighbour plants close, by and yields per unit area were simply a direct function of plant population (Table x). However, the yield benefits of closer spacing were also evident when yields exceeded a computed 50 t/ha, and canopies would have touched between adjacent plants within a row. It would appear that delayed harvest (e.g. from early-June to mid-August) would favour the proportion of commercial-sized comers.

Nutrition

Only one trial was successfully competed on crop nutrition, a topic for which yield considerations are intimately linked with soil fertility. That trial resulted in yields < 10/ha. Under those conditions, additional N (raising from 100 to 150 kg/ha) resulted in 35% more yield, whereas raising K from 200 to 300 kg/ha reduced yield by 43%.

Other practices

Based upon data from one trial only, single row planting (with mechanical weeding) was superior to bed planting (with herbicides); drip irrigation outperformed overhead sprinklers, and herbicides did not affect total yield but did influence daughter corm number and weight.

Commercial-sized comers

Corms > 20 g or > 30 g can be considered marketable. In the current trials up to 80% of corms could be considered of commercial size (more so in NSW and Northern Territory than in Queensland), but the average across trials was closer to 30%. This is a serious disincentive to growers wishing to access export markets, and with little desire to offload small corms onto a domestic and/or processing market.

During harvest all corms were quite strongly attached together when plants were lifted from the bed. These were separated manually, adhering roots removed and then washed with high pressure water. On a large scale, mechanisation to separate and clean the corms would be required.

5. Virus testing

As sato-imo planting corm material was being distributed initially in 2001/2 from established growers to new growers interested in the crop, and as planting material was being distributed for experimental trials in different regions in New South Wales, Queensland, the Northern Territory and Western Australia, there was an urgent need to make an initial investigation into potential taro pathogens that may be harboured in the distributed material of cultivar NORADA-1. Researchers at the Queensland University of Technology had been participating in the ACIAR project "Virus indexing and DNA fingerprinting for the international movement and conservation of taro germplasm", and had developed protocols for testing for the presence of five viruses associated with a number of important taro diseases in the Pacific region.

The five viruses that were tested for were dasheen mosaic potyvirus (DsMV), taro bacilliform badnavirus (TaBV), taro reovirus (TaRV), and two putative rhabdoviruses, taro vein chlorosis virus and Colocasia bobone disease virus. DsMV and TaRV were tested using reverse-transcriptase PCR, while TaBV was tested using PCR. To make sure that the results were valid, the Southern blot technique was employed using DNA probes specific for DsMV, TaBV and TaRV. Transmission electron microscopy of taro leaf material was employed to check for bacilliform particles of taro vein chlorosis virus and Colocasia bobone disease virus.

Leaf samples of sato-imo cultivar NORADA-1 were collected for virus testing from a number of commercial and trial plantings in a number of geographic regions (Table 13), in May 2002. Leaf samples from two other small-corm type taro cultivars were also collected from Burringbar, NSW (Table 13) One leaf (youngest fully expanded leaf) per plant was collected from each of three plants in most locations. One leaf from one plant each of three different cultivars was collected from Burringbar. Due to the poor condition of the Burringbar leaf samples on arrival at the testing laboratory, the three samples were pooled for testing. The three leaf samples from the NT site were also pooled as the leaves were not packed or labelled separately. There were no reports of virus-like symptoms on collected leaves nor were there reports of symptoms observed on other plants in the sampled taro plantings.

Results are shown in Table 14. All samples tested negative for the five taro viruses, except for one sample from the trial plot at Southedge in north Queensland, which tested positive by PCR and Southern blot methods.

The presence of TaBV is not surprising because this virus has already been found in Australia and it is also widespread throughout the Pacific (Personal Communication Rob Harding). Also, taro is commercially cultivated on a reasonable scale in north Queensland (however, more commonly near the coast than on the drier Atherton Tablelands where Southedge located), so the infected NORADA-1 plant in the trial plot could have been infected from either local sources during growth rather than the original planting material from NSW necessarily being the source of infection. By itself, TaBV does not seem to cause much in the way of symptoms (Personal Communication Rob Harding).

