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Developing new export vegetables with emphasis on burdock, daikon and globe artichoke

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Agriculture Western Australia

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Project VG 97042

DEVELOPING NEW EXPORT VEGETABLES

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Department of Agriculture
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Developing New Export Vegetables

VG 97042

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This publication is the Final Report of the project VG 97042 and contains the findings of research conducted from January 2001 to May 2003. This report continues on from the research published in the VG 97042 Summary Report that covered research conducted from July 1997 to December 2000.

The project aimed to develop new export vegetables for Western Australia, such as burdock, daikon, shallots and other potential export vegetables. Horticulture Australia Ltd, Ausveg and the Department of Agriculture, Western Australia, funded this project.

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1.0. MEDIA SUMMARY

The second half of the 'Developing new export vegetables' project (VG 97042) with emphasis on root vegetables burdock and daikon, shallots and other vegetables, has been completed. The project was funded by Horticulture Australia Ltd. and the Department of Agriculture, Western Australia. The aim of the project was to identify optimal agronomy practices for burdock, daikon and shallots, which were identified as potential export vegetables for Western Australia from the first half of the project. Other project aims included determining the economic viability of exporting fresh and/or semi-processed burdock, and to identify other potential export vegetables for Western Australia.

The industry significance of the project is that it provides information to assist growers to make decisions when diversifying their businesses away from main stream vegetable production. The vegetable industry is keen to find suitable rotational crops and to develop new overseas markets with produce that meets market requirements. This project attempted to provide Western Australian growers with potential vegetable export opportunities.

The key outcomes/conclusions of the project are:

- A study tour to Japan in December 2001 concluded that WA could not viably export fresh burdock to Japan due to burdock imports from China.
- As fresh burdock was considered uneconomic, semi-processed burdock imported to Japan was investigated. The costs of processing burdock in WA and importing to Japan were also considered not viable based on the prices per kilogram received for imported processed burdock in Japan.
- Shallots have showed promising results in agronomic trials and may be a potential export crop, particularly to the Indonesian market.
- Japanese taro, Japanese yam, vegetable green soybean, and Japanese broad bean may have export potential for WA.

Some of the recommendations include:

- Discontinue further agronomy trials on burdock.
- Revise the economic analysis of semi-processed burdock exported to Japan when more detailed data are available.
- Conduct a detailed economic analysis on exporting shallots to a range of potential markets.
- Continue agronomic trials of Japanese taro in suitable areas.
- Monitor studies conducted by Central Queensland University and Taro Growers Association and remain involved in agronomic trials to determine best practice for WA growing conditions.
- Complete detailed market analyses on other potential export vegetables, Japanese yam, vegetable green soybean and Japanese broad bean.

2.0. TECHNICAL SUMMARY

Competition from other countries is a growing concern for the Western Australian export vegetable industry. Unfortunately, this statement is very true for the potential export vegetable, burdock (Arctium lappa). In the time it took for the research to determine optimum agronomic practices to produce high quality fresh burdock in WA for export to Japan, the fresh market has become uneconomic. Chinese imports into Japan have caused low prices of imported burdock resulting in low returns for fresh export burdock from WA. Initial studies into semi-processed burdock have also indicated that the Japanese market is not viable.

Daikon (*Raphanus sativus*) and shallots (*Allium ascalonicum*) were also identified as having export potential for Western Australia. This project has investigated the cultural practices required to successfully grow these vegetables in Western Australia. Desk-top studies have also been conducted on Japanese taro, Japanese yam, Japanese broad bean and Japanese green soybean with initial field trials on Japanese taro.

The major findings and industry outcomes were:

- Best total yield for burdock was about 47 t/ha when 400 – 600 kg N/ha was applied.
- Marketable yields recorded from the nitrogen burdock trial were very poor (8 t/ha or less) across all nitrogen treatments. Therefore, further trials should be conducted for spring-sown burdock before optimum N rate can be determined.
- Pre-emergent herbicides Kerb® (propyzamide) at 4.4 L/ha and trifluralin at 2.0 L/ha slightly affected burdock seedlings planted in November and January, with no effect on total yield. No pre-emergent herbicides are registered for use on burdock in Australia.
- Based on yields, an intra-row spacing of between 5 – 8 cm is suitable for spring-sown burdock if harvested at 20 weeks or 134 days after sowing.
- Priming burdock seed (soaked in water for 12 hours) did not significantly increase germination rate at a summer planting.
- A flat bed formation increased germination rate and marketable yields of summer-sown burdock compared to a hilled bed formation.
- Shallot varieties, Ambition and Matador, are suited for the Manjimup and Medina areas.
- The optimum density for Ambition and Matador is 905,797 plants/ha and 1,602,564 plants/ha respectively.
- Small bulbs (0 – 20 mm diameter) can be used to propagate shallot vegetatively.
- To achieve higher total and marketable yields in daikon, a density of 18 plants/m^2 (14.5 cm x 29 cm) harvested at 65 days after sowing is better for both varieties, Narumi and Minowase Summer Cross No. 3.
- A study tour to Japan in December 2001 concluded that WA could not viably export fresh burdock to Japan due to burdock imports from China.
- As fresh burdock was considered uneconomic, semi-processed burdock imported to Japan was investigated. The costs of processing burdock in WA and importing to Japan were also considered not viable (A$8.69 /kg) based on the prices per kilo received for imported processed burdock in Japan (A$4.00 - $6.00 /kg).
- Four export vegetables, Japanese taro, Japanese yam, vegetable green soybean, and Japanese broad bean may have export potential for WA.
- Japanese taro trials at Medina Research Station have shown promising results with a comparable total yield of 48.3 t/ha.

Some of the recommendations include:

- Discontinue further agronomic trials on burdock.
- Revise the economic analysis on semi-processed burdock exported to Japan with more detailed costings.
- Continue agronomic trials of Japanese taro.
- Conduct a detailed economic analysis on exporting shallots from Australia with input from industry partners.
- Revise market analyses on other potential export vegetables, Japanese yam, vegetable green soybean and Japanese broad bean, before conducting any agronomic trials in WA.

3.0. INTRODUCTION

A preliminary evaluation of potential export opportunities was presented to industry at the 'Asian Vegetable Opportunities in Japan and North-East Asia – Export Focus Workshop', conducted in Perth, December 1995. The workshop, jointly funded by Department of Agriculture and the Rural Industries Research and Development Corporation, identified several seasonal and high value Asian vegetables to be evaluated further regarding suitable varieties/cultivars, yield, cultural practices, location of commercial production and postharvest handling. Burdock (*Arctium lappa*) and daikon (*Raphanus sativus*) were identified as potential new export vegetables for Western Australia. Hence the first half of the project 'Developing new export vegetables with emphasis on burdock, daikon and globe artichoke 1997 - 2000' (VG 97042) was undertaken.

The aims of part one (1997 – 2000) of the project were:

- To evaluate and identify burdock and daikon varieties/cultivars suitable for Western Australian conditions.
- To carry out a feasibility study to evaluate market potential and requirements for globe artichoke.
- To improve/develop innovative postharvest handling and storage methods for export markets.

Part two of the project (2001 – 2003) follows on from the initial project and mainly focussed on further agronomic trials of burdock, shallots and daikon, as well as desk-top studies of other potential vegetables such as Japanese taro, Japanese yam, vegetable green soybean and Japanese broad bean.

The aims of part two of the project were:

- To conduct further agronomic trials such as fertiliser trials, herbicide crop tolerance, intra-row spacing, effect of fungicides on germination, seed priming and bed formation effects and the effects of storage temperature.
- To conduct a study tour to Japan with the following objectives:
    - i) To visit burdock growers to determine their growing and handling methods for burdock and to gather information on crop agronomy.
    - ii) To visit vegetable importers, wholesalers and processors to discuss prospects of exporting fresh and/or semi-processed burdock to Japan.
    - iii) To visit wholesale markets and inspect local and imported burdock quality and determine wholesale price.
- Preliminary studies were carried out by Food Science Australia to assess the possibility of semi-processing burdock roots
- To conduct an economic analysis of supplying Western Australian semi-processed burdock to Japan.
- Agronomy trials on shallots to include variety evaluation, density and seed bulb-size trials.
- To conduct a trial to determine optimum density of two daikon varieties.
- Assess other potential export vegetables such as Japanese taro, Japanese yam, vegetable green soybean and Japanese broad bean.

The project's significance to industry is to diversify the Western Australian vegetable industry, to provide suitable rotational crops by developing new overseas markets with products that meet market requirements.

4.0. BURDOCK RESEARCH

4.1. Effect of nitrogen on yield and quality of spring sown burdock

From the nitrogen observations completed in May 2001, it was found that a higher rate of nitrogen (423 kg N/ha) increased marketable yield of summer sown burdock. To complete the agronomic package for export burdock production, a trial investigating the effects of various rates of nitrogen on burdock sown in the spring of 2001 was conducted. The aim of this trial was to create a nitrogen response curve to determine optimum nitrogen rate of spring sown burdock and to examine the effects of various nitrogen rates on yield and quality of burdock.

4.1.1. Materials and method

The trial was planted at the Medina Research Station in Spearwood sand Uc 4.13 (Northcote, 1979). Table 1 lists the preplanting soil test details of the site. Water analysis of the two bores that watered the trial was also done during the growing period to determine any significant leaching of nitrate-N in the ground water (Table 2). The site was irrigated to germinate the weeds and a knockdown herbicide was sprayed to kill the weeds. Three to four weeks prior to planting, the site was fumigated using metham sodium and Nemacur® was applied to control nematodes. The site was deep ripped and preplant fertilisers; double superphosphate (1500 kg/ha), muriate of potash (120 kg/ha), gypsum (250 kg/ha) and trace element mix (150 kg/ha), were broadcast and incorporated using a rotary hoe. The site was deep ripped a second time and the Kawabe root trencher cultivated the soil and the beds were formed.

Each plot was 3 m long with two rows (60cm apart) per 1.5 m wide bed. The trial was sown by hand, with 8 cm intrarow spacing, on the 19 October 2001 using the burdock variety, *Takinogawa Long*. The pre-emergent herbicide, chlorthal dimethyl (Dacthal®), was used at 6 kg/ha for further weed control.

Table 1: Soil characteristics (0 – 15 cm) of the trial site before fertilisation.

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)

There were six nitrogen treatments (Table 3) and four replicates per treatment (24 plots). The treatments were arranged in a randomised block design. The nitrogen was applied as ammonium nitrate in 18 weekly dressings using watering cans. In addition to the nitrogen applications, weekly top dressings of potassium sulphate (31 kg/ha) and

magnesium sulphate (13 kg/ha) were applied through the irrigation system. Immediately after N fertiliser application, the plots were irrigated to apply 5 mm of water.

Table 2: Water characteristics of irrigation water used for the trial (average from two bores).

pH	7.6
Electrical conductivity	0.93 ms/cm
Total dissolved salts	555 ppm
Bicarbonate	218 ppm
Nitrate-N	Nil
Total iron	2.6 ppm
Hardness (as $CaCO_3$)	250 ppm
Alkalinity (as $CaCO_3$)	180 ppm
Dissolved carbon dioxide	10 ppm

Table 3: Details of nitrogen treatments

Treatment no.	Treatment (kg N/ha)	Time of application	Rate of ammonium nitrate (kg/ha)	Total N (kg/ha)
1.	0	Pre-plant	Nil	0
		Top dressing 18 weekly applications	Nil	0
2.	100	Pre-plant	100	34
		Top dressing 18 weekly applications	194	66
3.	200	Pre-plant	100	34
		Top dressing 18 weekly applications	488	166
4.	400	Pre-plant	100	34
		Top dressing 18 weekly applications	1076	366
5.	600	Pre-plant	100	34
		Top dressing 18 weekly applications	1665	566
6.	800	Pre-plant	100	34
		Top dressing 18 weekly applications	2253	766

Three methods of analysis were used to measure total-N and nitrate-N of each plot during growth. One method was to randomly sample twenty youngest fully expanded leaves (YFEL), comprising of petiole and blade, from each plot between 9 and 10 am at 76 and 144 days after sowing (DAS). The whole leaf samples were taken to the

Chemistry Centre for laboratory analysis of total-N and nitrate-N as a percentage of dry weight.

The second method was to collect twenty petioles from YFEL from each plot between 9 and 10 am at 70 and 144 DAS. The petioles were taken to the Chemistry Centre and sap nitrate-N concentrations were measured.

The third method was to measure sap nitrate concentrations using the Nitrachek® meter and Merckoquant® test strips. An additional twenty petioles from YFEL were collected from each plot at the same time of the day at 70, 91, 108, 117,130 and 144 DAS. The petioles were washed using distilled water and cut into sections. Two millilitres of sap was extracted from the randomly selected cut pieces using a garlic press. Sap from treatments 1 to 3 was diluted to 1:10 and sap from treatments 5 to 6 diluted to 1:20. Nitrate standards were used to calibrate the meter prior to nitrate measurements. The nitrate sensitive square of the test strip was submerged into the diluted sap for one minute and a reading was taken in mg/L.

Finally, at harvest (144 DAS), a 0.5 m section of both rows of each plot was removed. The leaves (blade and petiole) were detached from the root and fresh weight of the leaves (leaf yield) and the roots were recorded. The roots were then cut into sections and delivered to the Chemistry Centre to measure total-N and nitrate-N as a percentage of dry weight.

The remaining burdock was harvested and other measurements were recorded. Forty roots from each plot were measured for root weight (g), root length (mm), diameter (mm), ratings of pithiness and quality (Table 4 and 5). The remaining roots were sorted into two groups; marketable and unmarketable. The two grades were weighed and total and marketable yields were calculated. From a sample of forty roots, each root was graded using the Japanese grading system (Table 6). Roots were graded according to root length and diameter as well as the ratings of pithiness and quality. Roots had to have a rating of three or less for both pithiness and quality as well as receive a grade category using the Japanese grading system. Those roots that were 40 g and under were not measured.

Table 4: Pithiness ratings for burdock

Score	Description
1	None
2	Slight
3	Moderate
4	Severe
5	Very severe

Table 5: Quality ratings for burdock

Score	Description
1	Excellent export standard
2	Export standard
3	Good marketability
4	Poor marketability
5	Reject

Table 6: Burdock size grading for Japanese markets

Sub-grade	Size	Root diameter (mm)	Root length (cm)
A	3L	≥36	>60
	2L	31 - 35	>60
	L	26 - 30	>60
	M	21 - 25	>60
	2M	16 - 20	>60
	S	11 - 15	>55
	2S	≤10	>35
B	BL	>35	45 – 60
	BM	25 - 35	45 – 60
	BS	>15	45 – 60
	Process	>20	>40

The results were analysed by analysis of variance using Genstat statistical software.

4.2.2. Results and discussion

Effect of N rate on yield and quality

Nitrogen rates of 400 – 600 kg/ha significantly increased total yield by 16 – 38% when compared with the other N treatments (Table 7). Marketable yield was not significantly different between N treatments. Marketable yield was very poor with only 10 – 17% of total yield being marketable roots.

Table 7: The effect of N rate on total yield, marketable yield, leaf yield and plant density of burdock

Treatment (kg N/ha)	Total yield (t/ha)	Marketable yield (t/ha)	Leaf yield (t/ha)	Plant density (plants/m^2)
0	29.55	4.28	12.59	19.0
100	36.98	5.78	16.42	18.0
200	38.03	3.93	18.99	17.5
400	47.03	6.65	28.05	17.3
600	47.58	7.95	31.85	17.3
800	45.10	6.95	34.01	15.8
Significance	***	ns	***	**
LSD (P=0.05)	5.74	4.33	7.18	1.9

*** = P<0.001 * *= P<0.05 ns = not significant

The main cause for the reject roots was forking and severely bent roots. Forking of burdock roots is mainly caused by the lack of adequate cultivation (Nguyen 1998). Nguyen (1998) explains that up to 80% of roots that fork do so in the top 15 cm due to lack of cultivation, a change in soil structure or if fertiliser with a N content has been banded below the seed line. The Kawabe trencher used to cultivate the site reduces forking in the burdock roots. Excessive use of chemical fertilisers have been known to cause forking (Anonymous 1998). In this N trial, forking may have been caused by the excessive use of chemical fertilisers, however this does not explain why plots with N rates of less than 200 kg/ha applied still produced less than 4 t/ha marketable yield.

Leaf yield increased with increased nitrogen rate. Leaf yield increased from 12.59 t/ha with nil N applied reaching 34.01 t/ha with 800 kg N/ha. Plant density was the opposite effect as density decreased with increasing nitrogen rate. Plant density decreased from 19.0 plants per m^2 with nil N applied down to 15.8 plants per m^2 with 800 kg N/ha.

A quadratic polynomial was fitted to describe the response of total yield to applied nitrogen (Figure 1). The additional nitrogen increased the total yield from 29.8 t/ha where no nitrogen was applied up to a maximum of 47.8 t/ha with 575 kg of N.

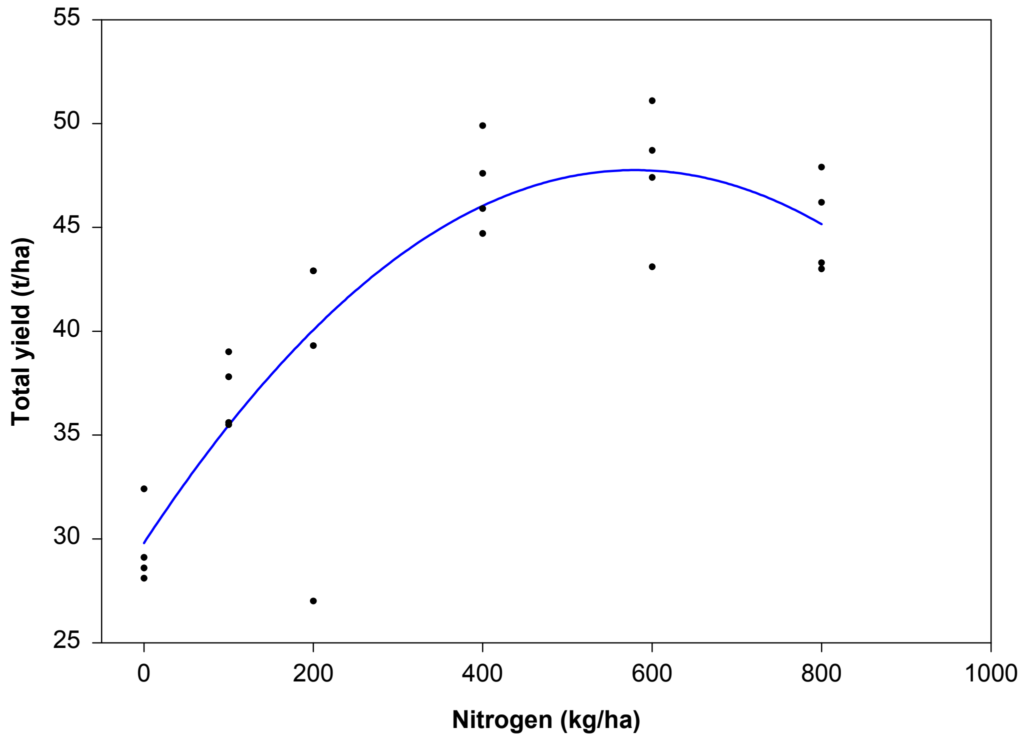

Figure 1: The response of total burdock yield to applied nitrogen. Fitted function $Y = 29.80 + 0.0620 \times N - 0.0000535 \times N^2$ ($R^2 = 0.75$) where Y = total yield and N = nitrogen rate (kg N/ha).

Table 8: The effect of N rate on average root weight, length, diameter, pithiness and quality of burdock

Treatment (kg N/ha)	Weight (g)	Length (mm)	Diameter (mm)	Pithiness Rating (1-5)	Quality Rating (1-5)
0	179.4	631.7	19.46	2.06	4.14
100	215.3	632.1	21.51	2.11	4.11
200	240.2	624.7	23.41	2.06	4.29
400	284.9	616.2	25.42	2.63	4.14
600	275.6	586.0	25.71	2.87	4.09
800	293.1	591.1	26.53	2.93	4.05
Significance	***	***	***	***	**
LSD (P=0.05)	23.98	27.35	1.11	0.11	0.16

*** = $P<0.001$ ** = $P<0.05$

Higher rates of nitrogen (400 – 800 kg N/ha) significantly increased root weight and diameter compared plots with 200 kg N/ha or less (Table 8). Longer root lengths between 616.2 – 632.1 mm were recorded when 0, 100, 200 and 400 kg N/ha were applied. The rate of N seems to have an opposite effect on root length than weight and diameter. With lower N rates the roots are longer, while the roots with higher N rates applied are shorter and thicker at the crown.

Pithiness ratings were significantly higher when 600 and 800 kg N/ha were applied. Although the differences between treatments were significant, ratings of pithiness were still considered slight to moderate. Quality ratings across all treatments were considered of poor marketability which was reflected in the marketable yield of each treatment.

Petiole nitrate-N and leaf N concentrations

Table 9 outlines the sap nitrate concentrations (mg/L) of petioles of youngest fully expanded leaves (YFEL) collected at 70, 91, 108, 117, 130 and 144 days after sowing. Sap nitrate concentrations generally decreased towards the end of the crop. At 70 DAS, 600 N rate had a petiole nitrate of 3105 mg/L which fell to 1100 mg/L at 144 DAS, not before it peaked at 2450 mg/L at 130 DAS (Figure 2). Similarly with 200 N rate, at 70 DAS petiole nitrate was 1150 mg/ha then dropped to 220 mg/ha but not before it peaked at 858 mg/L at 108 DAS.

The reason why some treatments initially decreased in petiole nitrate then peaked at certain sample dates, only drop down again at the end of the season, is not clear. The fertiliser was normally applied two days before sampling but other factors such as weather may have affected the uptake of nutrients.

Table 9: The effect of N rate on the sap nitrate and nitrate-N (70 and 144 DAS) concentration (mg/L) in the petioles of YFELs collected six times during growing period.