Table 14. Results of virus testing of sato-imo leaf samples collected from 2001-2002 season sato-imo crops and trials.

Sample Description	DsMV	TaBV	TaRV	EM
DPIF CPHRF Darwin NT, "NORADA-1": 3 leaves = 3 sample plants (pooled)	–	–	–	–
DPI South Johnstone, Qld, NORADA-1: Plant No. 27	–	–	–	–
DPI South Johnstone, Qld, NORADA-1: Plant No. 9	–	–	–	–
DPI South Johnstone, Qld, NORADA-1: Plant No. 41	–	–	–	–
CQU Rockhampton Qld, NORADA-1: Sample plant 2	–	–	–	–
CQU Rockhampton Qld, NORADA-1: Sample plant 3	–	–	–	–
CQU Rockhampton Qld, NORADA-1: Sample plant 1	–	–	–	–
Murwillumbah NSW, NORADA-1: Sample plant 1	–	–	–	–
Murwillumbah NSW, NORADA-1: Sample plant 2	–	–	–	–
Murwillumbah NSW, NORADA-1: Sample plant 3	–	–	–	–
DPI Southedge Qld, NORADA-1: Sample plant 1	–	–	–	–
DPI Southedge Qld, NORADA-1: Sample plant 2	–	–	–	–
DPI Southedge Qld, NORADA-1: Sample plant 3	–	+	–	–
DPI Gatton Qld, NORADA-1: Sample plant 2	–	–	–	–
DPI Gatton Qld, NORADA-1: Sample plant 14	–	–	–	–
DPI Gatton Qld, NORADA-1: Sample plant 6	–	–	–	–
Burringbar NSW, "Dodari?": 2 leaves = 2 sample plants (pooled)	–	–	–	–
Burringbar NSW, NORADA-1: 2 leaves = 2 sample plants (pooled)	–	–	–	–
Burringbar NSW, "X5": 2 leaves = 2 sample plants (pooled)	–	–	–	–

DsMV = dasheen mosaic potyvirus
TaBV = taro bacilliform badnavirus
TaRV = taro reovirus
EM = electron microscopy to check for bacilliform particles of taro vein chlorosis virus and Colocasia bobone disease virus

Appendix 3. Postharvest Management of Japanese Taro

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

POSTHARVEST MANAGEMENT OF JAPANESE TARO

Collaborators report for
RIRDC Project
Development of taro, yam, yam bean and sweet potato exports to Japan and USA

Report prepared by:
Dr Suzie Newman, Research Horticulturist (Postharvest)

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1. Introduction

Export opportunities for Australian grown Japanese taro (*Colocasia esculenta antiquorum*) are expanding. Japanese taro or sato-imo produces smaller corms (40-100g) and has a distinctive texture and flavour, often described as 'sticky' and 'nutty'. Ensuring the product reaches the Japanese consumer in optimum condition is critical to realising market opportunities. Harvesting, washing, grading, curing and packaging are all labour intensive processes in taro production. For Australian production to be economically viable these processes need to be mechanised to some extent. There is a considerable variability in taro product produced in the various growing regions. Quality standards specifying size, shape and colour criteria need to be developed to ensure that only top-quality taro reaches our emerging export markets. The Japanese market prefers corms in the M-2L size range (20-80g) with the shape being typical of that variety. To meet this export market opportunity Australian producers need to satisfy Japanese market specifications and quality requirements The objective of this study was to determine the acceptability of Australian grown product to Japanese consumers and to develop appropriate shipping and storage recommendations.