N rate (kg N/ha)	70 DAS	70 DAS (nitrate-N)	91 DAS	108 DAS	117 DAS	130 DAS	144 DAS	144 DAS (nitrate-N)
0	155	35	50	85	62	48	45	10
100	255	58	105	225	287	202	80	18
200	1150	260	220	858	475	568	245	55
400	1708	386	1505	1415	1440	1455	905	204
600	3105	702	1485	1595	1970	2450	1100	249
800	3435	776	2740	3315	2745	2360	1295	293
Significance	***		***	***	***	***	***	
LSD (P=0.05)	719.3		1058.5	714.4	711.6	346.6	274.8	

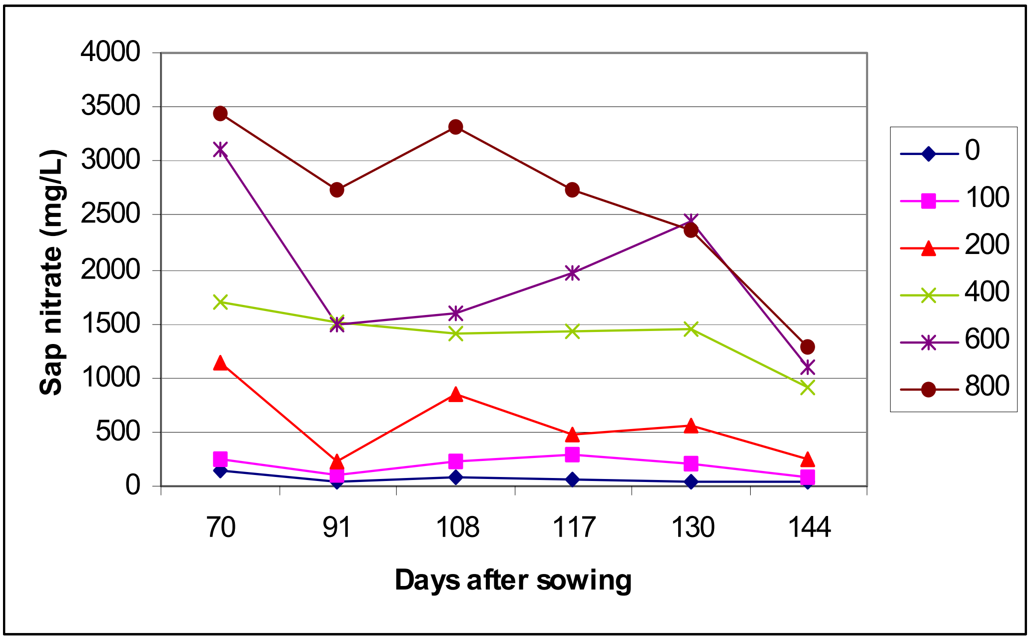

Figure 2: Sap nitrate concentrations in the petioles of YFEL of burdock collected at six times during the growing period

The laboratory, the Chemistry Centre, measured sap nitrate-N (NO_3-N) concentrations from the petioles of the YFEL taken at 70 and 144 DAS (Table 10). The manual method using the test strips measured sap nitrate (NO_3) only, therefore to compare results, the nitrate levels obtained by the test strip can be multiplied by 0.226 to get the nitrate-N reading (Merck, 2002).

At lower N rates, the readings of nitrate-N are relatively similar. For example, at 70 DAS, the average nitrate-N level from plots with 100 kg N/ha applied recorded 58 mg/L (Table 9) using the manual test strip method, while laboratory tests recorded 79 mg/L at the same sample date. However, the higher the N rate, the greater the difference between the test strip reading and the Chemistry Centre readings. At 70 DAS, the nitrate-N level from 800 kg N/ha was 776 mg/L obtained from the manual method compared to the Chemistry Centre reading of 1000 mg/L at the same rate and sample date. Perhaps the test strips become less accurate when higher levels of nitrates are measured.

Table 10: The effect of N rate on the sap nitrate-N concentration measured by laboratory (mg/L) in the petioles of YFELs at 70 and 144 DAS.

N rate (kg N/ha)	70 DAS	144 DAS
0	8	2
100	79	18
200	200	69
400	467	187
600	815	320
800	1000	445
Significance	***	***
LSD (P=0.05)	176.1	108.6

Table 11: The effect of N rate on total nitrogen and nitrate-N (%d.w.) in YFELs (whole leaves) at 76 DAS and 144 DAS.

N rate (kg N/ha)	76 DAS		144 DAS	
	Total N	Nitrate-N	Total N	Nitrate-N
0	2.56	0.01	2.40	0.04
100	2.71	0.04	2.64	0.05
200	2.89	0.03	2.75	0.13
400	3.17	0.10	3.19	0.15
600	3.97	0.25	3.32	0.21
800	4.37	0.38	4.02	0.39
Significance	***	***	***	**
LSD (P=0.05)	0.53	0.09	0.28	0.15

The total and nitrate-N as a percentage of dry weight in whole leaves of the YFEL, was significantly higher in the higher N rates. Total nitrogen from plots with 800 kg N/ha applied, was 4.37% d.w., 76 days after sowing (Table 11). Total N at 144 days after sowing was similar at 800 kg N/ha with 4.02% d.w. Nitrate-N at 800 kg N/ha was 0.38% d.w. at 76 DAS. Total N and nitrate-N in whole roots had a similar trend with higher percentage d.w at the higher N rates. In whole roots, total N and nitrate-N from 800 kg N/ha was 1.90% and 0.90% respectively.

Table 12: The effect of N rate on the N concentration (total and nitrate-N) (%d.w.) in whole roots at 144 DAS.

N rate(kg N/ha)	Total N	Nitrate-N
0	0.30	0.01
100	0.53	0.01
200	0.79	0.01
400	1.27	0.03
600	1.50	0.05
800	1.90	0.09
Significance	***	***
LSD (P=0.05)	0.23	0.02

The percentage dry weight of total N in the roots after 144 DAS was half of what was recorded in the leaves when 800 kg N/ha was applied (Table 12). Nitrate-N in whole roots at harvest was less than 0.1% d.w.

In conclusion, nitrogen rates of 400 – 600 kg N/ha did significantly increase total yield by 16 – 38%. However, further research needs to be done on why marketable yields are less from a spring sown crop compared to a summer sown crop. Marketable yields from this trial were very poor (8 t/ha or less) across all N treatments. Therefore further research should be done for spring sown burdock before optimum nitrogen rate can be determined.

4.2. Nitrogen observation of summer sown burdock

In December 1999, the first burdock nitrogen trial was planted at the Medina Research Station, 40 km south of Perth. However, a combination of hot weather at germination and high fertiliser rates resulted in poor growth (McVeigh, Hoffmann and Tan, 2000). The treatments were modified and the trial repeated for a September/October planting. This was completed as discussed in section 4.1. However, another nitrogen trial was planted in January 2001 using nitrogen rates above and below the standard nitrogen rate applied on previous burdock trials. It was thought that nitrogen rates of 600 kg/ha and above applied in the initial nitrogen trial may have contributed to the poor growth together with the high temperatures at germination. This trial aimed to observe the effect of three nitrogen rates and different harvest times on the yield and quality of burdock roots.

4.2.1. Materials and method

Results were assessed only by observation, therefore no replication or data analysis was done. The trial site was deep ripped and irrigated to germinate weeds. A knockdown herbicide was then applied and fenamiphos (Nemacur®) was applied four days before sowing to control nematodes. Pre-plant fertilisers, double superphosphate at 900 kg/ha, gypsum at 250 kg/ha and a trace element mix at 150 kg/ha were broadcast and incorporated using rotary hoe. Ammonium nitrate at 100 kg/ha was banded 60 cm apart and incorporated by the Kawabe trencher used to cultivate the soil and encourage root elongation.

There were 12 plots, 1.5 m wide by 6 m long with two rows per bed. Each nitrogen treatment was repeated four times so that at each harvest time, a plot with a different nitrogen rate was harvested. There were three nitrogen rates: 242 kg/ha, 378 kg/ha and 423 kg/ha. Nitrogen was applied in the form of ammonium nitrate and applied weekly using a watering can. Table 13 outlines the fertiliser type, rate and total nitrogen applied on each plot.

Forty roots from each harvest plot were measured for root weight (g), root length (mm), diameter (mm), ratings of pithiness and quality (Table 4 and 5). The remaining roots were sorted into two groups; marketable and unmarketable. The two grades were weighed and total and marketable yields were calculated. From a sample of forty roots, each root was graded using the Japanese grading system (Table 6). Roots were graded according to root length and diameter as well as the ratings of pithiness and quality. Roots had to have a rating of three or less for both pithiness and quality as well as receive a grade category using the Japanese grading system. Those roots that were 40 g and under were not measured.

The trial was hand sown on 2 January 2001 using the variety *Takinogawa Long*, with an intra-row spacing of 8 cm and 60 cm between the rows.

Table 13: Fertiliser type, rate and total nitrogen applied on burdock nitrogen observation trial.

Treatment No.	Application	Fertiliser	Rate (kg/ha)	Kg N/ha	Total N	Kg N/ha
1.	Pre-plant	Ammonium nitrate	100	34	34	
	Top dressing 16 weekly applications	Potassium nitrate	31	4.2	67.2	
		Ammonium nitrate	26	8.8	140.8	**242**
2.	Pre-plant	Ammonium nitrate	100	34	34	
	Top dressing 16 weekly applications	Potassium nitrate	31	4.2	67.2	
		Ammonium nitrate	51	17.3	276.8	**378**
3.	Pre-plant	Ammonium nitrate	100	34	34	
	Top dressing 16 weekly application	Potassium nitrate	31	4.2	67.2	
		Ammonium nitrate	59	20.1	321.5	**423**

4.2.2. Results and discussion

Three plots with different nitrogen rates were harvested at each harvest time. The first harvest was 140 days after sowing with three subsequent harvests one week apart (Table 14).

Table 14: Harvest dates and days after sowing of nitrogen observation

Harvest No.	Harvest date	No. days after sowing (DAS)
1.	22 May 2001	140
2.	1 June 2001	150
3.	8 June 2001	157
4.	15 June 2001	164

Average total yields increased by 6% with increasing nitrogen regardless of harvesting date from 34.6 t/ha with 242 kg N/ha to 37.4 t/ha with 423 kg N/ha (Table 15). Average marketable yields were similar with increasing nitrogen, from 21.8 t/ha (242 kg N/ha) to 22.2 t/ha (423 kg N/ha). The higher nitrogen rate of 423 kg/ha produced an average of 68.5% marketable yield and the lower rate of N at 242 kg/ha produced 64.0% marketable roots. The percentage marketable roots on average produced from plots with

378 kg N/ha was 60.5%, which was lower than the percentage marketable yield from the lower N rate of 242 kg/ha.

When comparing harvest dates, the range of total yield and percentage marketable are quite large between harvests particularly for the low N rate. The low N rate of 242 kg N/ha had a total yield of 28.5 – 38.0 t/ha with 46 – 76% marketable roots depending upon harvest date. However, averages of total yield for a particular harvest date are similar. For example, 157 days after sowing total yield was 34.5, 35.9 and 35.2 t/ha for 242, 378 and 423 kg N/ha respectively.

Although, total yields peaked for the 242 kg N/ha and 423 kg N/ha treatments, this is most likely a variation in the unreplicated data (Figure 3). Marketable yield trend for each nitrogen treatment is similar when comparing harvest dates. Marketable yields decreased at the second harvest (150 DAS) for all treatments, only to gradually increase to the highest marketable yield at the final harvest, 164 days after sowing (Figure 4). Again this is most likely contributed to variability in the unreplicated data.

Table 15: Total and marketable yields of nitrogen treatments at four harvest dates

Nitrogen treatment	Harvest no.	Total yield (t/ha)	Marketable yield (t/ha)	% Marketable
1 – 242 kg N/ha	1	28.5	21.7	76
	2	38.0	17.6	46
	3	34.5	23.2	67
	4	37.2	24.9	67
	Average	**34.6**	**21.9**	**64.0**
2 – 378 kg N/ha	1	34.9	21.7	62
	2	32.1	17.8	55
	3	35.9	21.0	58
	4	40.1	26.5	67
	Average	**35.8**	**21.8**	**60.5**
3 – 423 kg N/ha	1	33.6	25.1	75
	2	40.9	16.9	75
	3	35.2	20.7	59
	4	39.9	26.1	65
	Average	**37.4**	**22.2**	**68.5**

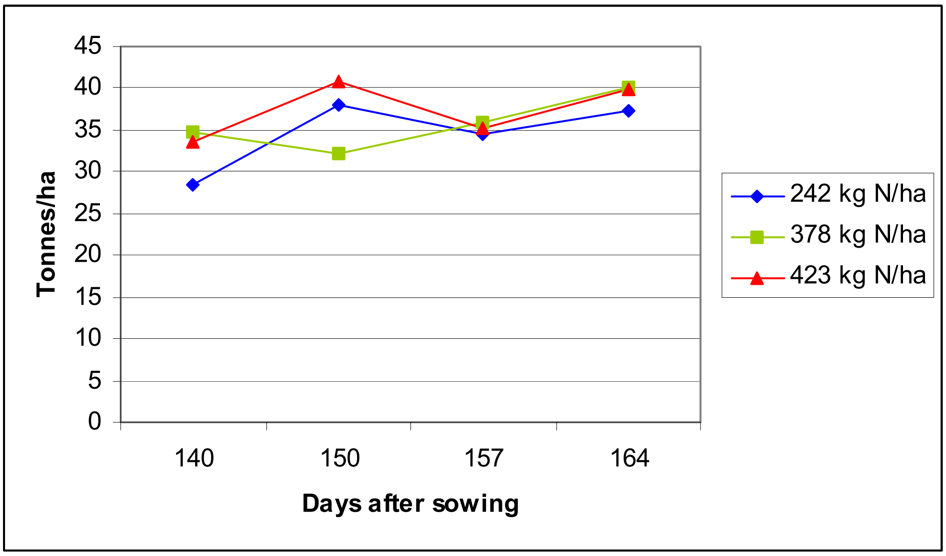

Figure 3: Total yield (t/ha) at various harvest dates with different rates of nitrogen

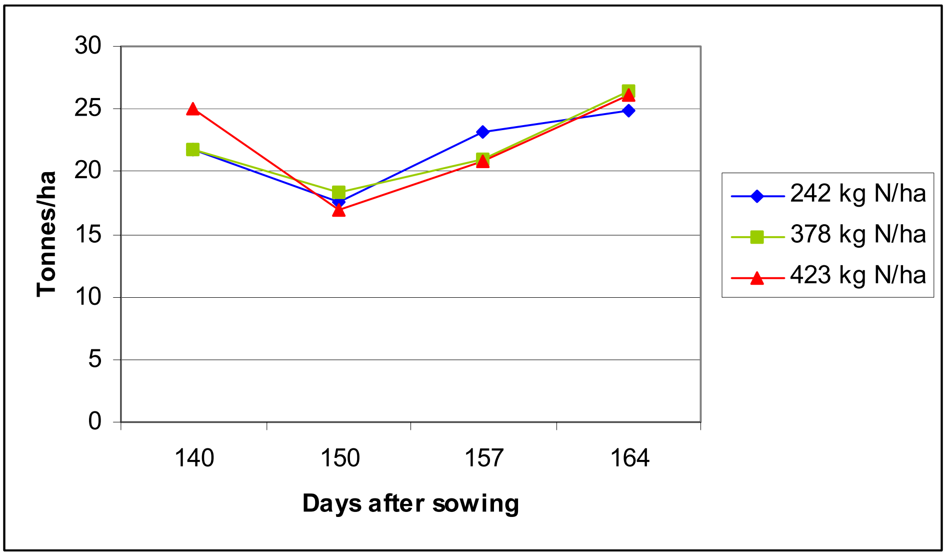

Figure 4: Marketable yield (t/ha) at various harvest dates with different rates of nitrogen

Regardless of harvest date, average root weight and length was the highest when 423 kg N/ha was applied, with 250.9 g average weight and 712 mm average length (Table 16). Average diameter, pithiness and quality ratings remained similar across all three N treatments. When considering harvest dates, root weight, length and diameter was the highest for all N treatments after the fourth harvest or 164 days after sowing. The ratings of pithiness were higher at the later harvest date but the ratings were slight to moderate which is considered acceptable for the Japanese market. Quality ratings are taken from a sample of forty randomly selected roots, therefore these ratings do not relate to percentage marketable. However, these roots were considered marketable if root diameter was greater than 11mm root length greater than 55 mm and pithiness and quality ratings greater than 4.

Table 16: Average weight, length, diameter, pithiness and quality ratings of burdock roots from different N rates

N treatments	Harvest date	Weight (g)	Length (mm)	Diameter (mm)	Pithiness (1-5)	Quality (1-5)
1 – 242 kg N/ha	22/5/01	177.7	634.0	19.4	1.3	3.1
	1/6/01	261.8	717.5	23.8	1.5	3.2
	8/6/01	214.3	684.5	21.4	1.5	3.3
	15/6/01	308.5	796.4	25.7	2.0	3.1
	Average	**240.6**	**708.1**	**22.6**	**1.6**	**3.2**
2 – 378 kg N/ha	22/5/01	266.3	660.8	25.4	1.6	3.6
	1/6/01	236.4	649.0	23.0	1.5	3.1
	8/6/01	181.9	634.0	20.0	1.6	3.2
	15/6/01	294.6	771.8	26.9	2.3	3.4
	Average	**244.8**	**678.9**	**23.8**	**1.8**	**3.3**
3 – 423 kg N/ha	22/5/01	219.9	695.3	21.6	1.4	2.9
	1/6/01	264.3	656.8	23.6	1.9	3.5
	8/6/01	225.5	711.3	21.5	1.6	2.8
	15/6/01	293.9	784.5	26.3	2.3	3.5
	Average	**250.9**	**712.0**	**23.3**	**1.8**	**3.2**

From these results, it appears that a N application of 423 kg N/ha increased total yield by 5-6% and marketable yield by 1% compared to the lower N rates of 242 kg/ha and 378 kg/ha. Root weight and diameter also increased with the higher N rate. With regards to the harvest date, higher marketable yields were recorded at the fourth harvest across all N treatments. Total yield did not have the same trend with 242 kg N/ha and 423 kg N/ha recording the highest total yield at the second harvest and 378 kg N/ha recorded the highest total yield at the fourth harvest.

Although the results were not analysed and no significant differences are known, our observations indicate that burdock can receive a higher rate of N (up to 423 kg N/ha) when sown in summer. From the results, burdock can also be harvested at a later date (up to 164 days after sowing), to achieve small increases in yield without compromising root quality. However, pithiness must be closely monitored if later harvests are considered as this may be of concern in the Japanese market.

4.3. Herbicide observation

From previous trials, it has been shown that burdock can be grown successfully in the sandy soils of the Swan Coastal Plain and in the levee soil of Kununurra. Further agronomy trials were completed such as fertiliser and herbicide trials. Herbicide trials on burdock in New Zealand have shown promising results with terbacil, diuron and pendimethalin (Burgmans, 1996). The aim of this trial was to determine efficacy and crop tolerance of various pre-emergent herbicides on burdock grown along the Swan Coastal Plain.

No herbicides are registered in Australia for use on burdock. The herbicides used in this trial were chosen because they were used for the control of weeds in other vegetables. Any treatment used in this trial proven to be successful as a pre-emergent herbicide for burdock would require an off label permit in order to be used in commercial burdock plantings.

4.3.1. Materials and method

The herbicide trial was prepared similar to the nitrogen trial with regards to site preparation and pre-plant fertilisers. The trial was established at the Medina Research Station on Spearwood sand. Previously, the site remained unused for about three years with only pasture grown previously. The site was deep ripped and after the application of pre-plant fertilisers, the Kawabe trencher was used to further cultivate the soil. Double superphosphate (900 kg/ha), gypsum (250 kg/ha) and a standard trace element mix (150 kg/ha) was incorporated using a rotary hoe before sowing. Ammonium nitrate at 100 kg/ha was banded at 60 cm apart which was incorporated using the trencher. Post-plant fertilisers were applied one week after sowing and applied through the irrigation. For the first seven weeks, 10.3 kg /ha of potassium nitrate and 8.7 kg/ha of ammonium nitrate was applied weekly. From week eight to sixteen 43.4 kg/ha of potassium nitrate and 36.0 kg/ha ammonium nitrate was applied weekly. A total of 229 kg N/ha was applied during the duration of the trial.

Two days after sowing, the pre-emergent herbicides were applied at the recommended rate (rate on the label for vegetables) and double this rate to observe crop tolerances (Table 17). The burdock variety was Takinogawa Long and the trial was planted on 2 January 2001.

There were fourteen herbicide treatments, replicated four times. The trial was a randomised block design and the results were analysed by analysis of variance using Genstat statistical software.

The trial was harvested on 1 May 2001, 119 days after sowing. Every two weeks for the first eight weeks, visual scores of efficacy and crop tolerance for each plot were recorded. The scores were from 1 to 9, with 1 being complete kill of weeds and no effect on burdock seedlings and 9 being no weed kill and total loss of plant and yield (Table 18). Other measurements of the harvested burdock roots include total and marketable yields, weight, length, diameter, pithiness (Table 2) and quality (Table 3) ratings for each plot.

Table 17: The herbicide treatments and rates applied

Treatment No.	Chemical name	Trade name	Rate
1	Control (regular hand weeding)		
2	Trifluralin	Trifluralin	2.0 L/ha
3	Trifluralin	Trifluralin	4.0 L/ha
4	Pendimethalin	Stomp® 330E	3 L/ha
5	Pendimethalin	Stomp® 330E	6 L/ha
6	Propyzamide	Kerb® Flo	4.4 L/ha
7	Propyzamide	Kerb® Flo	8.8 L/ha
8	Propachlor	Ramrod®	5 L/ha
9	Propachlor	Ramrod®	10 L/ha
10	Chlorthal dimethyl	Dacthal®	6 kg/ha
11	Chlorthal dimethyl	Dacthal®	12 kg/ha
12	Diuron	Diuron	1.0 kg/ha
13	Diuron	Diuron	2.0 kg/ha
14	No herbicide or hand weeding		

Table 18: The scoring system used for measuring efficacy and crop tolerances of each herbicide treatment.

Score	Efficacy (weed kill)	Crop Tolerances
1	complete kill	no effect
2	excellent	very slight effects; some stunting & yellowing visible.
3	very good	slight effects; stunting & yellowing obvious; effects reversible.
4	good – acceptable	substantial chlorosis and (or) stunting; probably no effect on yield; most effects probably reversible.
5	moderate, but not generally acceptable	strong chlorosis/stunting; thinning of stand; some yield loss expected.
6	fair	))
7	poor	)) increasing severity of damage
8	very poor	))
9	none	Total loss of plant and yield

(Source: Australian Weeds Committee, 1979)

4.3.2. Results and discussion

All herbicides were effective in controlling weeds with efficacy scores ranging from 1.06 (complete kill) to 2.81 (excellent to very good weed kill) (Table 19). However, treatment 14 where no hand weeding was done or herbicides were applied, showed that the site chosen for the trial had a small weed population. Although weeds were evident in the untreated plots, they caused minimal effect on the growth of the burdock. Some herbicides did damage the burdock seedlings as they emerged. Treatments 2, 3, 4, 5, 7, 11, 12, and 13 had crop tolerance scores significantly worse than the other treatments. The scores were above 4 which was considered damaging therefore those plots suffered crop damage in the form of chlorosis, stunting and in the worse cases, total plant loss (Figure 5).

Table 19: Average efficacy and crop tolerance scores of each treatment.