2. Methodology

2.1 Defining taro quality – Japanese focus group and restaurant evaluation

To evaluate product acceptability, we carried out a taste panel with a focus group of ten Japanese ladies from the Central Coast region of New South Wales. The main objective of using this untrained panel was to provide the research team with some information on the important quality attributes of Japanese taro. This group was presented with samples from 8 different growing areas ranging from Darwin in the Northern Territory, to Gatton in southern Queensland and Gosford in central NSW. Each panellist was randomly allocated samples from each region. For each sample they were first asked to evaluate the general appearance of the sample using a scale for 'shape' and 'external colour' (Appendix 1). Panellists then cut open the taro and evaluated each sample for 'stickiness', 'internal colour' and 'acceptability to Japanese consumers'. Following completion of the appearance assessments taro samples were steamed in a standard manner. Each panellist tasted the samples and evaluated them for 'stickiness', 'texture', 'nuttiness', 'overall eating quality' and 'acceptability to Japanese consumers' using a linear scale. Panellists were then asked to choose the best and worst samples based on 1) appearance and 2) texture and flavour. The results from this panel were used as guide to determine the key quality attributes of Japanese taro.

In addition to the focus group, we also presented samples to prominent Sydney restaurateur Tetsuya Wakuda (Tetsuya restaurant, Sydney) for him to compare the samples from each region. As with the focus group Tetsuya evaluated the samples for appearance and then texture and taste following steaming.

2.2 Storage Trial: effect of temperature and relative humidity on storage life

Taro grown at Cudgen was harvested, cleaned and transported to Gosford Horticultural Institute. Corms were sorted into 108 experimental units (6 replicates of 10 corms) and cured for 2 days at 20°C, prior to the application of treatments. Treatments were randomly allocated to experimental units. Corms were stored at 7°C, 12°C or 20°C for a period of 4, 8 or 12 weeks. These temperatures were selected to determine whether or not the corms were sensitive to chilling injury at 7 or 12°C and to assess whether or not corms could be transported using unrefrigerated containers 20°C. Within each temperature, corms were stored at a relative humidity of 70% or 90-95%. Desired relative humidity was generated by bubbling air through solutions of glycerol and/or water (Forney and Brandl, 1992).

2.2.1 Assessment of Taro quality and storage life

Corms were assessed for weight loss and sprouting both immediately following storage and after 5 days at 20°C. Sprouting was assessed using a subjective scale where a score of '1' indicated small nodules, '3' a root with a length greater than 0.5cm and '5' a root with a length greater than 1 cm At this final assessment corms were also evaluated for disease incidence and severity, internal colour and in some cases cooked textural quality.
Disease incidence was evaluated using the following scale where:

0 = no decay
1 = 6-15% decay
2 = 16-25% decay
3 = 25-50% decay
4 = >50% decay.

Disease severity was then calculated. Internal colour was measured on cut corms using a Minolta CR-100 chromameter using the L a* b* colourspace (McGuire, 1992). Texture was evaluated following a standard cooking process on cylindrical samples (20mm diameter x 20mm height) of tissue using a uniaxial compression test with Lloyd TA500 texture analyser.

Fig 1. Taro storage trial

2.3 Curing trial: effect of curing temperature and time on storage life

Taro grown at Gosford Horticultural Institute was harvested, cleaned and the following curing treatments randomly allocated:

1) 20°C for 0, 2, 4 or 8 days
2) 30°C for 0, 2, 4 or 8 days

All corms were then stored at 7°C for a period of 8 or 12 weeks.

Corms were assessed for weight loss, disease incidence and sprouting immediately following removal from storage, as described in section 2.2.1. These measurements were repeated following a 5 day shelf life simulation at 20°C. At this final assessment, corms were also evaluated for internal colour.

2.4 Statistical Analysis

2.4.1 Storage trial

The response variables were analysed using a maximum likelihood estimation on the following model:

Y = Storage Temp + Storage time +RH + interactions +*Cabinet* + *Cabinet:treat* + *bags* + *error*

Where the italicised terms were assumed to have random effects and, Cabinet effects and their interaction with all treatment effects were estimated using the data from combined trials with common treatment factors.

The standard error of differences and least significant difference (LSD) at alpha= 5%   were calculated.

2.4.2 Curing trial

The analysis was run as above on the following model:

Y = Curing temp + Curing time + Storage time + all interaction + +*Cabinet* + *Cabinet:treat* + *error*

Where all parameters were estimated using the data from this trial only.

3 Results and Discussion

3.1 Japanese Focus Group

The main objective of running this focus group was to enable the research team to determine the key quality attributes for Japanese taro. These results are presented to illustrate the large amount of variability in corm quality. However, to determine the acceptability of the product a larger consumer panel would need to be carried out.

Figure 2 and Table 1 illustrates the considerable variability in corm shape, colour and appearance from each of the growing regions. Colour varied from pale tan to very dark brown, some were smooth skinned while others looked almost shaggy, while shape ranged from large, even corms to small, knobbly or teardrop shaped.
To meet export market specifications, grading standards will need to be developed covering size, shape and colour specifications. These grading standards would need to be strict enough to protect our emerging export markets but flexible enough to recognise the large amount of variability in this product.

Region	**Weight (g)**		**Length (mm)**		**Width (mm)**	
	Average	**Std Dev**	**Average**	**Std Dev**	**Average**	**Std Dev**
Eden Creek	36	5.8	49	6.9	38	3.3
Darwin	52	5.9	61	3.7	40	2.7
Cudgen	55	17.0	62	10.5	40.3	4.0
Burringbar	50	5.7	59	5.2	41	2.0
Gosford	49	10.5	55	8.7	43	3.1
Gatton	42	7.3	55	5.4	41	2.5
Kairi	39	5.7	55	5.4	37	2.1
South Johnstone	39	10.6	58	10.2	39	5.2

Table 1 Physical attributes of regional samples used in taste panel (average of 20 corms per sample)

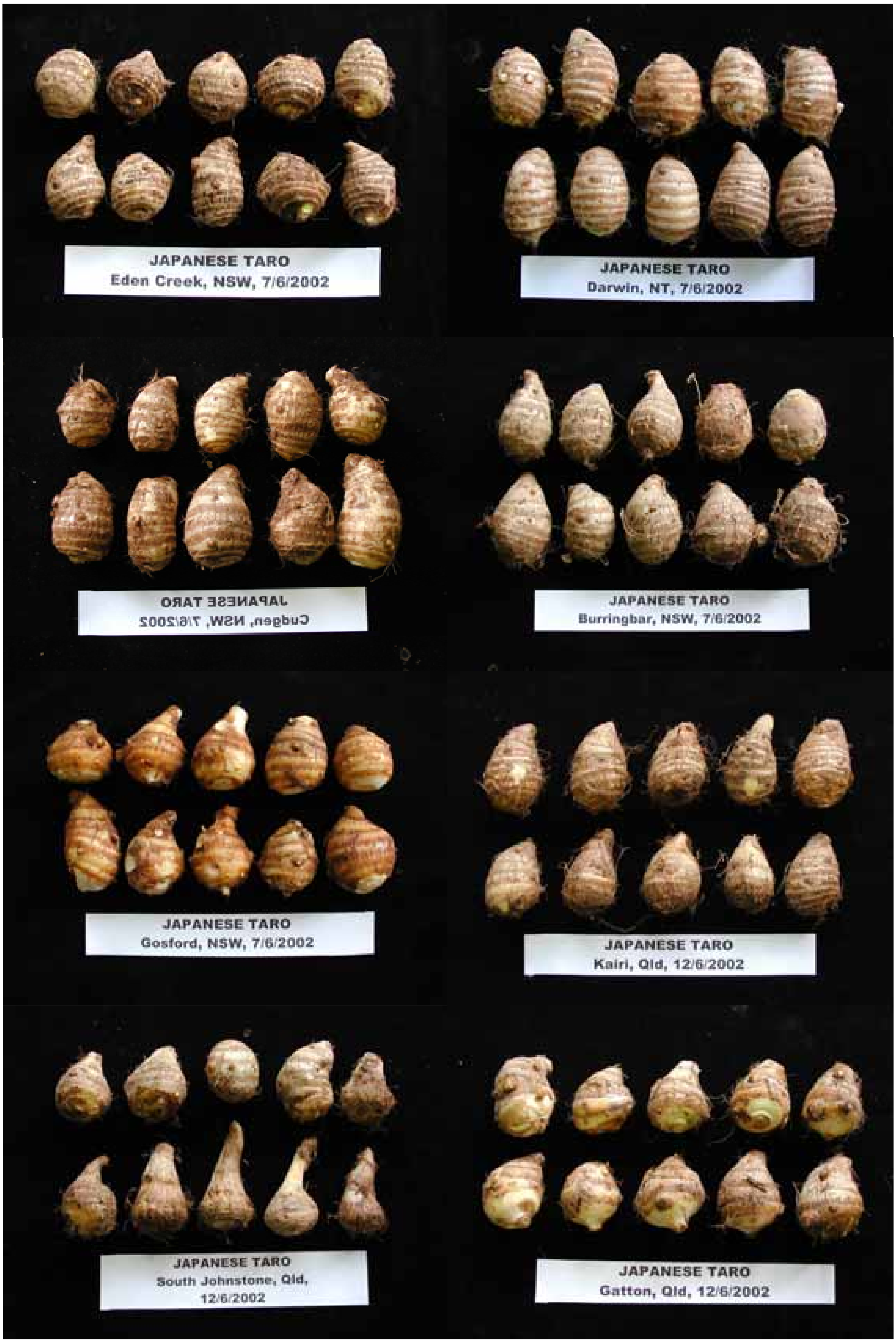

Fig. 2 Variability in size, shape and colour of Japanese Taro produced in different growing regions of Australia

Table 2 summarises the results from the taste panel. The highest rated corms for both appearance and sensory attributes were the samples from Darwin and Kairi. This selection was also confirmed when panellists were asked to provide the sample that 1) looked the best and 2) tasted the best (data not presented). Whilst some samples scored poorly on the appearance test (eg South Johnstone) they may have scored well for taste and texture. Overall their preference was for corms with a light colour and attractive appearance that exhibited the typical 'sticky' and 'nutty' characteristics. Whilst there was a considerable difference in the quality of the product produced from each of the eight growing regions, 4-5 of the samples were considered to be of acceptable quality for the Japanese market.

Region	Appearance		Sensory		Total	Accept?
	External	Internal	Texture	Taste	Mean	y/n/m
Eden Creek	76[1]	49	78	84	**72**	5[2]
Darwin	88	70	75	77	**78**	7
Cudgen	70	51	61	70	**63**	4
Burringbar	75	53	57	56	**60**	1