Treatment No.	Treatment	Efficacy (weed kill)	Crop tolerance
1	Control (hand weed)	1.06	1.12
2	Trifluralin 2.0 L/ha	2.50	4.56
3	Trifluralin 4.0 L/ha	2.00	4.94
4	Stomp® 3.0 L/ha	1.25	5.56
5	Stomp® 6.0 L/ha	1.69	7.69
6	Kerb® 4.4 L/ha	1.19	3.37
7	Kerb® 8.8 L/ha	2.81	7.44
8	Ramrod® 5 L/ha	1.69	3.25
9	Ramrod® 10 L/ha	2.19	3.19
10	Dacthal® 6 kg/ha	1.69	2.44
11	Dacthal® 12 kg/ha	1.88	5.25
12	Diuron 1.0 kg/ha	1.81	7.31
13	Diuron 2.0 kg/ha	1.56	8.50
14	No herbicide or hand weed	1.75	2.87
Significance		***	***
LSD (P=0.05)		0.81	1.12

*** = P<0.001

Figure 5: Typical herbicide damage of burdock seedlings

Table 20: Average total and marketable yield of each treatment

Treatment No.	Treatment	Total yield (t/ha)	Marketable yield (t/ha)	% Marketable yield
1	Control (hand weed)	36.2	19.1	52.8
2	Trifluralin 2.0 l/ha	29.9	15.3	51.2
3	Trifluralin 4.0 L/ha	31.3	11.5	36.7
4	Stomp® 3.0 l/ha	31.2	13.4	42.9
5	Stomp® 6.0 l/ha	15.9	2.2	13.8
6	Kerb® 4.4 l/ha	34.1	17.2	50.4
7	Kerb® 8.8 l/ha	21.6	7.3	33.8
8	Ramrod® 5 l/ha	33.3	11.9	35.7
9	Ramrod® 10 l/ha	35.0	13.8	39.4
10	Dacthal® 6 kg/ha	35.0	18.3	52.3
11	Dacthal® 12 kg/ha	29.8	13.1	44.0
12	Diurion 1.0 kg/ha	15.0	2.7	18.0
13	Diurion 2.0 kg/ha	17.7	3.4	19.2
14	No herbicide or hand weed	34.1	16.5	48.4
Significance		***	***	
LSD (P=0.05)		8.4	5.8	

*** = P<0.001

Four herbicide treatments recorded total yields of less than 22 t/ha. (Table 20). Those treatments were: Diuron at both rates of 1.0 and 2.0 kg/ha, Kerb® at 8.8 L/ha, and Stomp® at 6.0 L/ha. These treatments had poor crop tolerance scores recorded in the first eight weeks of growth. As to be expected the highest total yield was the control treatment (hand weeding) with 36.2 t/ha. Treatment 14 with no herbicide or hand weeding also recorded a good total yield on 34.1 t/ha because the site did not have a high population of weeds.

Marketable percentage from all treatments was low with highest being 52.8% of total yield from the control treatment. Dacthal® at 6 kg/ha, Kerb® at 4.4 L/ha and trifluralin at 2.0 L/ha recorded the highest marketable yields of between 15.3 – 18.3 t/ha and good total yields ranging from 29.9 to 35.0 t/ha.

Treatment 5 (Stomp 6.0 L/ha) had the highest weight, the shortest length, the thickest diameter, a higher rating for pithiness and a quality rating of 4 which is considered unmarketable (Table 21). This treatment also had the lowest total and marketable yields (Table 20).

Table 21: Weight, length, diameter, pithiness and quality figures for each treatment.

Treatment No.	Treatment	Weight (g)	Length (mm)	Diameter (mm)	Pithiness (1-5)	Quality (1-5)
1	Control (hand weed)	253.7	694.9	23.3	1.7	3.4
2	Trifluralin 2.0 l/ha	261.4	710.9	23.5	1.8	3.3
3	Trifluralin 4.0 L/ha	257.0	690.0	23.2	1.6	3.6
4	Stomp 3.0 l/ha	256.2	705.8	22.9	1.7	3.6
5	Stomp 6.0 l/ha	346.9	674.9	27.6	2.1	4.1
6	Kerb 4.4 l/ha	268.3	704.3	25.2	1.9	3.0
7	Kerb 8.8 l/ha	264.0	668.0	24.0	2.3	3.9
8	Ramrod 5 l/ha	252.0	703.9	23.3	1.6	3.8
9	Ramrod 10 l/ha	246.7	701.4	23.1	1.4	3.7
10	Dacthal 6 kg/ha	232.9	705.5	21.8	1.7	3.3
11	Dacthal 12 kg/ha	215.2	668.2	21.2	2.0	3.5
12	Diurion 1.0 kg/ha	336.7	697.7	28.2	2.1	4.5
13	Diurion 2.0 kg/ha	310.7	687.0	26.8	1.4	4.4
14	No herbicide or hand weed	225.5	686.3	22.1	1.6	3.5
Significance		***	**	***	***	***
LSD (P=0.05)		25.5	25.7	1.3	0.21	0.22

*** = P<0.001 ** = P<0.004

Kerb at 4.4 L/ha was promising having reasonable weight and length figures, one of the highest diameters, low pithiness and a significantly better rating of quality compared to the other herbicide treatments. Total and marketable yields were also higher than the other treatments. Dacthal® 6 kg/ha was another promising treatment with significantly high total and marketable yield, longer length, low pithiness and better rating of quality compared to other treatments.
Trifluralin at 2.0 L/ha also recorded favourable quality attributes of the burdock roots with high total and marketable yield. However, from the crop tolerance scores this treatment resulted in substantial chlorosis and stunting of the burdock seedlings compared to Kerb® (4.4 L/ha) and Dacthal® (6 kg/ha) which recorded slight effects to the herbicide during the first eight weeks of growth. Trifluralin at 2.0 L/ha sprayed in this trial did effect the burdock seedlings but the damage was not severe and the burdock plants were able to grow out of the initial herbicide effect.

In conclusion, Dacthal at 6 kg/ha, Kerb at 4.4 L/ha and Trifluralin at 2.0 L/ha were considered the best treatments in terms of efficacy, crop tolerance, yield and quality for summer sown burdock. Another herbicide trial was conducted with the above treatments on spring sown burdock, refer to section 4.4.

4.4. Herbicide crop tolerance

From the previous herbicide trial planted in January 2001, pre-emergent herbicides, Dacthal®, Kerb® and Trifluralin, showed promising results in terms of efficacy, crop tolerance, yield and quality of burdock roots. The aim of this trial was to confirm the effects of these three herbicides on spring sown burdock.

4.4.1. Materials and method

The trial site was prepared in the same manner as the herbicide observation trial sown in the summer of 2001, with the exception of the fertiliser applied. Incorporated using a rotary hoe, double superphosphate at 1000 kg/ha, gypsum at 250 kg/ha and trace element mix at 150 kg/ha were applied before sowing. Post-plant fertiliser were applied weekly through the irrigation and commenced one week after sowing. For the first three weeks 30 kg/ha of potassium nitrate and 40 kg/ha of ammonium nitrate was applied weekly. From week four to week nineteen 60 kg/ha of potassium nitrate 40 kg/ha ammonium nitrate and 12 kg/ha of magnesium sulphate was applied.

The trial was hand planted on the 6 November 2001 using the burdock variety Takinogawa Long at 8 cm intra-row spacing. The herbicide treatments were applied two days after sowing (Table 22). The trial was a randomised block design with eight herbicide treatments, replicated three times. The results were analysed by analysis of variance using Genstat statistical software.

Crop tolerance scores (Table 23) were measured for each plot during the first eight weeks of growth. Efficacy was not recorded as this was done in the previous herbicide observation, therefore the trial site was hand weeded twice. Other measurements include total and marketable yield, root weight (g), length (mm), diameter (mm), ratings of pithiness (Table 4) and quality (Table 5). The trial was harvested on 8 April 2002, 153 days after sowing.

Table 22: Herbicide treatments and rates applied

Treatment No.	Chemical name	Trade name	Rate
1	Chlorthal dimethyl	Dacthal®	6 kg/ha
2	Chlorthal dimethyl	Dacthal®	12 kg/ha
3	Chlorthal dimethyl	Dacthal®	18 kg/ha
4	Propyzamide	Kerb®	4.4 L/ha
5	Propyzamide	Kerb®	8.8 L/ha
6	Trifluralin	Trifluralin	2.0 L/ha
7	Trifluralin	Trifluralin	4.0 L/ha
8	Control (no herbicide)		

4.4.2. Results and discussion

Table 23: Average crop tolerance scores (1 = no effect, 9 = total loss, see Table 18 for complete details)

Treatment No.	Treatment	Crop tolerance
1	Dacthal 6 kg/ha	3.83
2	Dacthal 12 kg/ha	4.50
3	Dacthal 18 kg/ha	4.50
4	Kerb 4.4 L/ha	2.50
5	Kerb 8.8 L/ha	4.00
6	Trifluralin 2.0 L/ha	2.00
7	Trifluralin 4.0 L/ha	2.50
8	Control (no herbicides)	2.67
Significance		**
LSD (P=0.05)		1.73

** = P<0.021

The four treatments that had significantly better crop tolerance scores (very slight effects) compared to the other treatments were Kerb® at 4.4 L/ha, Trifluralin at both rates of 2.0 and 4.0 L/ha and the control (no herbicide). Dacthal® at the higher rates of 12 and 18 kg/ha recorded substantial chlorosis and stunting.

Table 24: Average total and marketable yield

Treatment No.	Treatment	Total yield (t/ha)	Marketable yield (t/ha)	% Marketable yield
1	Dacthal 6 kg/ha	38.4	11.7	30.4
2	Dacthal 12 kg/ha	37.1	9.4	25.3
3	Dacthal 18 kg/ha	32.1	8.6	26.8
4	Kerb 4.4 L/ha	39.6	11.1	28.0
5	Kerb 8.8 L/ha	31.8	8.9	28.0
6	Trifluralin 2.0 L/ha	43.5	12.9	29.7
7	Trifluralin 4.0 L/ha	36.2	8.2	22.7
8	Control (no herbicides)	39.9	9.5	23.8
	Significance	ns	ns	
	LSD (p=0.05)	8.4	5.8	

ns = not significant

There were no significant differences between treatments for total and marketable yield (Table 24). The total yield ranged from 31.8 t/ha to 43.5 t/ha. Marketable yields were considered very poor ranging from 22 – 30% of total yield. Poor marketable yields are not due to the herbicide treatments as the control treatment also recorded poor marketable yield of only 9.5 t/ha. The higher rates of nitrogenous fertiliser and the different planting time may have an influence on yields. A total of 234 kg N/ha was applied to the herbicide trial planted in January 2001. On this trial, a total of 463 kg N/ha was applied. A higher nitrogen rate was applied as a result of the nitrogen trial conducted in the summer of 2001, where higher N rates of 423 kg N/ha slightly increased yields. However, these higher rates were not tested in spring sown burdock.

Table 25: Weight, length, diameter, pithiness and quality figures for each treatment.

Treatment No.	Treatment	Weight (g)	Length (mm)	Diameter (mm)	Pithiness (1-5)	Quality (1-5)
1	Dacthal 6 kg/ha	277.1	579.5	25.1	2.1	4.4
2	Dacthal 12 kg/ha	268.1	541.2	24.9	2.1	4.4
3	Dacthal 18 kg/ha	240.7	530.8	23.8	2.1	4.6
4	Kerb 4.4 L/ha	296.4	563.7	27.5	2.1	4.4
5	Kerb 8.8 L/ha	278.8	543.8	25.9	2.3	4.5
6	Trifluralin 2.0 L/ha	335.1	608.6	27.3	2.0	4.3
7	Trifluralin 4.0 L/ha	288.0	544.0	25.4	2.0	4.6
8	Control (no herbicides)	302.1	505.0	26.0	2.1	4.5
	Significance	***	***	***	ns	***
	LSD (p=0.05)	40.5	38.5	1.7	0.1	0.1

*** = P<0.001 ns = not significant

Trifluralin at 2.0 L/ha significantly had heavier root weight, longer root length, wider diameter and a higher quality rating than the other herbicide treatments (Table 25). Kerb® at 4.4 L/ha also had significantly different weight, diameter and quality rating compared to the other herbicide treatments. Pithiness ratings were similar for all treatments at 2 (slight) but no significant differences were recorded. Quality ratings recorded for all treatments had poor marketability but Kerb® 4.4 L/ha, Dacthal® at 6 kg/ha and Trifluralin at 2.0 L/ha significantly had higher quality ratings than the other treatments.

Kerb® at 4.4 L/ha, and Trifluralin at 2.0 and 4.0 L/ha were the herbicides that had slight effects on the seedlings during the first weeks. However, none of the herbicide treatments resulted in significant differences in total and marketable yield. Trifluralin at 2.0 L/ha did result in significantly heavier root weight and longer root length the other herbicide treatments. The results from this trial confirms the results from the previous herbicide observation in that Kerb® at 4.4 L/ha and Trifluralin at 2.0 L/ha were considered that best pre-emergent herbicides in terms of crop tolerance to burdock.

4.5. The effect of intra-row spacing and harvest time on yield and quality of spring sown burdock

As part of establishing agronomic guidelines for export burdock production, optimum plant spacing needed to be established. Initial burdock trials used an intra-row spacing of 8 cm which was based on Japanese recommendations. With Western Australia's different growing conditions, a trial to determine optimal intra-row spacing of spring sown burdock was completed. Time of harvest has also been an issue with previous trials therefore the effect of harvest time on yield and quality was also examined.

4.5.1. Materials and method

The trial was planted in Spearwood sand at the Medina Research Station. The last trial on the same site was a phosphorus trial conducted three years previously. Additional phosphorus was applied to counteract any effect from previous P treatments.

The site preparation was similar to other burdock trials. Fumigation using metham sodium was done 3 weeks before planting and Nemacur® was applied two days before sowing. The site was then deep ripped and using a rotary hoe, the following pre-plant fertilisers were incorporated; double superphosphate 2000 kg/ha, gypsum 250 kg/ha and trace element mix 150 kg/ha. The site was deep ripped again and the Kawabe trencher was used to further cultivate the soil.

Top dressing commenced three days after sowing. The fertilisers were applied weekly through a fertigation system. For the first four weeks, potassium nitrate at 30 kg/ha and ammonium nitrate at 40 kg/ha was applied weekly. Thereafter, 60 kg/ha of potassium nitrate, 60 kg/ha ammonium nitrate and 12 kg/ha of magnesium sulphate was applied weekly.

Tensiometers at depths of 15, 30, 45, 60 and 90 cm where used to monitor irrigation. One day after planting Dacthal at 6 kg/ha was sprayed as a pre-emergent herbicide. Three to four weeks after sowing, ninety percent of seedlings showed evidence of herbicide distortion. It was later revealed that the spray unit used to apply the herbicide was not calibrated correctly resulting in uneven spraying. Those seedlings that were severely affected by the herbicide took about ten weeks to fully recover.

Caterpillars and cabbage white butterfly began to attack the seedlings on the outside row. It was suggested that the seedlings were susceptible to attack due to being weakened by the herbicide damage. As there was only about 5% of seedlings that were damaged, no chemical control was warranted.

The trial was a ramdomised block design with four treatments/intra-row spacings randomised in each of the four blocks or replicates (Table 26). Harvest time could not be randomised within the blocks because harvesting was done by machine and had to be done starting from the outside rows and going inwards to avoid damage of the plots remaining during each harvest. This meant the only valid comparisons could be made between spacing of the one harvest not between harvests.

The trial was planted on 10 October 2001 and harvested at four different harvest times (Table 27). The burdock variety planted was *Tohoku Riso*.

Table 26: Intra-row spacing treatments and target plant densities

Treatment No.	Intra-row spacing x inter-row spacing (cm)	Target plant density (plants/m^2)
1	5 cm x 60 cm	27 plants/m^2
2	8 cm x 60 cm	17 plants/m^2
3	11 cm x 60 cm	12 plants/m^2
4	14 cm x 60 cm	10 plants/m^2

Table 27: Harvest dates and number of days after sowing

Harvest	Weeks	Date	Days after sowing (DAS)
1st harvest	18 weeks	7 February 2002	120 DAS
2nd harvest	20 weeks	21 February 2002	134 DAS
3rd harvest	22 weeks	7 March 2002	148 DAS
4th harvest	24 weeks	21 March 2002	162 DAS

Measurements taken after each harvest were: total and marketable yields, plant counts, length, weight, diameter, pithiness (Table 4) and quality (Table 5) ratings and grade category (Table 6) for a sample of forty roots from each plot.

4.5.2. Results and discussion

Highest total yield of 45.2 t/ha was recorded from the highest plant spacing of 24.3 plants/m^2 harvested at 24 weeks (Table 28). However, this only produced 20% marketable roots. The majority of roots were downgraded because of forking and root shape (bent).

As expected higher total yields were recorded with higher plant spacings. Marketable yields followed the same trend. Harvest at week 18 recorded the highest percentage marketable yield of 47% with a spacing of 25.3 plants/m^2. However, total and marketable yields were only 27.7 and 13.1 t/ha respectively.

Harvest at 20 weeks produced higher total and marketable yields but the percentage of marketable yields lower at less than 42%. Intra-row plant spacing of 5 – 8 cm (16.7 – 26.4 plants/m^2) were significantly the best treatment with regards to total and marketable yields when harvested at 20 weeks or 134 days.

Later harvests did produce higher total yields but root quality was compromised resulting in lower marketable yields (Figures 6 and 7).

Table 28: Yields and actual spacings for each harvest time.

Harvest	Target spacing (plants/m^2)	Actual spacing (plants/m^2)	Total yield (t/ha)	Marketable yield (t/ha)	% Marketable yield
18 weeks	27	25.3	27.7	13.1	47.1
	17	15.9	24.3	8.2	34.3
	12	13.2	22.7	4.3	19.2
	10	8.8	18.8	3.3	17.9
	Significance		**	*	
	LSD (P=0.05)		3.84	5.52	
20 weeks	27	26.4	35.5	15.2	42.8
	17	16.7	31.8	12.1	38.0
	12	12.0	26.6	5.0	19.5
	10	9.8	26.3	3.6	13.7
	Significance		**	**	
	LSD (P=0.05)		4.64	5.24	
22 weeks	27	23.2	38.7	10.0	26.0
	17	15.4	34.6	7.1	20.9
	12	11.8	32.9	4.8	14.5
	10	9.7	28.8	2.4	8.2
	Significance		**	***	
	LSD (P=0.05)		4.15	2.42	
24 weeks	27	24.3	45.2	9.3	20.4
	17	17.1	44.0	9.6	22.3
	12	11.9	37.6	3.8	10.2
	10	11.0	36.4	3.1	8.4
	Significance		**	*	
	LSD (P=0.05)		4.85	4.67	

* < 0.05 ** < 0.01 *** < 0.001

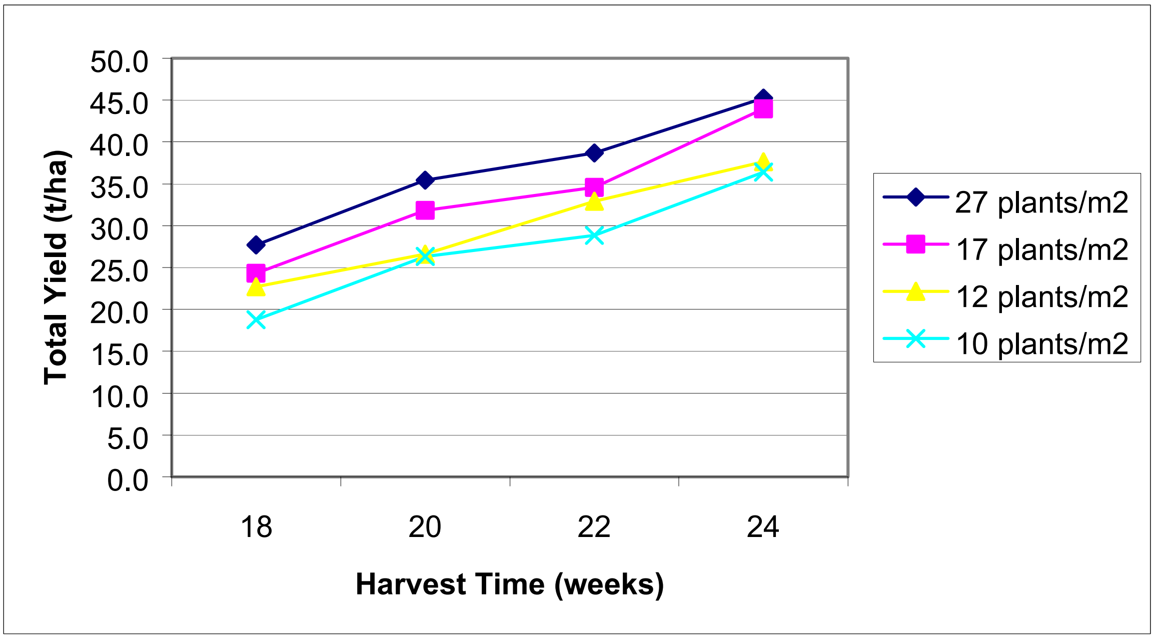

Figure 6: The effect of plant spacing and harvest time on total yield (t/ha).

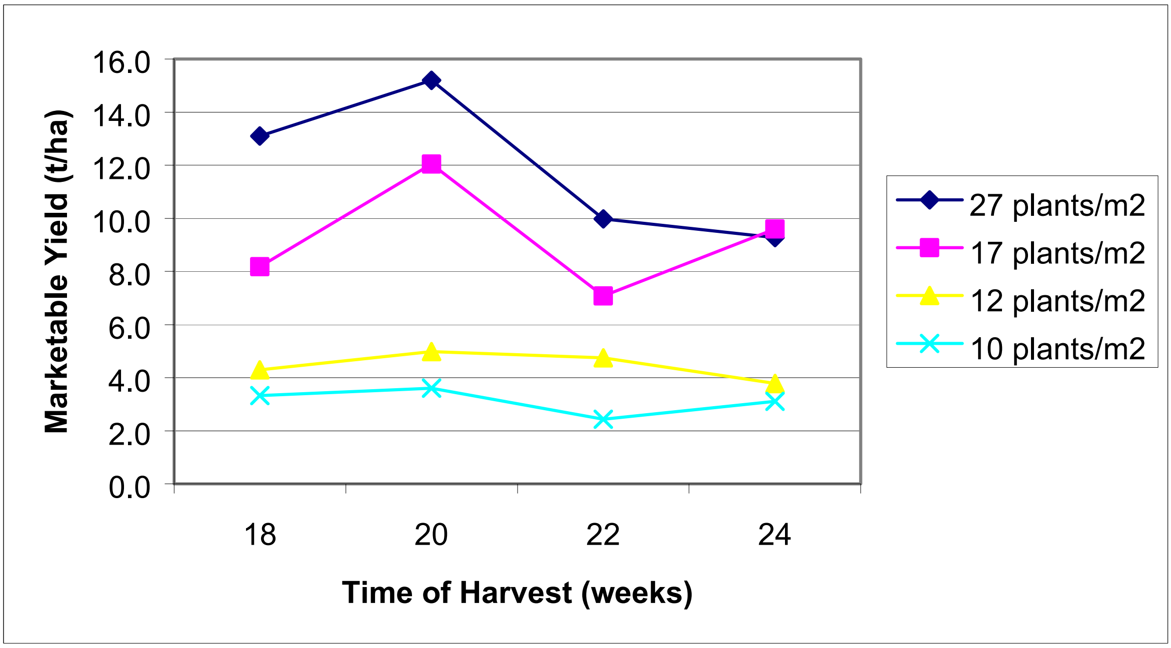

Figure 7: The effect of plant spacing and harvest time on marketable yield (t/ha).