Gosford	69	66	74	74	**71**	6
Gatton	75	67	62	62	**67**	3
Kairi	84	73	74	80	**78**	7
South Johnstone	43	48	74	78	**61**	3

[1]where minimum score =0 and maximum score =100
[2] where the minimum score is -10 (if all each panellist thought the sample was unacceptable) and the maximum score is 10 (if all ten panellists thought the sample was acceptable)

Table 2 Sensory ratings and acceptability of Japanese taro samples

Tetsuya Restaurant

Tetsuya's preference was for samples from 'Burringbar' and 'Eden Creek'. He believed these samples most closely approximated typical characteristics of taro purchased in Japan. He particularly liked the dark colour of these samples. In his opinion size was not particularly important, with the 'ideal' depending on the intended end-use.

In terms of taste, Tetsuya preferred the sample from 'Eden Creek'. He described this sample as being sweet and having a fine texture. His basis for judgement seemed to relate to the way samples compared to taro typically available in Japan. He described both 'Eden Creek' and 'Burringbar' samples as 'being like the taro we used to have'. Tetsuya though that sample 'Burringbar' was also good, although its texture and taste were not as good as the 'Eden Creek' sample. In terms of texture, his preference was for taro with a fine, silky texture. Coarseness, graininess and crumbliness were undesirable characteristics.

The difference in the response of these two groups are interesting. Sydney restaurateur Tetsuya Wakuda preferred small corms which had relatively strong flavour and plenty of stickiness. He did not like larger corms which tended to develop a more fibrous, floury texture and was completely disinterested in the shape and colour of the taro. However, the Japanese focus group were influenced by the appearance of the corms, preferring those with light colour and even form. While there was a preference for sticky texture and sweet, nutty flavours, this group did not like the smallest corms.

Whilst the results from this preliminary study were designed to determine the important quality attributes of Japanese taro, it clearly demonstrates that a larger consumer study or series of focus groups would be warranted to more clearly define Japanese preferences for this product.