Table 29: Root measurements for each spacing at each harvest time.

Harvest	Intra-row spacing	Weight (g)	Length (mm)	Diameter (mm)	Pithiness (1-5)	Quality (1-5)
18 weeks	5 cm	130.8	574	16.02	1.21	3.67
	8 cm	177.7	611.1	18.59	1.47	3.82
	11 cm	197.8	596.2	18.94	1.94	4.31
	14 cm	217.6	593.3	21.41	1.79	4.29
	Significance	***	*	***	***	***
	LSD (P=0.05)	19.12	26.71	0.96	0.17	0.17
20 weeks	5 cm	178.5	612.8	17.58	1.94	3.64
	8 cm	222.6	652.6	20.65	2.24	3.8
	11 cm	242.9	603.7	22.41	2.04	4.13
	14 cm	291.2	636.6	24.54	2.68	4.28
	Significance	***	**	***	***	***
	LSD (P=0.05)	24.63	27.40	1.13	0.17	0.17
22 weeks	5 cm	187	595.2	19.58	2.03	3.96
	8 cm	242	632.3	21.58	2.17	4.04
	11 cm	297.8	639.7	24.44	2.68	4.3
	14 cm	315	651.2	25.28	2.78	4.41
	Significance	***	***	***	***	***
	LSD (P=0.05)	29.22	28.02	1.25	0.20	0.16
24 weeks	5 cm	213.6	612.2	20.46	2.13	3.98
	8 cm	294.1	674.6	23.91	2.78	3.98
	11 cm	327.1	646.4	25.61	2.91	4.31
	14 cm	361.1	613.6	27.48	2.99	4.46
	Significance	***	***	***	***	***
	LSD (P=0.05)	32.19	28.00	1.26	0.13	0.16

*** = <0.001 ** = 0.002 * = 0.057

From the results, it is difficult to determine the optimum plant spacing and harvest time due to poor quality roots across all treatments (less than 50% marketable yield). This also shows in the quality ratings with the majority of roots recording a rating of poor marketability (Table 28). At each harvest the higher densities (15.4 – 26.4 plants/m^2) had significantly lower quality ratings than the other densities.

Root length peaked at either 22 or 24 weeks after sowing across all spacings. However, week 20 or 134 DAS may be the better harvest time based on recorded yields. Plant densities of 9.8 plants/m^2 and 16.7 plants/m^2 significantly had longer root lengths (637 mm and 653 mm respectively) than the other spacing when harvested at 20 weeks.

Root diameter decreased with increasing plant spacing across all harvests and spacings (Table 29). A plant spacing of 9.8 plants/m^2 recorded higher root diameter at harvest of 20 weeks (25 mm) than a lower spacing of 26.4 plants/m^2 at 18 mm diameter.

Both root length and diameter conform with recommended Japanese quality parameters of greater than 600 mm in length and preferably 21 – 35 mm in diameter.

In summary, some spacings were more favourable than others as it depended on what attribute is examined. For example, spacings of 15.4 – 26.4 plants/m^2 recorded the highest total and marketable yield but a spacing of 9.8 – 16.7 plants/m^2 recorded longer root lengths and wider root diameter. It appears though, that week 20 or 134 days after sowing is the most preferred harvest time as later harvest times reduce root quality.

Based on yields from this trial, which were not favourable at less than 50% marketable roots, an intra-row spacing of between 5 – 8 cm is suitable if harvested at week 20 (134 days after sowing). Another trial should be done as the stress of herbicide damage may have caused the roots to fork and bend resulting in poor quality roots.

4.6 Effect of fungicides on germination and establishment of burdock seedlings to control *Pythium* spp.

On the 9th March 2001, a burdock trial was planted to determine the effects of bed formation and seed priming on burdock seedlings. This trial was abandoned to due infection of *Pythium* spp. causing seedling death The trial was re-sown the following year (see section 4.7). The burdock suffered pre and post-emergence damping off which resulted in rotting of the seed before emergence and soft decay of the taproot and shoot of the seedling at soil surface level (Persley, 1994). A sample of infected seedlings and soil was taken to Agwest Plant Laboratories for testing which revealed the damping off was caused by *Pythium* spp. The pathogen caused seedling deaths to over 50% of the trial. The trial site that was originally to determine the effects on bed formation and seed priming on burdock seedlings, was then changed to a trial to determine the efficacy of various pre-emergent fungicides to control *Pythium* spp. in burdock and also their effect on germination.

None of the fungicides used in this trial were registered for use on burdock. This trial was only a small, preliminary experiment to determine which pre-emergent fungicides showed promising results in the control of *Pythium* in burdock seedlings. Further testing of these fungicides would be warranted only if burdock became a large commercial crop and the incidence of damping off of burdock seedlings was high.

4.6.1. Materials and method

The trial was planted on Spearwood sand Uc 4.13 (Northcote, 1979) at the Medina Research Station. The site was rotary hoed and flat beds were formed. No trenching was done as observations were only done for the first eight weeks of growth. Post-plant fertilisers (31 kg/ha potassium nitrate and 51 kg/ha ammonium nitrate) were applied weekly using watering can. The trial was a randomised block design with four treatments (Table 30) and four replications. The trial was hand sown on the 2 May 2001 at an 8 cm intra-row spacing using the burdock variety *Takinogawa Long*. Each plot was 8 m long by 1.5 m wide and there were two rows per plot (200 seeds per plot). The fungicide treatments were applied as described in Table 30. The number of seeds germinated and the number of seedling deaths were counted every two days.

4.6.2. Results and discussion

Treatment 3 (metalaxyl + thiram) and Treatment 2 (metalaxyl) had significantly higher germination rates than the other treatments with 91% and 89% germination respectively (Table 31). Previcur® resulted in 84% germination and the control treatment recorded 63% germination. The number of seedling deaths for each treatment was quite low and no significant differences were recorded. The control plots with no fungicide treatment also recorded low incidence of seedling deaths due to Pythium with an average of 3.3 seedling deaths. It was suggested that the symptoms of Pythium became less as the temperatures became cooler, compared to mid March temperatures when the pathogen first appeared in the bed formation and seed priming trial which was consequently abandoned.

Table 30: Fungicidal treatments applied to burdock

Treatment No.	Fungicidal treatment	Rate	Application method/timing
1.	Previcur® (propamocarb)	1.5 mL in 1L water	Apply 2L of mixed solution per square metre by watering can immediately after sowing
2.	Apron XL 350® (metalaxyl-m)	2 mL per kg of seed	Apply diluted with water before sowing. Premix water to a total volume of not less than 5 mL more more than 10 mL per kg of seed. Apply solution to seed and vigorously mix for 1 to 2 minutes
3.	Metalaxyl + thiram	Metalaxyl: 2 mL per kg of seed Thiram: 5g per kg of seed	Mix thiram to form a slurry in a convenient volume of water Apply thiram to mixed metalaxyl
4.	Control (no treatment)	-	-

Table 31: Average final germination counts and number of seedling deaths for each treatment

Treatment	No. of seeds germinated	% germinated	No. of seedling deaths
1 – Previcur®	169.2	84.8	3.3
2 – Apron XL 350® (metalaxyl-m)	178.2	89.3	2.5
3 – Metalaxyl + thiram	182.8	91.5	3.8
4 – Control (no treatment)	125.5	63.0	3.3
Significance	***		ns
LSD (P=0.05)	13.16		3.65

*** = P<0.001   ns = not significant

Metalaxyl and a combination of metalaxyl and thiram were the most successful treatment of Pythium in burdock seedlings.

4.7. Effects of priming and bed formation on germination and establishment of burdock seedlings

As mentioned previously, a seed priming/bed formation trial was first attempted in early March 2001. With a severe *Pythium* infection, the trial was abandoned but replanted on the same site to determine promising fungicidal control of *Pythium* in burdock seedlings. This trial is the second planting of the priming and bed formation trials.

4.7.1. Seed priming

Burdock seed may vary in uniformity of germination and establishment resulting in variations in plant size within the crop. Nguyen (1998) reported that priming burdock seed can increase the rate of germination and the final percentage of germinated seed at both 15°C and 20°C in laboratory conditions. As germination and establishment within the first six weeks are essential in determining the successful growth of burdock, particularly during summer, a field trial was conducted to determine the effects of priming burdock seed on rate of germination and establishment.

Materials and method

The site was prepared in a similar manner as other burdock trials. Pre-plant fertilisers; double superphosphate at 1000 kg/ha, gypsum at 250 kg/ha and trace element mix at 150 kg/ha, were applied and incorporated using a rotary hoe. The Kawabe trencher was then used to further cultivate the soil as the mature burdock roots were to be used in a postharvest trial.

The trial was a randomised block design with two treatments (primed and natural burdock seed) and four replications. The plots were 1.5 m wide by 8 m long and there were two rows per bed. The trial was planted by hand using the variety Takinogawa Long at 8cm intra-row spacing and 60 cm inter-row spacing. The seed was primed by soaking the seeds in distilled water for 12 hours. The natural seed was as received from the Japanese seed company, Takii & Co.

Top dressing commenced one week after sowing. From week two to week five, 30 kg/ha of potassium nitrate and 20 kg/ha of ammonium nitrate was applied weekly. After week five until one week before harvesting, 60 kg/ha of potassium nitrate, 60 kg/ha ammonium nitrate and 12 kg/ha of magnesium sulphate was applied weekly.

From emergence until 42 days after sowing, the number of seeds germinated were recorded every second day or until no further germination occurred.

The trial was planted on the 16 January 2002.

Results and discussion

Maximum germination of both primed and natural seed treatments were high at 96.5% and 95.5% respectively (Table 32). No significant differences were recorded.

Table 32: Maximum germination (%) achieved from each replicated plot of both seed treatments (ns = not significant).

Treatment	Rep 1	Rep 2	Rep 3	Rep 4	Average
Primed seed	92.5	95.5	99.0	99.0	96.5
Natural seed	98.0	96.0	92.5	95.5	95.5
Significance					ns
LSD (P=0.05)					8.27

Table 33: Average time until maximum germination, 90% duration and maximum germination rate of primed and natural seed.

Treatment	Time at which max. germination rate occurs (days)	90% duration (days)	Max. germination rate (%/day)
Primed seed	13.3	7.0	4.6
Natural seed	15.3	7.8	4.6
Significance	ns	ns	ns
LSD (P=0.05)	14.05	2.39	0.44

No significant differences were found between primed seed and natural seed for time at which maximum germination rate occurs, number of days to achieve 90% germination and maximum germination rate per day (Table 33). Therefore, priming burdock seed does not have any significant benefit on germination rate at this time of year.

4.7.2. Bed formation

The Japanese trenchers used for pre-sowing cultivation to form hilled beds. In Japan's volcanic soils, the hilled bed is suitable for burdock production. However, from recent burdock trials at Medina Research Station, the sandy soils of Swan Coastal Plain have less soil moisture holding capacity. Therefore, it is believed during the summer, the hilled bed resulted in burdock seedlings suffering from heat and moisture stress. The seedlings on a hilled bed were thought to be more exposed than those on a flat bed. In order to test this theory, three bed formations will be compared to determine the effects on germination and establishment of burdock seeds.

The materials and method was the same as the seed priming trial. There were three bed formation treatments:

i) Hilled bed (60 cm hills formed by Kawabe trencher)
ii) Flat bed
iii) Flat bed with 5 cm deep furrow

Soil and air temperatures were also recorded.

Results and discussion

Differences between bed formation treatments for time at which maximum germination rate occurred, days taken to reach 90% germination (from the start of germination) and maximum germination rate were determined by analysis of variance using Genstat software.

The percentage of germinated seeds was significantly higher for the flat bed and the flat bed with furrow than the hilled bed formation (Table 34). Seeds sown on the hilled bed only had an average maximum germination rate of 77.6%.

Table 34: Maximum germination rate (%) achieved from each replicated plot of the three bed formations.

Treatment	Rep 1	Rep 2	Rep 3	Rep 4	Average
Hilled Bed	65.0	69.0	86.5	90.0	77.6
Flat bed	96.0	94.5	98.5	96.5	96.4
Flat bed with furrow	98.0	100.0	98.5	93.0	97.4
Significance					**
LSD (P=0.05)					13.38

** = P<0.02

Those seeds planted on a hilled bed formation reached a maximum germination rate at 17.3 days after sowing while the flat bed achieved maximum germination rate 11.0 days after sowing (Table 35). The differences in maximum germination rate were not highly significant with P = 0.09. There were no significant differences in the number of days to reach maximum germination rate between the flat bed with furrow and other bed formations.

Although, it took only 4.7 days to achieve 90% emergence (from the start of germination) for the hilled bed and 8.5 days to reach 90% germination for the flat bed with furrow, these differences were not statistically significant.

Table 35: Average time until maximum germination, 90% duration and maximum germination rate of various bed formations for burdock seed

Treatment	Time at which max. germination rate occurs (days)	90% duration (days)	Max. germination rate (%/day)
Hilled Bed	17.3	19.0	3.7
Flat bed	11.0	7.7	4.6
Flat with furrow	14.3	8.5	4.7
Significance	*	ns	**
l.s.d (P=0.05)	5.67	-	0.66

* = P<0.09 ** = < 0.02

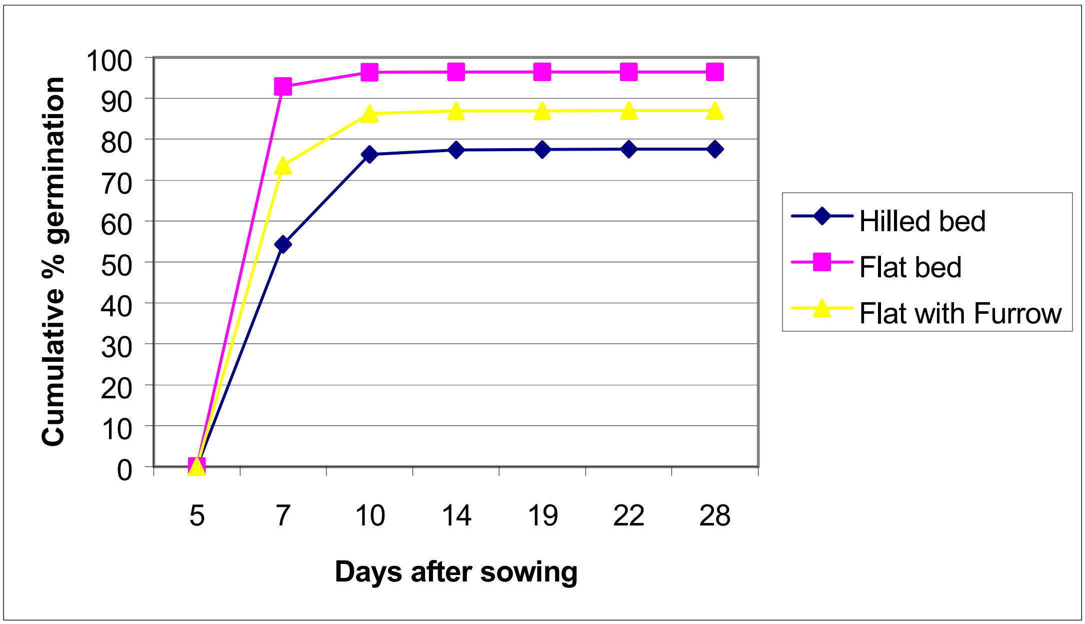

Figure 8: Cumulative percentage germination of various bed formation over time

Maximum germination rate per day for a hilled bed formation was 3.7% which was significantly different to a maximum germination rate per day of 4.7% for a flat bed with furrow.

The hilled bed recorded higher soil temperatures than the flat bed treatments. This may account for a lower germination rate per day and why it took longer to reach maximum germination than the other bed formations.

From Figure 8 it can clearly be seen that a higher maximum germination was achieved by the flat bed and the lowest germination rate can be seen by the hilled bed. Therefore the flat bed formation is the best for achieving maximum germination rate of over 95% and maximum germination rate per day of over 4%.

Over the course of the assessment (4 weeks after sowing), seedlings sown mainly on the hilled bed began to wilt, become necrotic and die (Table 36). Although these seedlings were not tested for disease, as no other treatment recorded significant seedling deaths, it was thought that the seedlings died due to high soil temperatures and lack of moisture immediately around the radicle of the seedling causing the seedling to wilt and die.

Table 36: Average number of seedling deaths during assessment (4 weeks after sowing)

Days after sowing	Hilled Bed	Flat bed	Flat bed with furrow
7	9.0	0	0
10	1.8	0	0
14	12.5	1	0
19	13.8	0	0
22	14.8	0	2
28	6.8	0	0
30	3.3	0	0
Total	62.0	1	2

The soil temperatures were recorded for the hilled bed and the flat bed, (Table 37, Figure 9). High maximum soil temperatures were recorded for both bed formations, but average maximum temperature for the hilled bed was only 2.6°C higher than the flat bed formation. According to Nishida (1998), optimum temperature for germination of burdock seed is 21 - 30°C, however, seed germinates between 10 - 36°C. Although, average soil temperatures of the hilled bed compared to the flat bed were not much higher, it still resulted in a delay of 6 days to achieve maximum germination in the hilled bed than the flat bed.

Table 37: Air and soil temperatures recorded during the four weeks after sowing

Temperature location	Minimum Temperature °C	Maximum temperature °C	Average min. temperature °C	Average max temperature °C
Air temp	12.0	41.5	19.0	27.8
Hilled bed soil temp	11.3	41.5	19.8	28.8
Flat bed soil temp	12.8	35.6	19.9	26.2

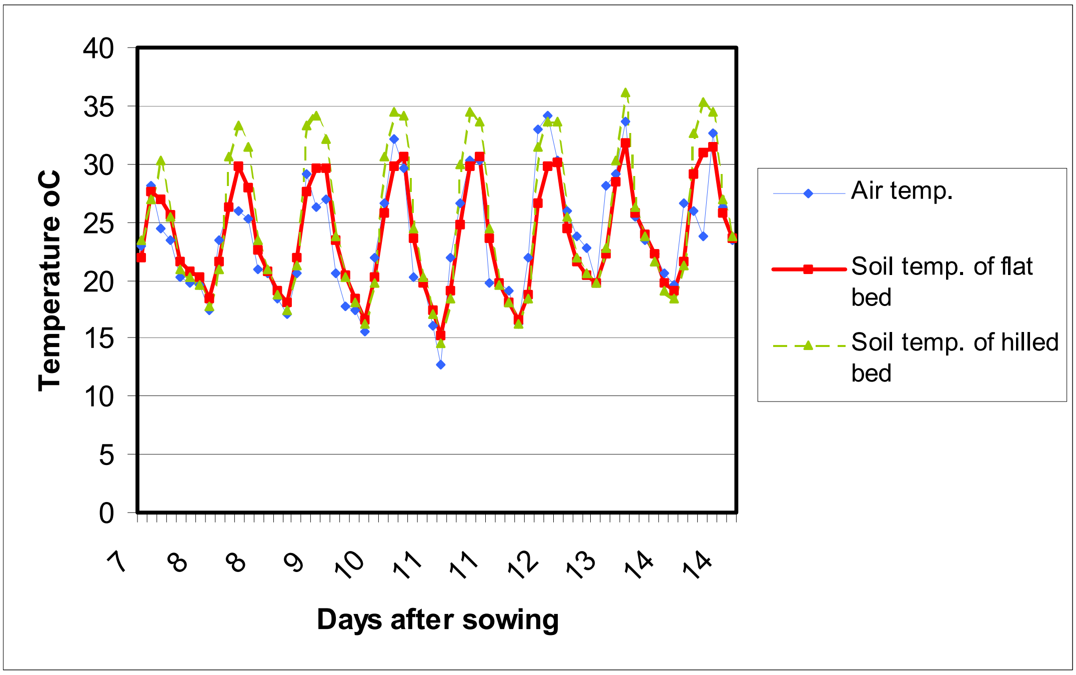

Figure 9: Soil temperatures (5 cm depth) of the flat bed and hilled bed formation and air temperatures from 7 – 14 days after sowing.

The trial was harvested on 24 June 2002. It was decided to take the trial to maturity and the roots were harvested 159 days after sowing. Below are the marketable yields of each treatment.

Table 38: Marketable yield of (t/ha) roots from each treatment

Treatment	Rep 1	Rep 2	Rep 3	Rep 4	Average
Hilled Bed	2.36	DNH	2.83	1.93	1.94
Flat bed	9.66	8.30	6.73	10.87	8.89
Flat bed with furrow	8.85	7.29	11.22	9.92	9.32
Significance					***
LSD (P=0.05)					2.53

***** = P<0.001 DNH – Did not harvest**

The flat bed and the flat bed with furrow both had significantly higher marketable yields than the hilled bed formation (Table 38).

4.8. The effects of storage temperature on the quality of burdock roots

From previous postharvest trials, it was found that both unsealed high and low density polyethylene bags maintained shelf life of burdock roots at 1°C for 28 days.

The use of a sealed modified atmosphere packaging (MAP) bag to extend shelf life can be risky if the cool chain cannot be maintained. Increase in temperature by a few degrees can increase respiration rate thus creating a low oxygen environment within the bag and develop anaerobic respiration. This in turn may create alcoholic off-flavours within the product (Kader, 1992). Therefore, this trial was done to test a sealed MAP bag at various storage temperatures for 28 days and to determine the effects on quality of burdock roots.

4.8.1. Materials and method

Only one type of MAP bag was used in the trial as there was limited amount of high quality burdock roots available to test other types of modified atmosphere bags. After considering the size specifications of the bag, the weight of burdock to be put in the bag and the desired oxygen and carbon dioxide levels to be achieved, it was decided that LifeSpan® L213 bag was to be used in the trial.

The L213 LifeSpan® bag was 30 micron thick based on polyethylene. The oxygen permeability at 1°C is 34,000 mL/day.atm per liner when sealed. The liner is manufactured from polymers and additives that are all suitable for food contact applications.

The burdock used for the trial was from the herbicide crop tolerance trial harvested on 8 April 2002. Only marketable roots were used in the trial and the variety of burdock was Takinogawa Long.

Five coolrooms each set at 0, 3, 6, 9 and 12°C were used to store the burdock. The aim to include high temperatures such as 9°C and 12°C was to get some idea as to how the burdock perform at these temperatures.

All the coolrooms were located at the postharvest laboratory at the Department of Agriculture, South Perth. Long cartons with the dimensions of 1050 mm (L) x 180 mm (W) x 140 mm (H) were used to store the burdock. Five kilograms of burdock was placed in the LifeSpan® L213 bag, sealed using a cable tie and placed in the carton, four replicates per treatment (i.e. four cartons of burdock per coolroom). They were then stored at different temperatures for 28 days.

Measurements of carbon dioxide and oxygen were measured twice weekly. To take the measurements, the sealed bags had a 2 cm piece of electrical tape with clear silicon hardened on the tape and stuck on the bag, near the vent hole of the carton for easy access. Using a 3 mL syringe, 2 cc of gas was collected from each sealed bag in each coolroom via the silicon and electrical tape. Percentage oxygen and carbon dioxide levels were measured using the LR 4220 Yokogawa Gas Analyser. After storage, percentage weight loss was measured for each carton as well as weight (g), length (mm), diameter (mm), pithiness (Table 4) and quality ratings (Table 5) were recorded for each root.

4.8.2. Results and discussion

Root characteristics

Analysis of variance was done to determine any significant difference between treatments with regards to weight, length, diameter, pithiness and quality ratings (Table 39). No significant differences were expected for length and diameter, as these attributes were unlikely to change between treatments. Weight and pithiness ratings had no significant differences between the various storage temperatures. There were significant differences with the quality ratings as those roots stored at 12°C began to sprout and reduced the marketability of the roots.

After the eleventh day of storage, the burdock in all four cartons stored at 12°C began to sprout at the crown of the root and side roots began to emerge along the main root (Figure 10). This sprouting made the burdock unmarketable. Therefore in this particular trial, burdock stored in LifeSpan® bags at various coolroom temperatures of between 0 - 9°C for 28 days had no effect on root quality.

Burdock stored in LifeSpan® bags at temperatures of between 0 – 9°C for 28 days seemed to have marketable quality. There was no significant differences in quality among these temperatures 0 - 9°C.

Figure 10: Sprouting of burdock roots stored at 12°C for 28 days.

Table 39: Average root characteristics of burdock stored at various temperatures for 28 days

Temperature °C	Root weight (g)	Root length (mm)	Root diameter (mm)	Pithiness (1 – 5)[1]	Quality (1 – 5)[2]
0	247.6	677.0	22.8	2.2	3.0
3	279.1	694.2	24.0	2.3	3.1
6	259.3	677.5	23.7	2.2	3.0
9	252.9	666.8	23.4	2.3	3.0
12	262.9	694.9	24.4	2.2	5.0#
Significance	NS	NS	NS	NS	*
LSD (P=0.05)	33.28	23.78	1.54	0.10	0.07

[1] 1 = none - 5 = severe [2] 1 = excellent export standard - 5 = reject
* = P < 0.001 # Sprouting reduced the marketability of burdock

Percentage weight loss

The weight of each burdock carton was measured before and after storage. Percentage weight loss increased as the storage temperature increased. As to be expected, roots stored at 0°C recorded the least weight loss at 6% while at storage temperatures of 3 – 12°C, weight loss was recorded at 11 – 12%.

Analysis of gas concentrations

For each measurement a linear mixed model was fitted to the data using the REML command in GenStat. A cubic smoothing spline was used to model temperature effects. The model included fixed terms for *vtemp* (linear effect of temperature), *vday* (linear effect of day), *Day* (deviations from linear) and interactions *vtemp.vday* and *vtemp.Day*; random terms for *spline Temperature* (curvilinear effect of temperature), *Temperature* (deviations from spline) and *Temperature.Rep.Day* (replicates within temperature for each day). A number of models were fitted to the variance/covariance for replicates within temperatures at different dates. Once an appropriate random model had been found, the fixed effects were tested using a Wald Test and adjusted means and effects were estimated from the model.

The validity of the mathematical assumptions underlying the linear mixed model were assessed using plots of residuals.

Oxygen

Figure 11 shows oxygen concentrations for each day of storage and temperature treatment. Outlying values (i.e. Temp 3°/Rep 2/Day 14, Temp 6° /Rep 1/Day 9, Temp 6° /Rep 2/Day 21) were removed from subsequent analyses. Figure 12 shows the oxygen concentrations at each storage temperature to demonstrate the different temperature regimes.

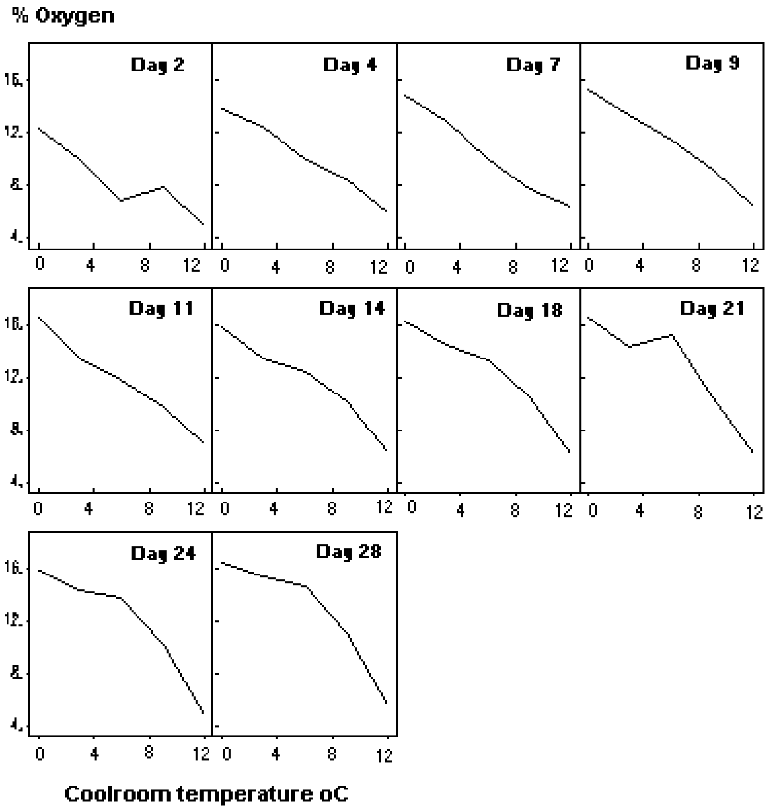

Figure 11: Average oxygen value (%) versus temperature (°C) for each day of storage

An auto-regressive model was chosen for the variance/covariance of residuals between dates. The significance of fixed effects is shown in Table 40.

Table 40: Significance of fixed effects in linear mixed model.

*Sequentially adding terms to fixed model					
		Oxygen		Carbon dioxide	
Fixed term	d.f	Wald/d.f	Chi-sq prob	Wald/d.f	Chi-sq prob
Vday	1	72.87	<0.001	1.13	0.288
Day	8	10.59	<0.001	10.91	<0.001
Vtemp	1	85.17	<0.001	110.10	<0.001
Vday.vtemp	1	4.22	0.040	5.39	0.020
Day.vtemp	8	0.83	0.575	0.65	0.740

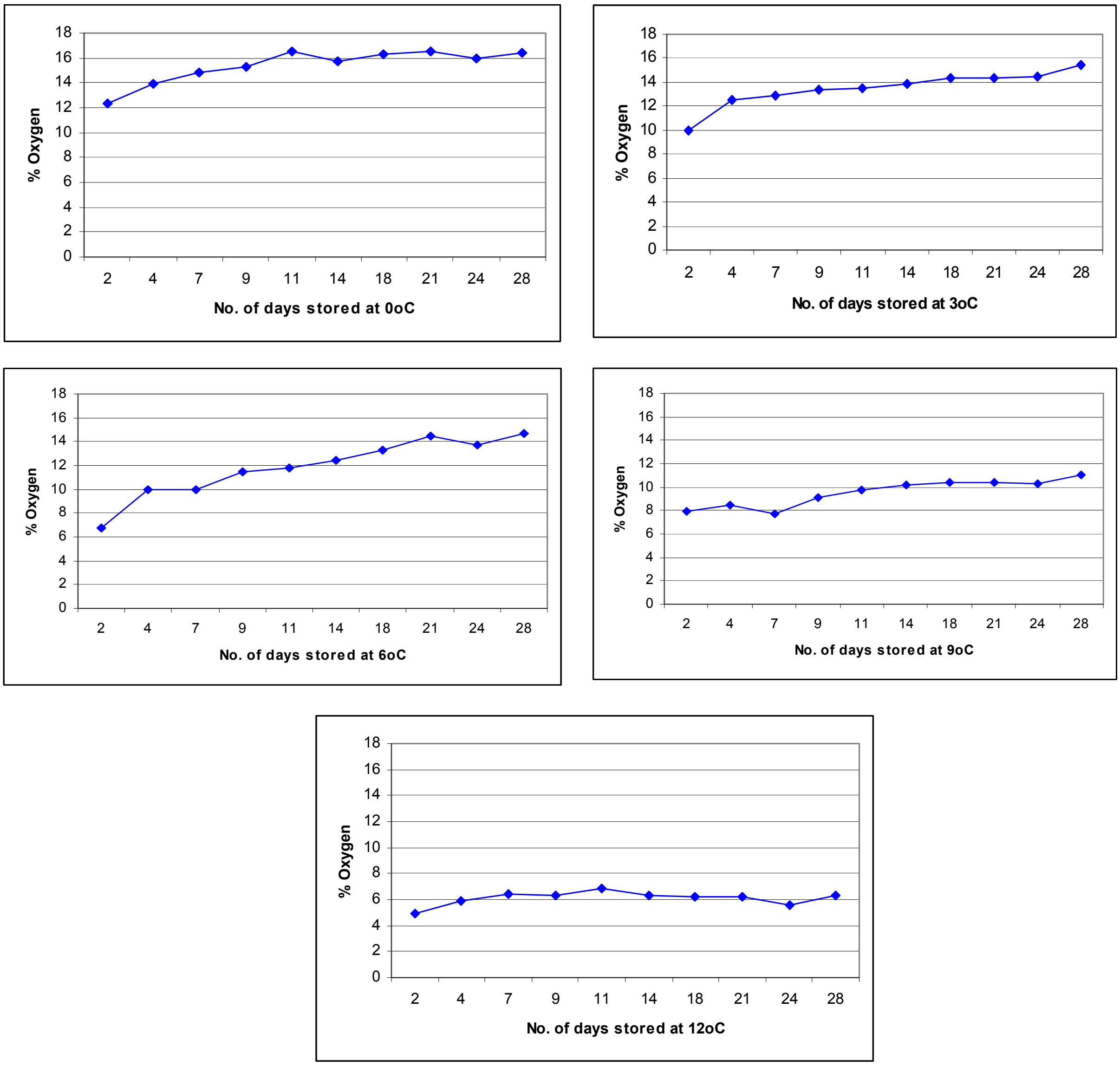

Figure 12: Percentage oxygen during 28 day storage in five separate coolrooms at 0, 3, 6, 9 and 12°C.

The curvilinear effect of temperature, *spline Temperature*, is not significant (p>0.05). There is a significant linear response to temperature, i.e. oxygen decreases as temperature increases, and this response may to interact with time (p=0.04). The slope of the temperature response for each day is shown in Table 41. The linear decrease in oxygen in relation to increasing temperature is becoming more pronounced as days progress (Figure 11). Note that in Table 40, there is a significant linear trend over days, although there are significant deviations from a linear trend.

Table 41: Slopes for oxygen response to temperature

Day	Slope
2	-0.560
4	-0.667
7	-0.735
9	-0.739
11	-0.769
14	-0.754
18	-0.804
21	-0.822
24	-0.820
28	-0.810
Average SED	0.077

Temperature by day means are shown in Table 42, which are the oxygen concentrations graphed in Figure 11 and 12.

Table 42: Predicted oxygen means for Temperature by Day.

	Temperature (°C)				
Day	**0**	**3**	**6**	**9**	**12**
2	12.30	9.96	6.79	7.88	4.93
4	13.90	12.53	10.00	8.47	5.92
7	14.84	12.94	9.98	7.74	6.41
9	15.31	13.43	11.45	9.16	6.35
11	16.54	13.49	11.83	9.76	6.87
14	15.79	13.85	12.44	10.15	6.29
18	16.26	14.41	13.28	10.43	6.19
21	16.56	14.39	14.46	10.39	6.23
24	15.91	14.43	13.75	10.25	5.61
28	16.40	15.45	14.72	11.05	6.28
Average SED for comparing within Temperature			0.663		
Average SED for comparing within Day			1.162		

Carbon dioxide

Figure 13 shows carbon dioxide concentrations for each day of storage and temperature treatment. Figure 14 shows the carbon dioxide concentrations at each storage temperature to demonstrate the different temperature regimes.

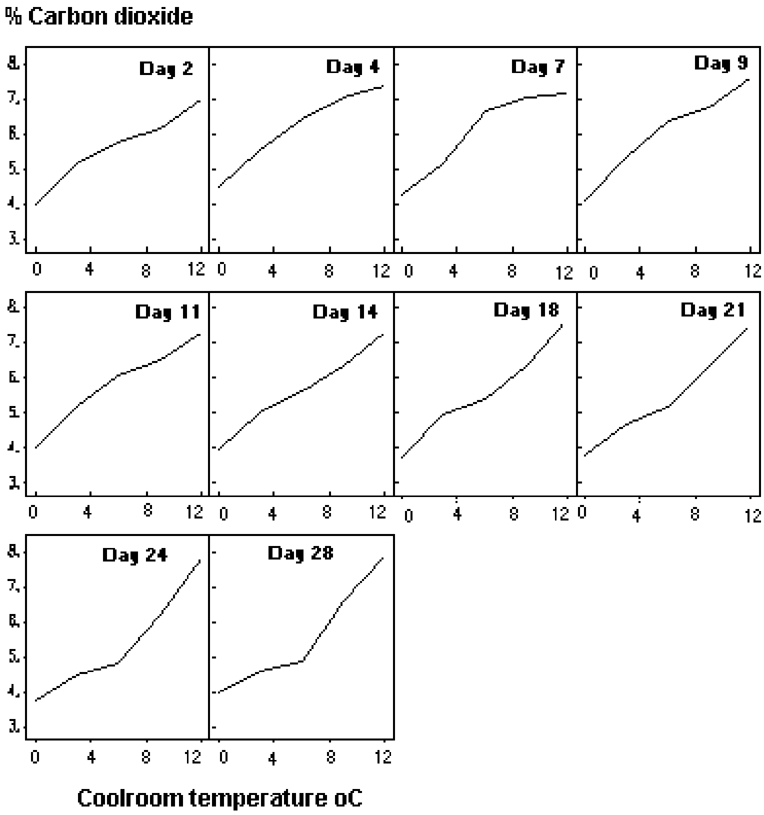

Figure 13: Average carbon dioxide value (%) versus temperature (°C) for each day of storage.

An auto-regressive model was chosen for the variance/covariance of residuals between dates. The significance of fixed effects is shown in Table 40. Note that the response to time is not linear. There is a significant linear response to temperature, i.e. carbon dioxide increases as temperature increases, and this response may interact with time ($p=0.02$). The curvilinear response to temperature is not significant ($p>0.05$). The slope of the temperature response for each day (Table 43) is increasing with time (see also Figure 13).

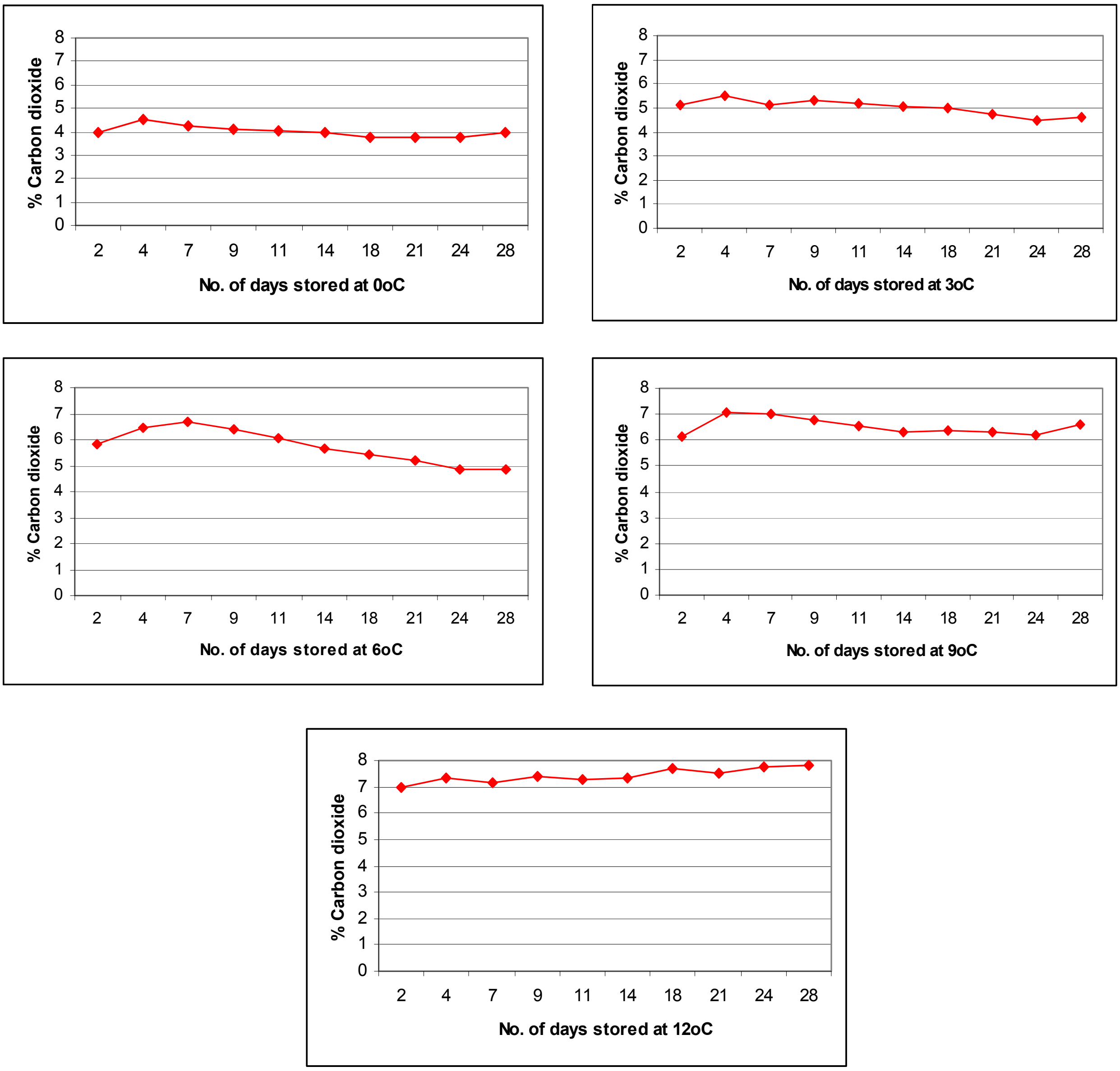

Figure 14: Percentage carbon dioxide during 28 day storage in five separate coolrooms at 0, 3, 6, 9 and 12°C.

Table 43: Slopes for carbon dioxide response to temperature

Day	Slope
2	0.232
4	0.241
7	0.256
9	0.263
11	0.261
14	0.267
18	0.310
21	0.304
24	0.319
28	0.317
Average SED	0.0278

Temperature by Day means are shown in Table 44, which are the carbon dioxide concentrations graphed in Figure 13 and14.

Table 44: Predicted carbon dioxide means for Temperature by Day

	Temperature °C				
Day	**0°C**	**3°C**	**6°C**	**9°C**	**12°C**
2	3.993	5.142	5.802	6.150	6.975
4	4.518	5.535	6.442	7.070	7.360
7	4.270	5.140	6.670	7.025	7.172
9	4.110	5.305	6.382	6.757	7.375
11	4.023	5.202	6.052	6.527	7.272
14	3.958	5.035	5.637	6.325	7.315
18	3.730	4.975	5.430	6.362	7.687
21	3.773	4.705	5.182	6.322	7.522
24	3.750	4.495	4.830	6.197	7.772
28	4.000	4.585	4.850	6.570	7.830
Average SED for comparing within Temperature			0.227		
Average SED for comparing within Day			0.426		

This trial showed that burdock can tolerate a wide range of oxygen and carbon dioxide concentrations at various temperatures. However, sprouting occurred in burdock stored at 12°C after oxygen fell below 7% and carbon dioxide rose over 7%. Therefore, storing burdock at 12°C and packaged in sealed bags resulted in unmarketable burdock roots.

Sprouting is known as a potential hazard of modified atmosphere storage when there is no sufficient temperature control. Other harmful effects include initiation and/or aggravation of certain physiological disorders, for example, blackheart in potatoes, off-flavours and off-odours may occur caused by anaerobic respiration at low oxygen concentrations, and susceptibility to decay increased by physiological damage (Kader, 1992). None of these harmful effects were detected on the burdock stored at 0, 3, 6 and 9°C for 28 days.

Obviously the optimum long term (e.g. 28 days) transit temperature with MAP for exporting is 0°C as this reduces dehydration and maintains shelf life. Burdock stored at 3 – 9 °C for 28 days also showed reasonably good quality. However, temperatures too high such as 12°C is undesirable.

5.0. SHALLOT RESEARCH

5.1. Variety evaluation

French shallots (*Allium ascalonicum*) have previously showed promise as a potential export crop for Asian markets (Burt *et al.*, 1996). In the past, shallots were only propagated vegetatively. However, with the introduction of hybrid varieties by de Groot and Slot, opportunities exist to propagate shallots from true seeds. Grown in a similar way to onions, shallots can be grown without major structural change to existing farms. They can be mechanically harvested and have a long storage life.

The 1995 trials showed that high yielding, good quality shallots could be grown in the metropolitan area. The high seed costs of A$16,000 - $20,000 /ha have previously been seen as an obstacle to commercial production. However, new market studies have indicated a profitable margin, if shallots are exported via sea containers to the United States. Traders in Los Angeles have indicated wholesale prices of $US 0.50 per pound. Shallots are currently imported to the US from France and Chile. One Los Angeles trader stated he could sell four to six containers per month. Another opportunity could be the export of virus free planting material to Asia, however this has not been investigated in detail as yet.

The objective of these trials was to screen some commercially available shallot cultivars and raise the general awareness of this crop in the Perth and Manjimup districts.

5.1.1. Medina Research Station

Summary
Seven varieties of shallots from true seed (Atlas, Bonilla, Prisma, Matador, Ed's Red, Tropix and Ambition) were planted in Medina, Western Australia in October, 1999. Bulbs were harvested between January and February 2000. Most varieties matured in 97 days, about half of the time taken in Manjimup. Ed's red took 128 days. Total yields as well as marketable yields were generally up to two thirds lower than in Manjimup. Ambition (21.6 t/ha), followed by Matador (20.4 t/ha) yielded best. Tropix dehydrated in storage before yield measurements were taken.

No conclusion can be drawn from this unreplicated screening, as seeds were planted in a spare area of a carrot trial and management was not optimal. Previous results from a shallot trial in Medina Research Station (Burt et al, 1996) showed, that shallots could produce double the yields produced in this observation planting.