3.2 Storage Trial

Taro quality was acceptable following 4 and 8 weeks storage at either 7 or 12°C, although weight loss at 12 °C was above acceptable levels, following 8 weeks storage. As expected corm weight loss increased with storage temperature and time spent in storage (Fig 3). Weight loss was also highly variable between corms and this may be explained by the different surface:volume ratios and the fleshiness of the corm tissue prior to storage. At 7 and 12 °C weight loss during the shelf life simulation was also quite high. This may be an indication of chilling injury occurring at these temperatures, however there were no other visual symptoms of chilling injury. A previous Japanese study (Rhee and Iwata, 1982) had found that taro showing chilling at 4°C storage, with definite internal browning symptoms. We did not observe this during this trial. There was no difference between the relative humidity treatments and this may due to the low flow rate used in this experiment leading to similar final relative humidity in both treatments.

Figure 4 shows the effect of temperature on corm sprouting. Storage at 20°C, particularly under high humidity conditions resulted in excessive sprouting. Storage at lower temperatures managed to largely suppress sprouting.

Disease incidence increased dramatically between 4 and 8 weeks at the higher temperatures. Five and twenty three percent of corms were affected by disease following 8 weeks storage at 7 and 12°C respectively. The major disease problems were caused by *Fusarium spp.* with *Erwinia spp.* and *Aspergillus* also contributing to the disease mix.