Materials and method

The trial site was at Medina Research Station (32° 13' S, 115° 38.5' E) in the Perth metropolitan area of Western Australia. The soil was a deep Karrakatta sand.
Before planting, superphosphate 1500 kg/ha plus 50 kg/ha magnesium sulphate and trace element mix at 100 kg/ha were applied and cultivated in. A carrot trial was sown on 22 September 1999. After the carrots had germinated, the plants were pulled out and six varieties of shallots (Table 45) were sown on 7th October, 1999. They were then

exposed to the same management regime as the carrots (Table 46). The total amount of N, P and K applied was 350.8 kg/ha, 136.5 kg/ha and 305.6 kg/ha respectively.

The trial was an unreplicated observation. Beds were 1.5 m wide and 3 m long. There was a 40-cm walk path between plots. Row spacing was 37.5 cm with three rows per bed. There was one treatment row and two buffer rows per bed. Distance between plants was approximately 1.7 cm (60 seeds per metre).

Table 45: Varieties, origin and time of sowing

Variety No.	Variety	Seed Company
1	Atlas	Fairbanks
2	Bonilla	Fairbanks
3	Prisma	Fairbanks
4	Tropix	Fairbanks
5	Matador	Fairbanks
6	Eds Red	Johnny's Seed Co
7	Ambition	Fairbanks

Table 46: Fertiliser program

Week No	Week Commencing	KNO_3 applied (kg)	KNO_3 (kg/ha)	K (kg/ha)	$(NH_4)_2SO_4$ applied (kg)	$(NH_4)_2SO_4$ (kg/ha)	TOTAL N (kg/ha)	$MgSO_4$ applied (kg)	$MgSO_4$ (kg/ha)	Borax applied (kg)	Borax (kg/ha)
1	27/09/99	Sowing									
2	4/10/99										
4	11/10/99	20.00	50.00	19.10	24.00	60.00	19.30	4.00	10.00		
5	18/10/99	20.00	50.00	19.10	24.00	60.00	19.30	4.00	10.00		
6	25/10/99	20.00	50.00	19.10	32.00	80.00	23.50	4.00	10.00		
7	1/11/99	20.00	50.00	19.10	32.00	80.00	23.50	4.00	10.00	2.00	5
8	8/11/99	28.00	70.00	26.74	40.00	100.00	30.38	8.00	20.00		
9	15/11/99	28.00	70.00	26.74	40.00	100.00	30.38	8.00	20.00		
10	22/11/99	28.00	70.00	26.74	48.00	120.00	34.58	8.00	20.00		
11	29/11/99	28.00	70.00	26.74	48.00	120.00	34.58	8.00	20.00		
12	6/12/99	32.00	80.00	30.56	48.00	120.00	35.92	8.00	20.00	2.00	5
13	13/12/99	32.00	80.00	30.56	48.00	120.00	35.92	8.00	20.00		
14	20/12/99	32.00	80.00	30.56	48.00	120.00	35.92	8.00	20.00		
15	27/12/99	32.00	80.00	30.56	32.00	80.00	27.52	8.00	20.00		
16	3/01/00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
17	10/01/00	Harvest									

Shallots were hand harvested when the tops fell and began to brown. Most shallots were harvested on January 10, 2000 except Ed's Red which was harvested on February 10, 2000.

The product was cured on drying racks in a dry packing shed. After harvest, the individual bulbs were assessed for weight, diameter and the number of sections in a cluster were estimated. Bulbs over 25 mm diameter were considered as marketable.

Results and discussion

Establishment
There was good germination and no establishment problems. The shallots grew much faster at Medina than in Manjimup and growth was good until January when tops started drying off. Tropix dehydrated before measurements could be made.

Growing Period
Shallots grown at Medina matured in almost half the period compared to Manjimup. (Table 47). Eds Red matured later than all other varieties.

Yield
Ambition had the highest yield followed by Matador, Eds Red and Prisma (Table 47). However, since the trial was not replicated, results should be interpreted with caution. Yields were much higher (up to 300% more) in Manjimup. As in Manjimup, Bonilla produced the most segments per plant and appears a good variety for the production of vegetative planting stock. Most shallots were considered marketable, as the local market wants small shallots (25 – 50 mm) as well as large bulbs. Only some bulbs were rejected due to under-size (< 25 mm) or rot.

Table 47: Average yield data of seven shallot varieties.

Variety	Days to maturity	Total yield (t/ha)	Marketable yield 0 – 50 mm diameter (t/ha)	Marketable yield > 50 mm diameter (t/ha)	Total marketable yield (t/ha)
Atlas	97	6.6	2.6	19.2	2.6
Bonilla	97	11.6	10.1	0.2	10.3
Prisma	97	14.9	13.8	0.3	14.1
Tropix	97	0.0	0.00	0.0	0.0
Matador	97	20.4	14.6	5.0	19.6
Eds Red	128	17.3	14.1	1.6	15.7
Ambition	97	21.6	13.2	0	13.2

Quality
Table 48 shows the quality parameters that were measured in the trial. Quality parameters had a similar trend to Manjimup. Matador had the largest bulbs with an average of 38.9 mm diameter and 38.8 g average weight. This was followed by bulbs of Prisma, whilst Atlas had the smallest bulbs. Shallots grow in a number of plantlets clustered together. Like garlic, there are a number of segments per plantlet. Table 48 shows that Prisma had significantly more plantlets per cluster.

Table 48: Bulb characteristics of shallot cultivars.

Variety	Average bulb weight (g)	Average bulb diameter (mm)	Number of plantlets per cluster	Number of segments per cluster	Flesh colour
Atlas	12.4	22.6	1.27	2.0	pink
Bonilla	13.7	30.8	1.5	2.9	yellow
Prisma	18.3	34.3	1.10	1.8	red
Tropix	0	0	na	na	red
Matador	38.8	38.9	1.30	1.9	red
Eds Red	21.3	32.3	1.00	1.1	red
Ambition	17.5	24.2	1.06	1.3	white

The results of this trial were disappointing and there is a need to repeat this trial. The screening plots were located in a carrot trial, and management would have been similar to carrots, which was possibly not optimal. Spacing was too dense and the plants should have been thinned. Compared to a previous shallot trial in Medina (Burt *et al*, 1996), yields were more than 50% down. It appears as if varieties Matador and Ambition are the most suitable varieties for Medina, although this needs to be confirmed in larger scale plantings.

5.1.2. Manjimup Horticultural Research Institute

Summary

Seven varieties of shallots from true seed (Atlas, Bonilla, Prisma, Matador, Ed's Red, Tropix and Ambition) were planted in Manjimup, Western Australia in September 1999. Bulbs were harvested between February and May 2000. Atlas had the shortest growing season (154 days) followed by Matador (182 days). The remaining varieties grew longer (219 – 257 days). Total yields as well as marketable yields were highest for Ambition (73.4 t/ha), followed by Matador (52.9 t/ha) and Prisma (45.8 t/ha). Eds Red and Tropix did not produce enough marketable product to evaluate yield and quality. The shelf life of Ambition and Matador was at least seven months.

Larger size and red flesh make Matador and Prisma good export varieties for the USA export market. Ambition, with its high yield and good size is more suited to the local market due to its yellow flesh. Good prices at the time of the trial made shallots a potential high value export crop for Manjimup.

Materials and method

The trial site was at the Manjimup Horticultural Research Institute (34° 18' S, 116° 7' E) in the south west of Western Australia. The soil was a duplex soil with the depth of the top layer being 40 to 60 cm of sandy loam, and the bottom layer gravely clay.

Approximately twelve months before planting, gypsum (1 t/ha), lime (1 t/ha), triple superphosphate (19.7% P, 500 kg/ha), chlorpyrophos (2 L/ha) and Nemacur® (24 L/ha) were applied and rotary cultivated in. Previously daikon had been grown on the trial site. Four weeks before transplanting, the trial site was sprayed with glyphosate (Roundup® 3 L/ha) and chisel-ploughed.

On September 7 1999, potato E at 1700 kg/ha, triple superphosphate at 500 kg/ha, trace element mix at 100 kg/ha plus kieserite (magnesium sulphate) at 175 kg/ha were applied and hand raked into the soil while forming the beds. Table 49 shows the varieties, planting dates and their source. Some of the varieties were planted later as they were held up by quarantine. All varieties were sown by hand.

Table 49: Varieties, origin and time of sowing

Variety No.	Variety	Seed Company	Date sown
1	Atlas	Fairbanks	7/9/1999
2	Bonilla	Fairbanks	7/9/1999
3	Prisma	Fairbanks	7/9/1999
4	Tropix	Fairbanks	7/9/1999
5	Matador	Fairbanks	28/9/1999
6	Eds Red	Johnny's Seed Co	28/9/1999
7	Ambition	Fairbanks	15/9/1999

The trial design was a randomised block with three replications. Beds were 0.9 m wide and 3 m long. There was a 40-cm walkpath between plots. Row spacing was 30 cm with three rows per bed. There was one treatment row and two buffer rows per bed. Distance between plants was approximately 1.7 cm (60 seeds per meter). From November 9 1999 onwards, urea and sulphate of potash at 70 kg/ha and 85 kg/ha respectively were applied fortnightly until the end of January. The total amount of N, P and K applied to the crop was 304 kg/ha, 217.5 kg/ha and 359 kg/ha respectively.

Weed control was achieved with one application of Prothal® (500g/kg chlorthal dimethyl and 214 g/kg propachlor) at 14 kg/ha immediately after seeding as well as hand weeding. No fungicides or insecticides were sprayed on the crop during its growth.

Shallots were hand harvested when the tops fell and began to brown. The product was cured on drying racks in a dry packing shed. Shallots were stored through autumn and winter in onion bags in an enclosed drying room with little ventilation until October 26, 2000 and assessed for marketability. After harvest, the individual bulbs were assessed for weight, diameter and the number of sections in a cluster were estimated. Bulbs over 25 mm diameter were considered as marketable. The data was analysed using analysis of variance.

Results and discussion

Establishment

There were establishment problems, which were clearly localised. Irrespective of the variety, germination rate in replication one was less then 50 %. Initially, the shallots grew slowly, presumably because of cold weather conditions in September and October. After that period, growth was good until February when tops started drying off. In replication one many shallots germinated later, and were still green when replications two and three were harvested. Tropix did not reach maturity in time and re-sprouted when autumn rains set in. Eds Red and Bonilla did not establish enough plots to collect meaningful data.

Growing period

The number of days from planting to harvest varied significantly between the cultivars. Atlas and Matador matured significantly earlier than Bonilla, Eds Red, Prisma, Tropix and Ambition (Table 50). Atlas matured earlier than all other varieties.

Table 50: Average yield data of seven shallot varieties.

Variety	Days to maturity	Total yield (t/ha)	Marketable yield 0 – 50 mm diameter (t/ha)	Marketable yield > 50 mm diameter (t/ha)	Total marketable yield (t/ha)
Atlas	154.0	38.3	18.8	19.2	37.9
Bonilla	237.3	(63.7)**	(30.8)	(31.4)**	(62.1)
Prisma	227.0	45.8	15.9	29.9	45.8
Tropix	257.0+	0.0	0.00	0.0	0.0
Matador	181.7	52.9	7.5	44.5	52.0
Eds Red	236.0	*	15.8	29.2	*
Ambition	219.0	73.4	21.6	50.6	72.3
LSD (P=0.05)	**34.4**	**23.2**	**8.3**	**22.7**	**22.6**

** Estimates made by Genstat statistical program using the overall variation of the trial

Yield

Ambition had the highest yield followed by Matador and Prisma (Table 50). Bonilla results should be read with caution, as only one replicate was successful. Bonilla also produced a large amount of small shallots. Most shallots were considered marketable, as the local market wants small shallots (25 – 50mm) as well as large bulbs. Only some bulbs were rejected due to under-size (< 25 mm) or rot.

Quality

Table 51 shows the quality parameters that were measured in the trial. Matador had the largest bulbs with an average diameter of 50 mm and 59 g average weight. This was followed by medium bulbs of Ambition and Prisma, whilst Atlas had the smallest bulbs. Shallots grow in a number of plantlets clustered together. Like garlic, there are a number of segments per plantlet. Table 51 shows that Prisma had significantly more plantlets per cluster. There was no significant difference in the number of segments per cluster.

Table 51: Average quality figures of shallot cultivars.

Variety	Average bulb weight (g)	Average bulb diameter (mm)	Number of plantlets per cluster	Number of segments per cluster	Flesh colour
Atlas	28.3	44.1	1.74	3.20	pink
Bonilla	(28.9)**	(46.6)**	(1.64)**	(4.37)**	yellow
Prisma	43.8	47.2	4.80	1.55	red
Tropix	*	*	*	*	red
Matador	59.1	50.1	1.33	2.63	red
Eds Red	*	*	*	*	red
Ambition	48.7	46.6	1.38	2.98	white
LSD (P= 0.05)	**12.6**	**ns**	**1.03**	**ns**	

** Estimates made by Genstat statistical program using the overall variation of the trial.

Shelf Life

Table 52 shows the shelf life of the shallots, which was assessed on the 26th October, 2000. Matador and Ambition had longest shelf life with least percentage of rejection, Prisma and Bonilla were acceptable, but Eds Red and Atlas showed poor post-harvest quality with relative high percentage of rejection, mainly due to shooting and softness.

Table 52: Percentage rejects and shelf life of shallots.

Variety	% Rejects	Days after harvest
Atlas	47.2	261.0
Bonilla	22.0	187.5
Prisma	15.5	179.3
Tropix	*	*
Matador	0.9	227.0
Eds Red	70.2	158.0
Ambition	4.7	207.7
LSD (P=0.05)	33.2	

Note: figures represent the average of three replications assessed

The results of this trial indicated an outstanding potential for shallots in the Manjimup area. Although the growing period appears to be considerably longer than in Medina (Burt *et al*, 1996), this may be an advantage with respect to long shelf life and low percentage rejects, for example, Matador and Ambition. Some market feedback was sought from wholesalers/importers such as Quality Produce International (Canning Vale, Western Australia) and Merex (New York). The local market can sell all types of shallots i.e. pink, red, yellow-fleshed bulbs of any size. Quality Produce is importing shallots currently from New Zealand, Holland and Tasmania. Shallots come packed in 5 kg hessian bags. Tightly packed, they can be stored at Canning Vale for more than three months and sold for $4 - $6 per kg.

In the USA, shallots are sold in 20 kg hessian bags at about A$2/kg (US$0.5/pound). Preferred varieties are red fleshed large bulbs, like Matador and Prisma. If the product had been available, Merex would have ordered one forty-foot container per week. There were no major phytosanitary restrictions when a sample was sent to Merex via airmail. The outstanding shelf life makes shallots a good export crop, however, the method of transport and optimum packaging needs to be investigated further. In our trial, shallots were stored in an enclosed drying room over winter. Other anecdotal evidence says that shallots can be stored at room temperature in ventilated areas for over a year. However, Holland is exporting shallots in refrigerated sea-containers at about 0 ^{o} C with 95% relative humidity.

In preliminary budget estimates, transport costs were calculated assuming shipment to the USA was in Fantainers. This would have resulted in a gross margin of $26,000 /ha or 65 cents/kg to the grower despite the high seed cost of $16,000/ha. The Australian and the US market stated that March is a very good time to supply shallots.

Another opportunity for shallots is their use as virus free seed material for Asian markets. During this project, a Perth exporter had a request for 2000 t of seed material for an Asian market. The cultivar Prisma would be the best variety to grow to get a maximum number of segments. However, spacing is closely related with number of segments (Johnny's Seed Catalogue, 2001) and further research needs to be conducted.

Shallots is an easy crop to grow in Manjimup for the local and export markets. They excel in yield, quality and storage characteristics. They can be mechanically harvested and prepared for market (topped and tailed). Long shelf life and hardiness of the product makes it possible to ship the product anywhere in the world. High seed costs are easily offset by high returns.

5.2. The effect of density on yield, quality and gross margin of export shallots

5.2.1. Summary

Two varieties of shallots from true seed (Matador and Ambition) were planted in Manjimup, Western Australia at six different densities in September 2001. Bulbs were harvested in March 2002. The crop was assessed for bulb diameter and quality (shape). It was found that wider spacings (above 9 cm) caused a clustering of the plants and produced more 'half-moon' shaped bulbs. An economic analysis, which used the presumption that 20 mm – 45 mm bulbs can be sold to Indonesia and 45 – 65 mm bulbs to the USA at current prices ($A 0.6/kg and $A 2.00/kg), determined the optimum density for Ambition and Matador to be 905,797 plants/ha and 1,602,564 plants/ha respectively. Total yields were high for both varieties (up to 80 t/ha) although Matador tended to produce more USA grade shallots. The variation in yields at high densities was very high.

5.2.2. Introduction

Rotation crops are needed to maintain an ecologically and economically sustainable horticultural production in Manjimup and in metropolitan production areas.

Part of the 'New Export Vegetable Crops' project is looking for crops, which are in a different plant family than the main crops, brassicas and carrots.

French shallots have previously been tested (Burt *et al.*, 1996), (Hoffmann *et al.*,1999) as potential export crop for Asian markets. Previously propagated vegetatively only, the introduction of hybrid varieties by de Groot and Slot has opened the opportunity to propagate shallots from true seeds. Grown in a similar way to onions, shallots can be produced without major structural change to existing farm practices. They can be mechanically harvested and have a very long storage life (up to two years).

The 1999 trial identified the varieties Matador and Ambition as the most promising varieties, yielding up to 70 t/ha of marketable product. The 1995 and 1999 trials showed that high yielding good quality shallots could be grown in the Metropolitan and Manjimup areas. The high seed costs of $16,000 – $20,000/ha have previously been seen as an obstacle to commercial production. However, new market studies have indicated a profitable margin, if shallots are exported via sea containers to the United States. Traders in Los Angeles have indicated wholesale prices of $US 0.50 per pound. Shallots are currently imported to the US from France and Chile. In 1998, one Los Angeles trader stated he could sell four to six containers per month. There is also a definite market in New York where an importer wants one 40-foot container (26 t) of large, pink fleshed, shallots per fortnight.

Trial samples, sent in 2000 to an American import company were received favourably. The importer stated that large, pink fleshed cultivars such as Matador and Prisma were preferred. There are other potential markets. Studies have indicated a demand for shallots in Asia (virus free planting material) as well as on the local market. Shallots are currently imported from New Zealand, Tasmania and Holland and sell for $A 4.00 – 6.00/kg wholesale.

The objective of this trial was to obtain information on the effect density on yield and size of shallots and determine the economic optimum spacing to grow bulbs with a diameter of 45 – 65 mm, which is preferred by the US market.

5.2.3. Materials and method

Location
The trial site was at the Manjimup Horticultural Research Institute (34^{o} 18' S, 116^{o} 7' E) in the southwest of Western Australia. The soil was a duplex soil with the depth of the top layer being 40 to 60 cm of sandy loam, and the bottom layer gravely clay. The trial site had been bare for two years.

Preparation
Approximately one month before planting, gypsum (1 t/ha), lime (1 t/ha), triple superphosphate (19.7% P, 500 kg/ha), chlorpyrophos (2 L/ha) and Nemacur® (24 L/ha) were applied and cultivated by rotary hoe. Two weeks before seeding, the trial site was sprayed with glyphosate (3 L/ha). On 4 September 2001, triple superphosphate at 500 kg/ha plus essential minor elements at 100 kg/ha plus kieserite at 175 kg/ha were broadcast and cultivated using rotary hoe.

Treatments
There were two cultivars; Matador and Ambition each trialed to measure the response to density. Treatments were:

Treatment 1	1.0 cm spacing	5,000,000 seeds/ha
Treatment 2	2.0 cm spacing	2,352,941 seeds/ha
Treatment 3	3.0 cm spacing	1,666,666 seeds/ha
Treatment 4	4.0 cm spacing	1,250,000 seeds/ha
Treatment 5	6.0 cm spacing	833,333 seeds/ha
Treatment 6	12.0 cm spacing	416,666 seeds/ha

Trial design
The trial was randomised block design with three replicates. The trial plots were 1.6 m wide and 3 m long, with 8 rows (4 double-rows, 40 cm apart). There were four treatment rows and four buffer rows. This distance was the spacing of a commercial onion air seeder. There was a 25 cm buffer distance between plots, i.e. 2.5 m was harvested.

Planting
On 7 September 2001, shallots in both trials were seeded using a four double-row onion seeder, banding triple-superphosphate at 610 kg/ha (120 kg/ha of P) and muriate of potash at 100 kg/ha (49.8 kg/ha of K). For the cultivar Matador, the seed spacing was 6 cm but the planter setting was adjusted for Ambition, which was sown at 3 cm. Treatments were imposed using a 2.5 cm spacing hand seeder, which was in some cases run twice over the trial rows. After emergence, treatments were hand-thinned to the correct density.

Fertiliser program
After planting 59.5 kg/ha of ammonium nitrate was top-dressed by boom spray. From 25 September 2001 onwards urea and sulphate of potash were applied via boom spray at the following frequency:

- Weekly applications of 31.5 kg/ha of urea and 42.5 kg/ha of sulphate of potash for two weeks.
- Fortnightly applications of 63 kg/ha of urea and 85 kg/ha of sulphate of potash until the 6 February, 2002 (Eight times).

The total amount of N, P and K applied to the crop was 340 kg/ha, 218.5 kg/ha and 367 kg/ha respectively. The trial received about 3 mm of irrigation after each top-dressing.

Irrigation
The crop was irrigated using a semi permanent irrigation system which applied 7 mm/hr of water through Pope Premier ® Impact sprinklers. Fifteen millimeters of irrigation was applied, when the soil moisture potential at 20 cm depth reached –25 kPa.

Weed control
Weed control was achieved with one application of Dacthal® (chlorthal dimethyl) at 8 kg/ha immediately after seeding, an application of Totril ® (ioxynil octanoate) at 2.8 L/ha as well as hand weeding.

Fungicides and insecticides
No fungicides or insecticides were sprayed on the crop during its growth.

Harvest and grading
Shallots were hand harvested when the tops fell and began to brown. The product was cured in the field. After harvest, plants were counted, broken up into individual bulbs, sorted according to their diameter (0 – 20 mm, 20 – 45 mm and 45 – 65 mm) and weighed. Bulblets were then sorted into round and half moon shaped ones, to distinguish between true bulbs and segments of clusters. This affected mainly the 20 – 45 mm diameter bulbs.

Data analysis
The data were analysed using regression analysis.

5.2.4. Results

Establishment
There were establishment problems, which were clearly localised. In September and October the shallots grew slowly, presumably because of cold weather conditions. After that period, growth was good until March/April when tops started drying off. Best quality and shelf life was obtained from shallots which were lifted after top-drying and harvested before the first rains fell.

Growing period
Although there was a trend towards shortening maturity with increasing density in Ambition, the variation between the replicates caused this difference not to be significant ($p = 0.05$) (Table 53). There was no trend in Matador. The maturity period was fairly similar to the 1999/2000 trial with Ambition being approximately two weeks longer.

Table 53: Maturity period of shallots (days after sowing)

Treatment	1	2	3	4	5	6	LSD 0.05
Maturity (days after sowing) **Matador**	191.3	195.7	191.3	193.0	195.7	200.0	n.s.
Maturity (days after sowing) **Ambition**	216.3	185.7	209.3	210.3	194.7	191.7	n.s.

Yield

Data selection

Due to uneven germination and fertiliser blockages during planting, the original trial design (randomised plots in three replications) could not be analysed as such as too many plots turned out to be different densities than originally intended. Data were analysed via regression analysis. Mainly data of treatment rows were selected but in some cases buffer row data were used. This was done in plots, where treatment rows were not established or had different densities and the buffer rows were not on the outside of the trial. In those cases, it was also confirmed that the average plant weight did not vary much from the other replicates of that density treatment. This led to some bigger than usual standard errors in the regression analysis.

Total yield

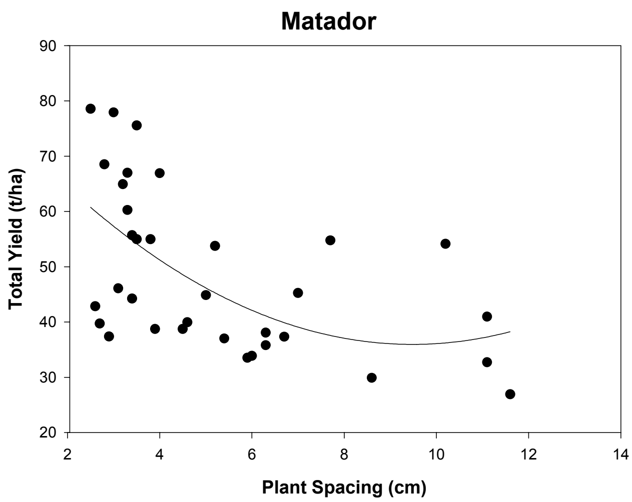

Figure 15*:* Effect of plant spacing on total yield of Matador shallots. The regression curve is: $y = 81.70 - 9.65x + 0.5098x^2$ $r^2 = 0.3243$ SE = 12.2

Figure 15 shows the relationship between plant spacing and total yield for Matador. The large variation in yields in the high density plots made it difficult to determine the optimum spacing. While total yield of Matador decreases rapidly with increasing spacing, the rate of decrease is significantly less in Ambition (9 t/ha per cm versus 0.6 t/ha per cm respectively). Total yield of Ambition produced a very poor relationship with plant spacing therefore the regression curve was not presented.

Grade
0 – 20 mm maximum diameter

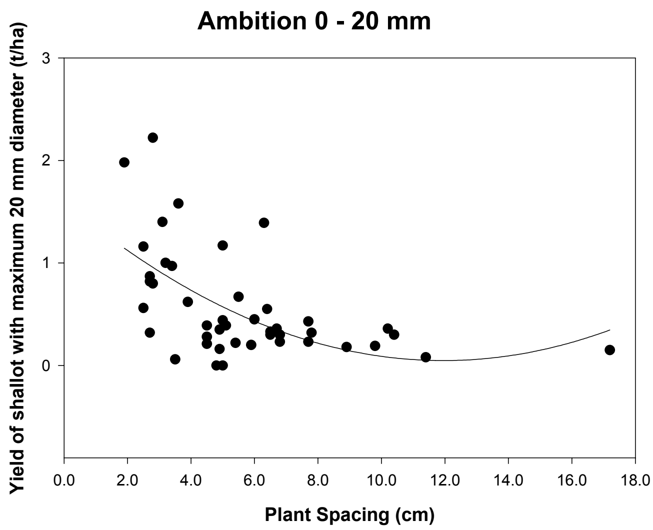

Figure 16*:* Effect of plant spacing on yield of small (20 mm) maximum diameter bulbs of cultivar Ambition. The regression curve is:
$y = 1.598 - 0.2592x + 0.01084x^2$ $r^2 = 0.3342$ SE = 0.432

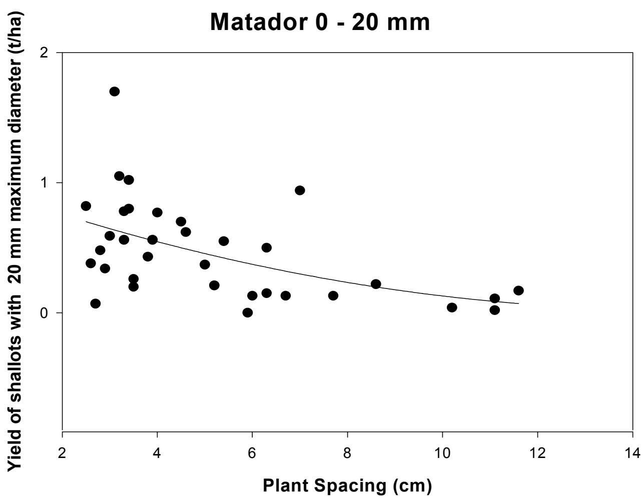

Figure 17*:* Effect of plant spacing on yield of small (20 mm) maximum diameter bulbs of cultivar Matador. The regression curve is:
$y = 1.000 - 0.131x + 0.00437x^2$ $r^2 = 0.2667$ SE = 0.331

Figures 16 and 17 show, that both varieties decreased the yield of small bulbs with increasing spacing. This material can be used for planting.

20 – 45 mm maximum diameter (Asian grade)

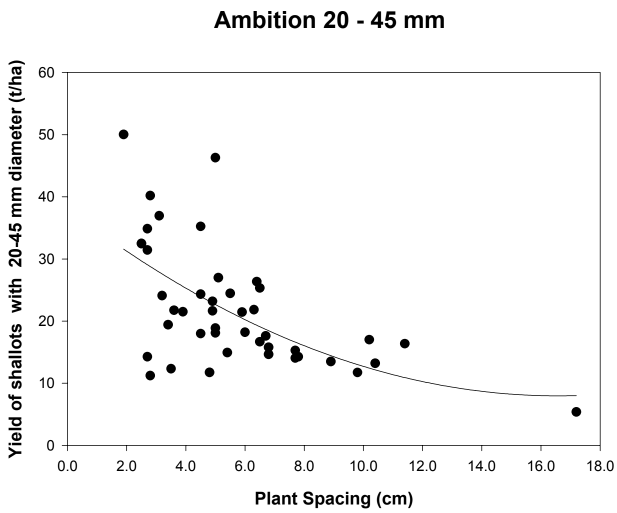

Figure 18*:* Effect of plant spacing on yield of medium (20 – 45 mm) maximum diameter bulbs of cultivar Ambition. The regression curve is: $y = 38.07 – 3.63 x + 0.1094 x^2$ $r^2 = 0.3518$ SE = 7.99

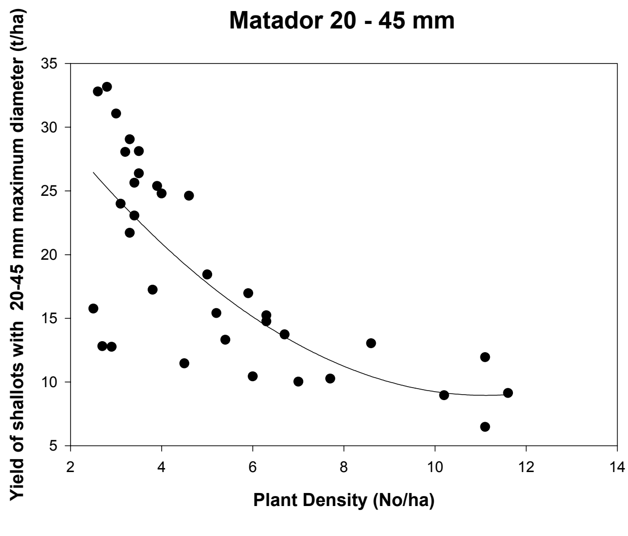

Figure 19*:* Effect of plant spacing on yield of medium (20 – 45 mm) maximum diameter bulbs of cultivar Matador. The regression curve is: $y = 38.08 – 5.24 x + 0.236 x^2$ $r^2 =0.5460$ SE = 5.39

For both varieties, the relationship between Asian Grade bulbs and spacing followed a similar direction as total yield (Figures 18 and 19).

45 – 65 mm maximum diameter (USA Grade)

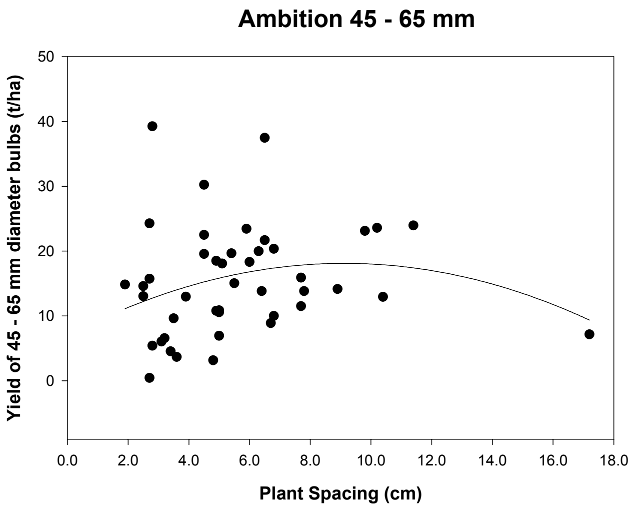

Figure 20: **Effect of plant spacing on yield of large (45 – 65 mm) maximum diameter bulbs of cultivar Ambition. The regression curve is $y = 6.95 + 2.45x - 0.1341x^2$ $r^2 = 0.0682$ SE = 8.34**

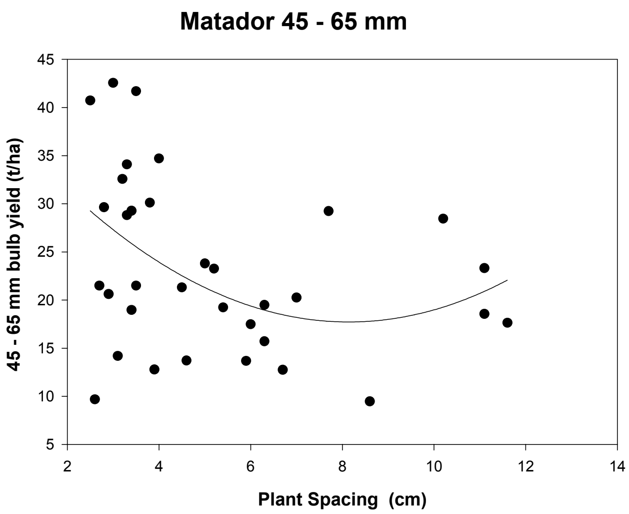

Figure 21: **Effect of plant spacing on yield of large (45 – 65 mm) maximum diameter bulbs of the cultivar Matador. The regression curve is: $y = 41.76 - 5.91x + 0.363x^2$ $r^2 = 0.1678$ SE = 8.43**

The effect of spacing on USA Grade bulbs was quite different in the two varieties. Whilst Ambition achieved the largest yield of that grade at spacings 5 - 12 cm spacing (Figure 20), Matador had the highest yield at 3 – 4 cm (Figure 21). With approximately 29 t/ha, Matador also yielded 38 % more of this grade than ambition. Ambition tended to produce more of the 20 – 45 mm grade.

Greater than 65 mm

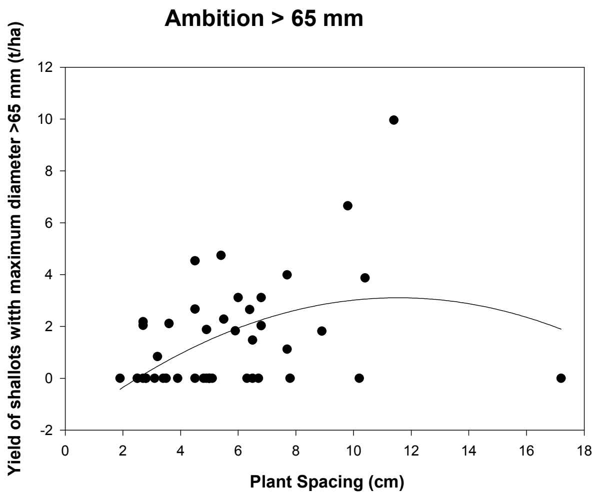

Figure 22*:* Effect of plant spacing on yield of extra large (> 65 mm) maximum diameter bulbs of the cultivar Ambition. The regression curve is: $y = -1.95 + 0.876\ x – 0.0379\ x^2$ $r^2 = 0.2115$ SE = 1.92

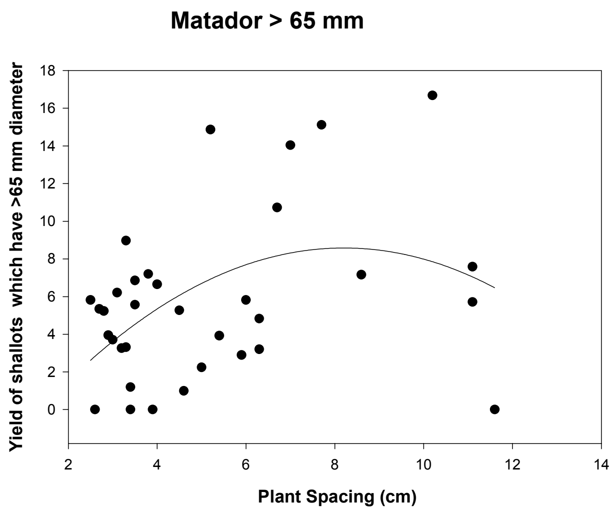

Figure 23: Effect of plant spacing on yield of extra large (> 65 mm) maximum diameter bulbs of the cultivar Matador. The regression curve is: y = - 3.76 + 3.01 x – 0.183 x2 r2 =0.1890 SE = 4.06

Figures 22 and 23 show the relationship between the yield of extra large (> 65 mm) shallots and spacing. This yield optimised at 10 cm and 8 cm for Ambition and Matador respectively. At larger spacings shallots tended to cluster producing segments with smaller diameters.

Percentage of true bulbs

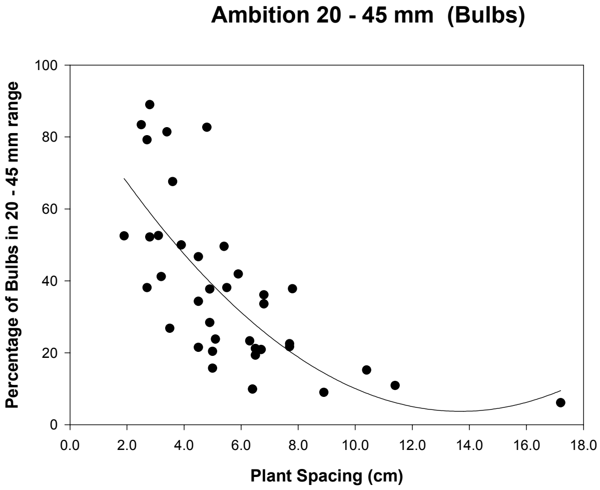

Figure 24: Effect of plant spacing on the percentage of true bulbs in the 20 – 45 mm maximum diameter yield of the cultivar Ambition. The regression curve is: y = 91.06 – 12.77 x + 0.4666 x2 r2 =0.5107

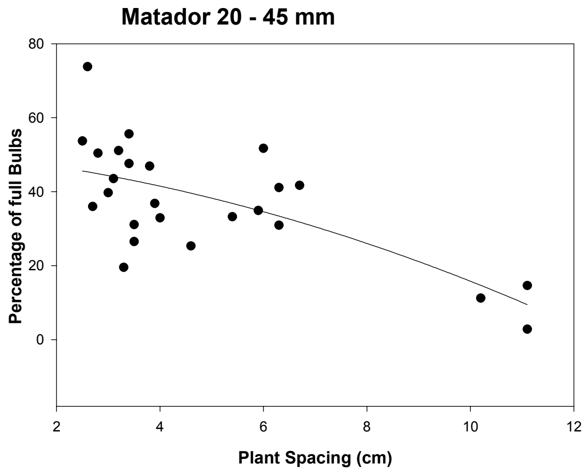

Figure 25: Effect of plant spacing on the percentage of true bulbs in the 20 - 45 mm maximum diameter yield of the cultivar Matador. The regression curve is: y = 50.35 + 1.3895 x – 0.2068 x2 r2 =0.4711

Figures 24 and 25 show, that both varieties respond to wider spacings by clustering. Clusters are the half moon shaped segments of the plant (Figure 24). This is most apparent in the Asian grade size – range, mainly because the size of the clusters are in that range. Here, high density plantings produced 85% (Ambition) and 45% (Matador) of true bulbs compared to only 5% at 10 cm spacing in both varieties. The other size ranges produced almost 100% of true bulbs in both varieties (no data presented).

Figure 26: Clustered plants of the variety Matador.

Plant weight

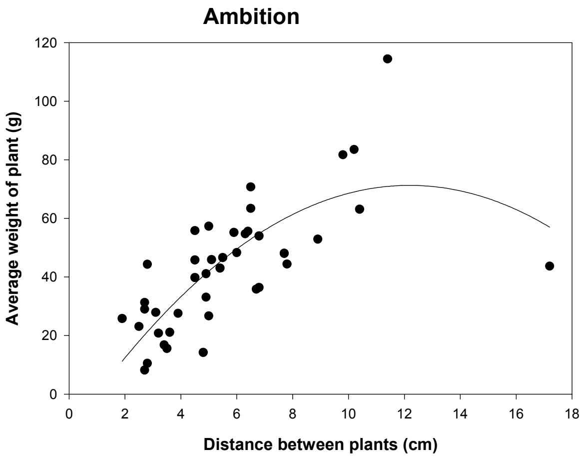

Figure 27*:* Effect of plant spacing on the average plant size of the cultivar Ambition. The regression curve is: $y = -12.99 + 13.83x - 0.567x^2$ $r^2 = 0.5872$

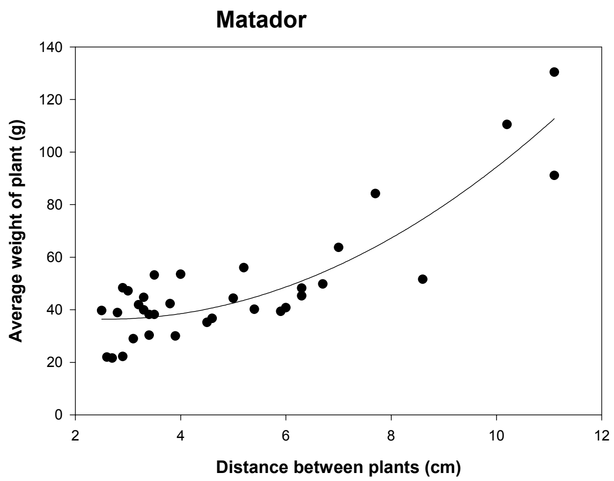

Figure 28*:* Effect of plant spacing on the average plant size of the cultivar Ambition. The regression curve is: $y = 43.46 + 5.45 x + 1.053 x^2$ r^2 =0.7.804

Figures 27 and 28 show increased plant weight with increasing spacing for both varieties. As Ambition had one plot at 17 cm spacing it showed a decrease in the response curve. This may be due to the fact that shallots tend to cluster at wider spacings, which may reduce total plant weight.

Ratio of USA grade to Total yield

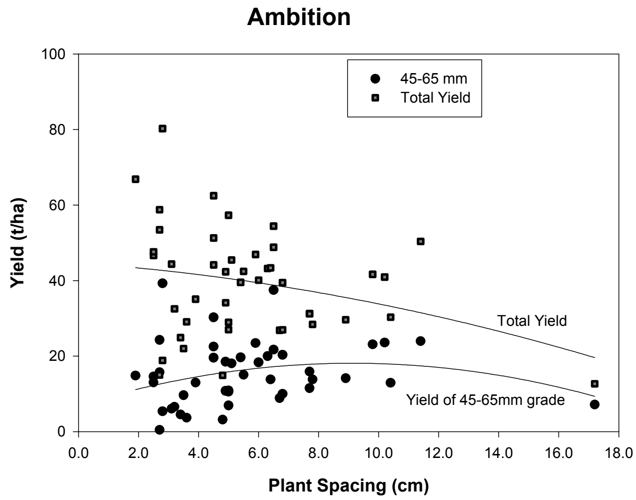

Figure 29: Effect of plant spacing on yield of bulbs in the 45 –65 mm maximum diameter range and total yield of the cultivar Ambition. Details of the curve is given in Figure 20.

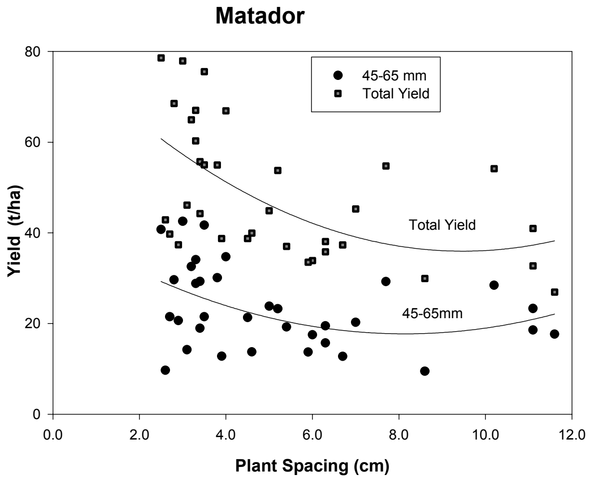

Figure 30: Effect of plant spacing on yield of bulbs in the 45 –65 mm maximum diameter range and total yield of the cultivar Matador. Details of the curves are given in Figures 15 and 21.

Figure 29 and 30 show the USA grade shallots produced in relation to total yield at different spacings. From these graphs, the optimum spacing can be derived.