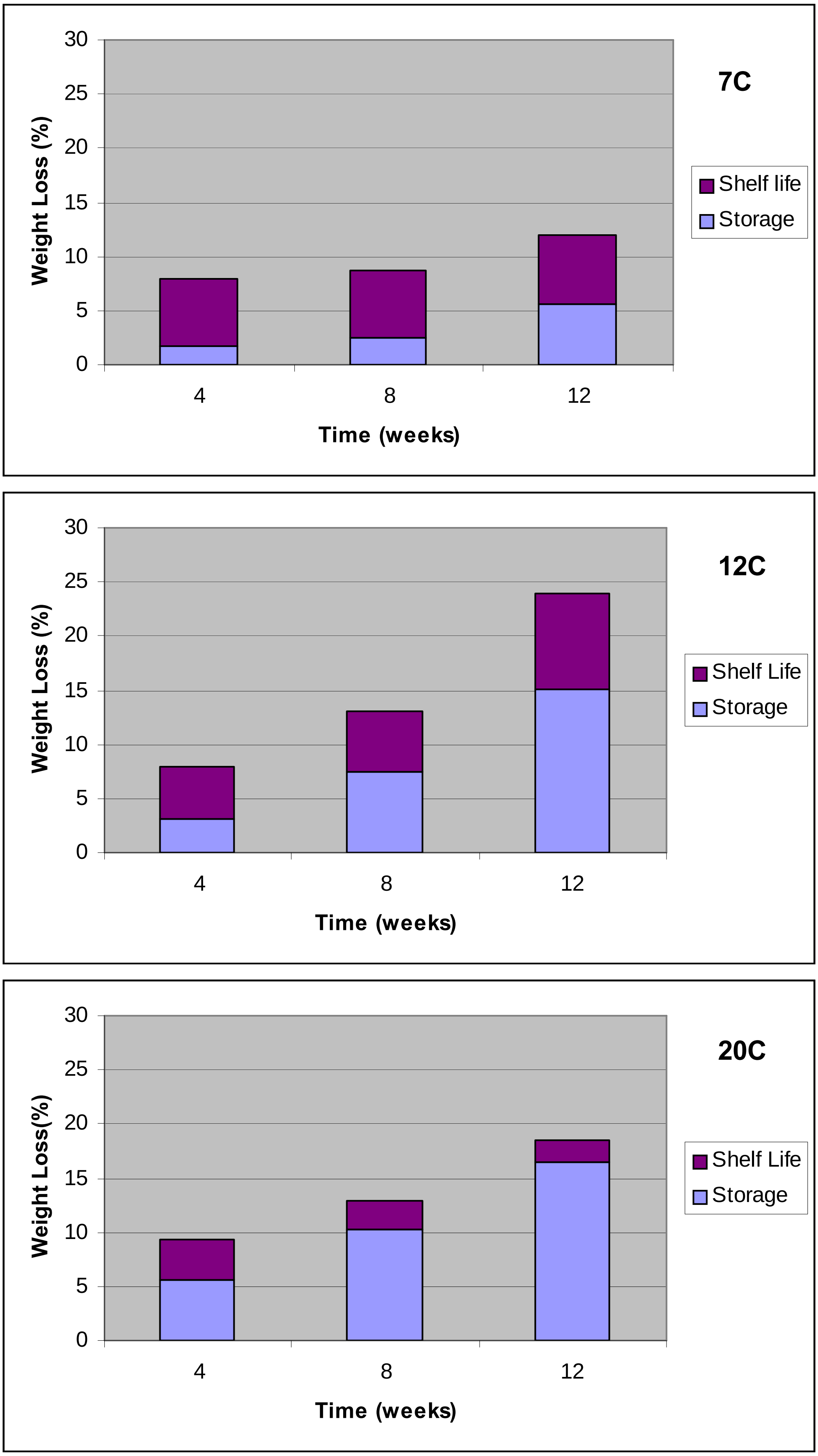

Fig 3. Corm weight loss following storage at 7, 12 or 20°C (storage) and Following a 5 day shelf life simulation at 20°C.

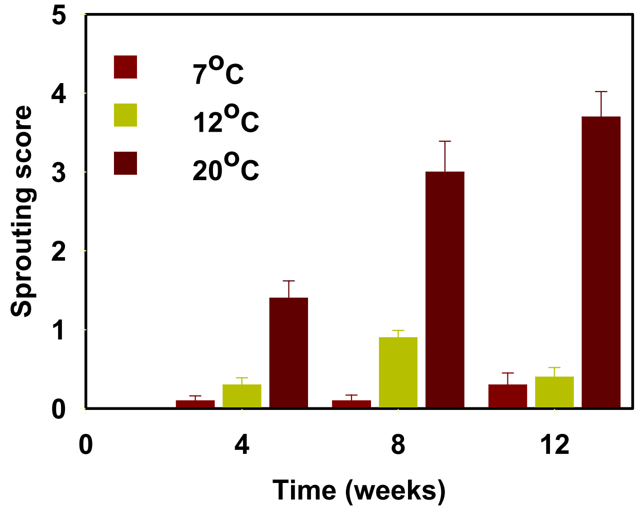

Fig 4. Effect of storage temperature on sprouting

Storage treatment had no effect on internal colour. Figure 5 compares the textural quality of cooked taro stored at 7, 12 or 20 °C. As storage temperature increased the cooked taro softened, clearly demonstrating that storage at lower temperatures maintains textural quality right through to the cooked product. So the benefits of the low temperature storage are carried right through to the final product.

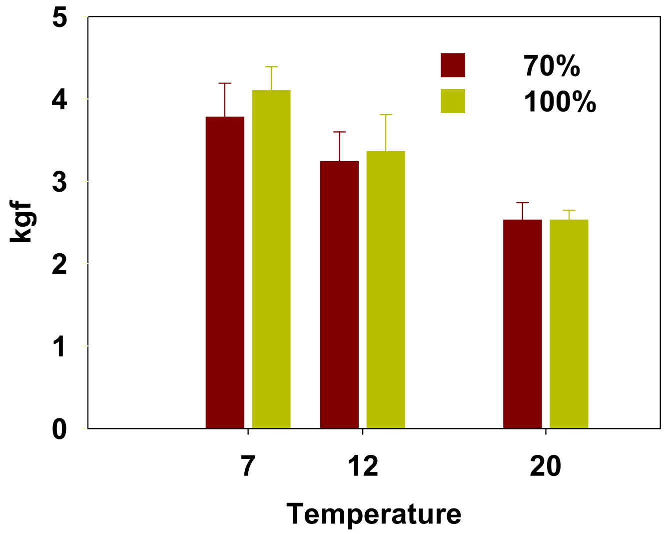

Fig 5. Effect of storage temperature on firmness following a standard steaming process.

3.4 Curing Trial

None of the curing treatments tried in this trial extended shelf life or improved corm quality. The curing treatments used in this study often had a detrimental effect on corm weight loss and in some cases led to a higher disease incidence. In this trial curing was undertaken under passive conditions and it may be that forced air curing may be a more effective treatment. However this may also lead to unacceptable level of weight loss. The use of curing for Japanese taro warrants further investigation.

4. Conclusion

To facilitate the development and maintenance of new export markets, the entire supply chain needs to be geared to meet consumer expectations. Australian produced Japanese taro appears to be acceptable to Japanese consumers despite the considerable variability evident. However to maintain market access quality specifications will need to be developed and adhered to by suppliers. The effect of climate and agronomic practices has also been shown to have a large effect on quality and needs to be studied further.

Storage at 7 or 12 °C appeared to be optimal, giving a maximum storage life of 6 weeks. Storage for longer than 6 weeks may lead to poor outturns due to weight loss or disease. Corms should be stored under high relative humidity to ensure that weight loss is minimised, however care should be taken to exclude any diseased corms from storage. Further work needs to be carried out to assess the susceptibility of Japanese taro to chilling injury.

5. Acknowledgements

Thanks to Emeline Mace, David Harris and Alan Westcott for their technical assistance with these trials. Thanks also to Idris Barchia for the statistical analysis of this data.

6. References

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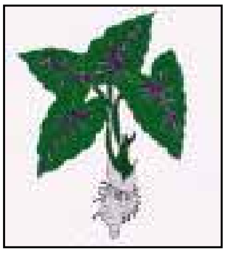


7. Taro Taste Test

SAMPLE CODE: .

Place a vertical mark on each line to indicate your opinion.

For example; What do you think of Sydney as a place to live?

Very bad	Bad	OK	Good	Excellent

APPEARANCE:

What did you think of the shape of the sample?

Very ugly and badly shaped	Poor shape	OK, not good or bad	Good shape	Very attractive, excellent shape

What did you think of the external colour of the sample?

Very bad	Poor	OK	Good	Excellent

What did you think of the internal colour of the sample?

Very bad	Poor	OK	Good	Excellent

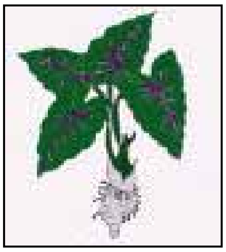
On cutting the sample, does it appear to be sticky?

No stickiness	Very little stickiness	Slight stickiness	Good stickiness	Lots of stickiness

Do you think that the appearance of this sample would be acceptable to Japanese consumers? (*tick a box)*

Yes ☐ No ☐ Maybe ☐

Do you have any other comments about the appearance of the sample?



SAMPLE CODE: .

Taro Taste Test

TEXTURE AND FLAVOUR:

How sticky did you find the sample?

No stickiness, crumbly texture	Barely sticky	Slightly sticky, OK	Quite sticky	Very sticky

How was the texture of the sample?

Very bad	Poor	OK, just average	Good	Excellent

How nutty did you find the sample?

No nuttiness	Very little nuttiness	Slightly nutty	Quite nutty	Very nutty

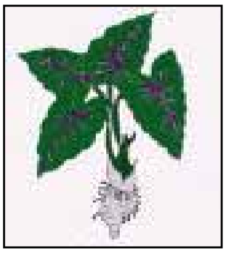
Overall, what did you think of the eating quality of the sample?

Very bad	Poor	OK, not good or bad	Good	Excellent, delicious!

Do you think that the flavour and texture of this sample would be acceptable to Japanese consumers? (*tick a box)*

Yes ☐ No ☐ Maybe ☐

Do you have any other comments about this sample?



Taro Taste Test

SUMMARY:

Do you prefer round or long shaped taro? ________

Which sample looked the best? ________

Which sample looked least attractive? ________

Which sample had the best flavour and texture? ________

Which sample had the least pleasing flavour and texture? ________