5.2.5. Economic analysis

Using the above figures the following economic analysis has been conducted:

Ambition

Tractor width	160 cm				
Rows	8				
Metres of row	6250 /ha				
Seed price/unit	$520				
Spacing (cm)	3	4	6	8	10
Seeds/ha	1,666,667	1,250,000	833,333	625,000	500,000
50K seed units	33.33	25.00	16.67	12.50	10.00
Cost per ha	$17,333	$13,000	$8,667	$6,500	$5,200

FOB price estimate $A	
Gross price $/kg	
Waste	0.00
20 – 45 mm	0.30
45 – 65 mm	1.47
> 65 mm	0.30

	Grade		
	20 – 45 mm	45 – 65 mm	> 65 mm
Wholesale price per tonne	600	2000	600
Freight cost per tonne	200	180	200
Sub total	400	1820	400
Commission 10%	60	200	60
Sub total	340	1620	340
Other	45	150	45
FOB	295	1470	295
$/kg	0.30	1.47	0.30

Spacing (cm)	3	4	6	8	10
Waste	2.3%	2.1%	1.8%	1.9%	2.4%
20 – 45 mm	66.1%	60.7%	51.0%	42.9%	36.7%
45 –65 mm	30.7%	35.0%	42.4%	48.1%	52.1%
> 65 mm	0.9%	2.2%	4.8%	7.1%	8.8%
Cost per ha	27,776	23,340	18,797	15,844	14,484
Yield (kg/ha)	42,500	41,600	39,400	36,800	33,800
Gross margin (GM)	**-196**	**5,782**	**12,246**	**15,604**	**15,939**
% Coverage (GM/Income)	-0.7	19.9	39.4	49.6	52.4
Price per kg (A$)	0.65	0.70	0.79	0.85	0.90
Cost per kg (A$)	0.654	0.561	0.477	0.431	0.429
Margin A$/kg	-0.005	0.139	0.311	0.424	0.472
Cost A$/kg					
Seed	17,160	13,000	8,840	6,240	5,200
Fert/Chem	3,125	3,125	3,125	3,125	3,125
Labour	1,169	1,169	1,169	1,169	1,169
Other	6,322	6,046	5,663	5,310	4,990

The above table is based on the assumptions:

- Shallots 20 – 45 mm diameter sell in Indonesia for $ 0.6/kg (current price due to oversupply from Burma, normal price $1.00/kg)
- Shallots 45 – 65 cm diameter sell in the USA for A$ 2.00
- Shallots > 65 mm sell on the local market for $ 0.6
- Transport to Indonesia in refrigerated container $ 200/t
- Transport to USA $180/t
- Commission 10 %
- Seed cost $520/50,000 seeds

From this table the following gross margin graph (Figure 31) has been developed:

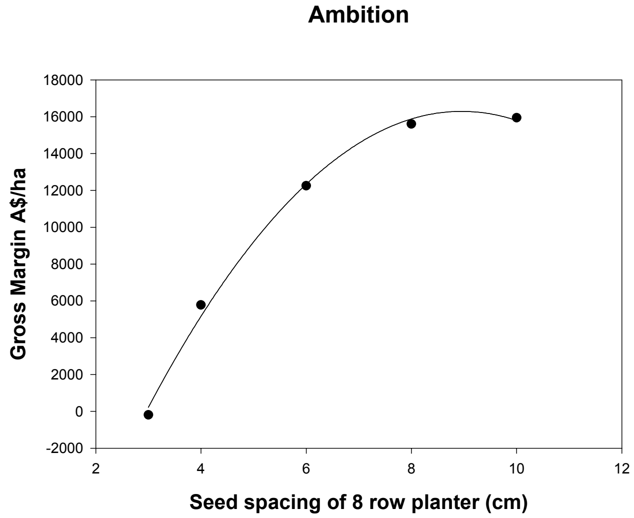

Figure 31: Relationship between seed spacing and gross margin of Ambition shallots. The regression curve is: $y = -20064.74 + 8118.91x - 453.28x^2$ $r^2 = 0.9966$

According to the analysis the optimum spacing would be 9.02 cm (905,797 seeds/ha) at which point the gross margin is $16,289.2/ha.

Matador

Tractor width	160 cm					
Rows	8					
Metres of row	6250 /ha					
Seed price/unit	$520					
Spacing (cm)	2	3	4	6	8	10
Seeds/ha	2,500,000	1,666,667	1,250,000	833,333	625,000	500,000
50K seed units	50.00	33.33	25.00	16.67	12.50	10.00
Cost per ha	$26,000	$17,333	$13,000	$8,667	$6,500	$5,200

FOB price estimate $A	
Gross price $/kg	
Waste	0.00
20 – 45 mm	0.30
45 – 65 mm	1.47
> 65 mm	0.30

	Grade		
	20 – 45 mm	45 – 65 mm	> 65 mm
Wholesale price per tonne	600	2000	600
Freight cost per tonne	200	180	200
Sub total	400	1820	400
Commission 10%	60	200	60
Sub total	340	1620	340
Other	45	150	45
FOB	295	1470	295
$/kg	0.30	1.47	0.30

Spacing (cm)	2	3	4	6	8	10
Waste	1.2%	1.2%	1.1%	0.9%	0.6%	0.3%
20 – 45 mm	45.9%	43.7%	41.2%	35.5%	29.8%	25.5%
45 –65 mm	50.5%	48.7%	47.2%	45.5%	46.8%	52.1%
> 65 mm	2.4%	6.4%	10.5%	18.1%	22.8%	22.1%
Cost per ha	38,959	29,074	24,201	19,066	15,911	14,751
Yield (kg)	64,400	57,300	51,300	42,220	37,100	36,200
Gross margin (GM)	**18,024**	**20,415**	**19,217**	**15,832**	**15,369**	**18,057**
% Coverage (GM/Income)	31.6	41.3	44.3	45.4	49.1	55.0
Price per kg (A$)	0.88	0.86	0.85	0.83	0.84	0.91
Cost per kg (A$)	0.605	0.507	0.472	0.452	0.429	0.407
Margin A$/kg	0.280	0.356	0.375	0.375	0.414	0.499
Cost A$/kg						
Seed	26,000	17,160	13,000	8,840	6,240	5,200
Fert/Chem	3,125	3,125	3,125	3,125	3,125	3,125
Labour	1,169	1,169	1,169	1,169	1,169	1,169
Other	8,665	7,620	6,907	5,932	5,377	5,257

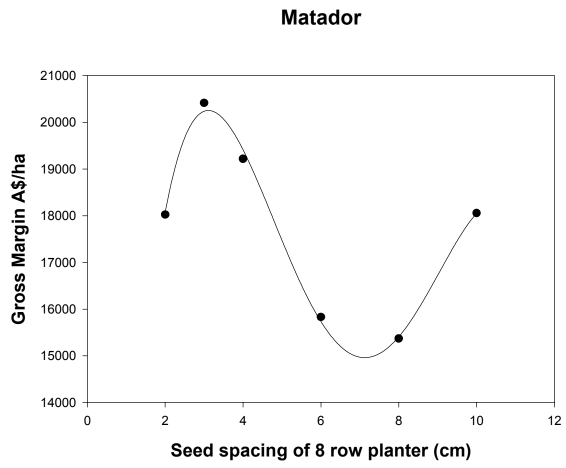

Figure 32: Relationship between seed spacing and gross margin of Matador shallots. The regression curve is: $y = -5416.38 + 21231.83\,x - 5913.47\,x^2 + 630.56\,x^3 - 22.81\,x^4$ $r^2 = 0.9955$

According to the analysis the optimum spacing would be 3.12 cm (1,602,564 seeds/ha) at which point the gross margin is $20252.80 /ha (Figure 32). Although percentage coverage, the ratio between gross margin and total income at wider spacings becomes higher, the quality at that spacing is inferior due to an excessive amount of clusters.

Shelf Life
To date both varieties have remained in good condition. Shelf life achieved is a minimum of five months.

2.5.6. Discussion

The optimum density for Ambition and Matador is 905,797 plants/ha and 1,602,564 plants/ha respectively. This corresponds to a seed spacing of 9.02 and 3.12 cm when an eight row air seeder with a distance of 40 cm between each pair of double-rows (current commercial practice) is used. Although, at wider spacings cost is considerably lower, bulbs tend to cluster and may get rejected at certain markets. Various markets and photos were screened, and no obvious rejection of shallot segments were noted. To verify this, a commercial shipment needs to be undertaken.

The economic analysis did not take into account the value of the 0 – 20 mm diameter bulbs. A 2002/2003 trial, which is currently in progress indicates that these bulbs can be used as planting material. While bigger bulbs tend to go to flower (bolt), smaller bulbs do not. This will save some seed costs in the following season.

Total yields were high for both varieties (up to 80 t/ha) although Matador tended to produce more USA grade shallots. The variation in yields at high densities was very high and could not easily be explained.

This trial has once again confirmed that shallots can be a very profitable crop of good quality with a long shelf-life. The patchy emergence which was observed in certain areas needs to be further investigated.

5.3. Effect of seed bulb-size on yield and quality of shallots

5.3.1. Summary

In two separate trials, two varieties of shallots (Ambition and Matador) were planted vegetatively using three sizes of bulbs, small (0-20 mm maximum diameter), medium (21-45 mm maximum diameter) and large (46 – 65 mm maximum diameter) to assess the suitability of the bulbs as vegetative planting material. The trials were planted at the Manjimup Horticultural Research Institute.

Results showed that medium and large bulbs tended to go to flower prematurely. At a similar density (250,000 plants/ha), small bulbs produced less but larger sized bulbs. Medium and large bulbs produced more small bulbs. Total yield was not significantly different between the treatments. Vegetatively propagated plants were approximately one month earlier maturing than seeded shallots. It was concluded that small bulbs can be used to propagate shallots vegetatively, thus giving an outlet for otherwise wasted product.

5.3.2. Introduction

Rotation crops are needed to maintain an ecologically and economically sustainable horticultural production in Manjimup and in metropolitan production areas. An aim of the 'New Export Vegetable Crops' project is to identify crops, which are in a different plant family to the main crops, brassicas and carrots. French shallots have previously been tested (Burt, 1996), (Hoffmann et.al.,1999, Hoffmann et.al., 2002) as a potential export crop for USA and Asian markets. Good yield and quality was achieved when shallots were propagated from true seeds.

The 1999 trial identified the varieties Matador and Ambition as the most promising varieties yielding up to 70 t/ha of marketable product. Optimum spacing and nitrogen levels were determined in 2002. At the time of planting, a trial shipment of bulb samples to Indonesia was under way to determine the suitability of Manjimup grown shallots as vegetative propagation material, advantaged by its low disease status. Currently, Indonesia imports planting material from the Philippines but virus problems reduce yields. It was thought, that this presents an opportunity for West Australian shallot growers to sell the 20 – 45 mm diameter shallots, which are too small for the USA export market.

The results of the Indonesian shipment are now known. It was found that the varieties Ambition and Matador were unsuitable as planting material for the tropics, as their growing season was longer than four months. This is the length of the growing season in Kediri (East Java) and Brebes (Central Java), where shallots are currently grown. Shallots, which grow longer, suffer disease problems due to climatic changes (Gunawan, Iwan pers. com).

This trial tested the suitability of the bulbs to produce a crop. It has also tested the potential yield and size range from planting different size bulbs. According to one US source (Johnny's, 2001), planting small bulbs will produce large bulbs, while large bulbs divide more and produce more small bulbs.

The objectives of this trial for the shallot varieties Matador and Ambition were:

i) To test the ability of Manjimup grown shallot bulbs to be used as planting material to produce a good quality crop for the South East Asian market.

ii) To determine the difference in quality when different size bulbs are planted.

5.3.3. Materials and method

Two cultivars of shallots were trialed, Ambition and Matador. Two separate trials were conducted on one bay, each trial had three treatments, replicated three times:

Treatment 1 Vegetative planting bulbs of <20 mm maximum diameter.
Treatment 2 Vegetative planting bulbs of 20 mm – 45 mm maximum diameter.
Treatment 3 Vegetative planting bulbs of 45 mm – 65 mm maximum diameter

The trial design was randomised blocks with three replicates. For practical purposes the cultivars were not randomised and could therefore not be compared with each other. The trial plots were 1.6 m wide and 3 m long, with 3 rows, 40 cm apart. There was one treatment row and two buffer rows. There was a 25 cm buffer distance laterally between plots, so 2.5 m was harvested. Harvest area was 0.4m * 2.5 m = 1.00 m^2 / plot.

Weeds were killed on the trial site in mid July with glyphosate (3 L/ha). Two weeks later, the site was chisel ploughed. On the 30 July, Nemacur® at 24L/ha and Lorsban® at 6 L/ha were applied for nematode and black beetle control. On the 7 August, gypsum and lime at 1t/ha as well as double-superphosphate at 1250 kg/ha (218.7 kg/ha of P) , essential minor elements at 100 kg/ha, kieserite at 175 kg/ha , muriate of potash at 100 kg/ha (49.8 kg/ha of K) and ammonium nitrate at 59.5 kg/ha (20 kg/ha of N) were broadcast using a spreader and incorporated with tines. On the 14 August, the bay was marked and the bulbs were hand-planted at 10 cm spacing.

Top-dressings:
Two weeks after shooting, urea and sulphate of potash at 49 and 85 kg/ha respectively were applied fortnightly by boom spray. This was done until a total amount of 231.6 kg/ha N, 218.7 kg/ha of P and 367.5 kg/ha of K had been applied.

Weed control:
Weed control was achieved with one application of Dacthal® (chlorthal dimethyl) at 8 kg/ha straight after seeding, an application of Totril® (ioxynil octanoate) at 2.8 l/ha as well as hand weeding.

Fungicides and insecticides
The following fungicides were applied to combat mildew.

Bravo® at 2.3 L/ha 1/11/02
Mancozeb WDG® at 3 kg/ha 20/11/02
Bravo® at 2.3 L/ha 4/12/02
Mancozeb WDG® 3 kg/ha 19/12/02

No insecticides were sprayed on the crop during its growth.

Harvest and grading
Shallots were hand harvested when the tops fell and began to brown. The shallots were cured in the field. After harvest, plants were counted, broken up into individual bulbs, sorted according to their diameter (0 – 20 mm, 20 – 45 mm and 45 – 65 mm) and weighed.

Data analyses
The data were analysed using Genstat's general Analysis of Variance.

5.3.4. Results

Sprouting
Ninety-eight percent of bulbs had broken their dormancy 28 days after planting.

Growing period
Ambition was harvested on the 23/1/03 (162 days after planting) and Matador two weeks later (176 days after planting).

Yield and quality

Table 54: Yield and quality data of two cultivars of shallots

Ambition	Total yield (t/ha)	0-20 mm (t/ha)	21-45 mm (t/ha)	46 - 65 mm (t/ha)	Average bulb weight (g)	Total numbers	No of bulbs produced/bulb planted
Treatment							
1	16.7	1.84	13.5	1.34	14.8	110.3	4.41
2	21.0	3.60	16.6	0.85	13.2	158.0	6.32
3	20.7	3.03	16.9	0.71	12.1	172.0	6.88
LSD	ns	1.55	ns	ns	ns	52.06	2.082
Matador	**Total yield (t/ha)**	**0-20 mm (t/ha)**	**21-45 mm (t/ha)**	**46 - 65 mm (t/ha)**	**Average bulb weight (g)**	**Total numbers**	**No of bulbs produced/bulb planted**
Treatment							
1	24.1	0.48	13.4	10.24	21.37	113.3	4.53
2	25.3	1.59	20.4	3.37	14.99	169.0	6.76
3	20.4	3.31	16.8	0.34	10.24	199.3	7.97
LSD	ns	1.404	9.71	3.990	16.41	49.69	1.988

Table 54 shows that total yield was not significantly affected by the treatments. However, size grades and average bulb weight were dependent on the size of the seed bulbs. Small bulbs produced less bigger ones and big ones produced more smaller bulbs. For Matador, the results were significant, while Ambition only showed non-significant trends. For both varieties, small bulbs produced an average of 4.5 bulbs, while large bulbs produced 7 – 8.

Flowering (bolting)

Table 55 shows that bigger bulbs tended to go to flower in both varieties. This clearly affects the use of medium to large bulbs as planting material.

Table 55: Number of flowers produced per 3 m row and percentage of bulbs produced, which are flowering.

Treatment	No. of flowers	% of produced bulbs flowering
Ambition		
1	1	0.9
2	18	11.6
3	32.7	18.9
LSD	15.2	6.88
Matador		
Treatment	**No of flowers**	**% of produced bulbs flowering**
1	1.3	1.3
2	32	19.8
3	51.7	25.7
LSD	21.47	16.41

5.3.5. Discussion

We suspect that the trial was confounded by the placement of P. The P fertiliser was broadcast via a machine and incorporated into the soil via rotary spring tines. This could have placed it too deeply and made it unavailable to the shallow root system. It is assumed, that the low yield (50% less than previous trials) is a result of lack of P.

Medium or large size shallot bulbs, produced in Manjimup, cannot be used as vegetative planting material. They tend to go to flower and produce too many small bulbs. However small (0 – 20 mm diameter) bulbs can be used to save on seed costs and get an earlier harvest, about one month earlier. Vegetative propagation also has less germination and establishment problems, which were noticed in previous seeded trials. Yields from those small bulbs consist of large, good quality bulbs. It is estimated that a shallot crop yields about 100,000 (0.5 t/ha) small bulbs/ha which can be planted out saving approximately $1,000 – $1,500 per hectare. This saving needs to be weighed against the cost of recovering the bulbs, cost of a special planting machine etc.

This trial confirmed the US findings (Johnny's, 2001), that planting small bulbs will produce large bulbs, while large bulbs divide more and produce more small bulbs. Unfortunately, these varieties cannot be used to send to Indonesia as virus free planting material as the growing season is too long.

6.0. DAIKON RESEARCH

6.1. Determining optimum density for two daikon varieties

Since the daikon variety trials completed by the project in 1999/2000, it was found that daikon would perhaps not be viable for the Japanese fresh market as profits were very marginal. Therefore no further work on daikon radish was completed. However, since then a new market opening is proving to be more economically viable. In 2001/2002, a few growers have grown daikon for export to the Taiwanese market. Therefore, interest from industry has prompted new trials on daikon.

The aim of this trial was to determine optimum density of two varieties of daikon (Narumi and Minowase Summer Cross No. 3) and the effects on yield and quality. The trial was also timed to have daikon plantings for the New Export Vegetables Field Walk at Medina Research Station held in late January 2002.

6.1.1. Materials and method

The trial was planted at the Medina Research Station on Spearwood sand. The trial tested five plant densities (Table 56), two harvests and two varieties, Narumi and Minowase Summer Cross No. 3, with three replications. There were 60 plots in total with each plot being 1.2 m in width and 3 m in length.

Table 56: Target densities and measured plant densities averaged for the two harvest times.

Target plant density (plants/m^2)	No. rows per bed	Spacing (intra-row x inter-row)	Actual plant density (plants/m^2)
6	2	22cm x 44cm	7
12	3	16.5cm x 33cm	13
18	4	14.5cm x 29cm	19
24	4	11cm x 22cm	23
30	4	9cm x 18cm	30

The site was deep ripped and the following fertilisers were broadcast and incorporated using a rotary hoe: double superphosphate at 1000 kg/ha, muriate of potash at 120 kg/ha, gypsum at 250 kg/ha and 150 kg/ha of a trace element mix. The beds were prepared according to density and the number of rows per bed. The daikon seed was sown by hand at a 2 cm depth on the 26 November 2001.

Post-plant fertilisers were applied after sowing using a fertigation system. For the first three weeks, 80 kg/ha of ammonium nitrate, 80 kg/ha potassium nitrate and 12 kg/ha magnesium sulphate were applied. From week four to week nine, 130 kg/ha ammonium nitrate, 130 kg/ha potassium nitrate and 12 kg/ha magnesium sulphate were applied.

For weed control, Dacthal® (chlorthal dimethyl) was used as pre-emergent and the site was regularly inspected and sprayed for Diamondback moth.

A two metre section of each plot was harvested with a half metre buffer at the ends of the plot. The following measurements of each root were taken: root weight (g), length (mm), diameter (mm), ratings of pithiness, rots and blemishes (Table 57) and quality (Table 58)

Table 57: Pithiness and rots/blemish ratings for daikon

Score	Description
1	none
2	slight
3	moderate
4	severe
5	very severe

Table 58: Quality ratings for daikon

Score	Description
1	excellent export standard
2	export standard
3	good marketability
4	poor marketability
5	reject

The two harvest dates were 30 January 2002, 65 days after sowing (DAS) and 14 February 2002, 80 days after sowing (DAS).

6.1.2. Results and discussion

Total and marketable yields

Polynominal functions were fitted to total yield versus density for each harvest and each variety. For a given plant density, total yield increased with later harvest (Figure 33). All of the varieties peaked in total yield between 18 – 22 plants/m^2. Maximum total yield at 80 days after sowing (2nd harvest) was 224 t/ha at a density of 19.5 plants/m^2 recorded by the Narumi variety. The total yield for Minowase peaked at 174 t/ha with a density of 21.8 plants/m^2, at the 80 day harvest.

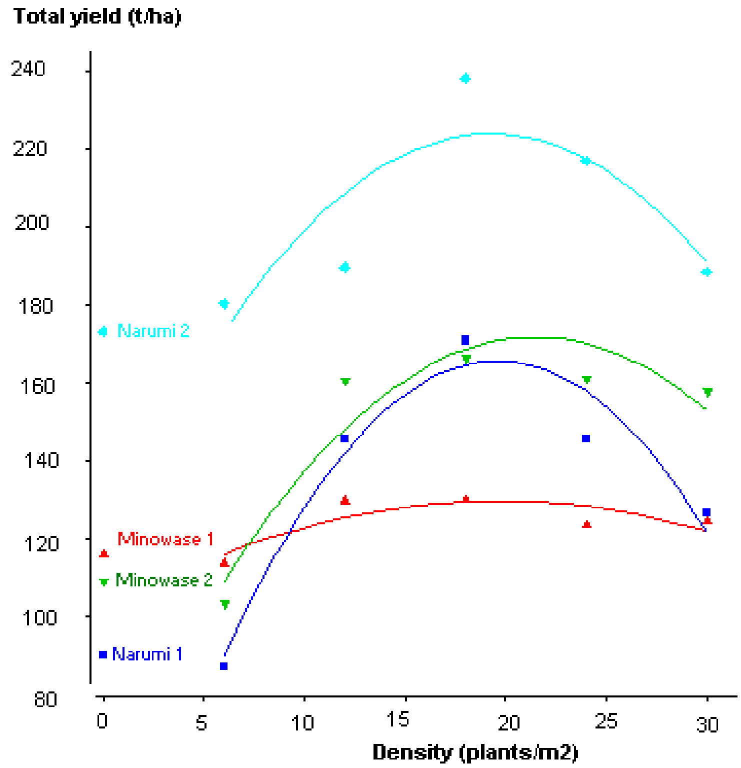

Figure 33: The effect of plant density and time of harvest (1= 65, 2 = 80 days after sowing) on the total yield of Narumi and Minowase daikon (R^2 = 0.89).

65 DAS Narumi	**$y1 = 8.7 + 16.01x – 0.4081x^2$**
65 DAS Minowase	**$y2 = 101.4 + 2.87x – 0.0728x^2$**
80 DAS Narumi	**$y3 = 117.0 + 11.12x - 0.2885x^2$**
80 DAS Minowase	**$y4 = 51.0 + 11.24x – 0.2613x^2$**

All treatments except Minowase harvested at 80 days after sowing, had a marketable yield peak at between 17 – 21 plants/m^2 (Figure 34). Minowase harvested at 80 days after sowing had no density effect on marketable yield as the majority of roots were considered unmarketable. Maximum marketable yield was 93.0 t/ha at a density of 17 plants/m^2 from Narumi harvested 65 days after sowing. The later harvest date resulted in lower marketable yields for both varieties. However, Minowase at both harvests recorded lower marketable yields than Narumi.

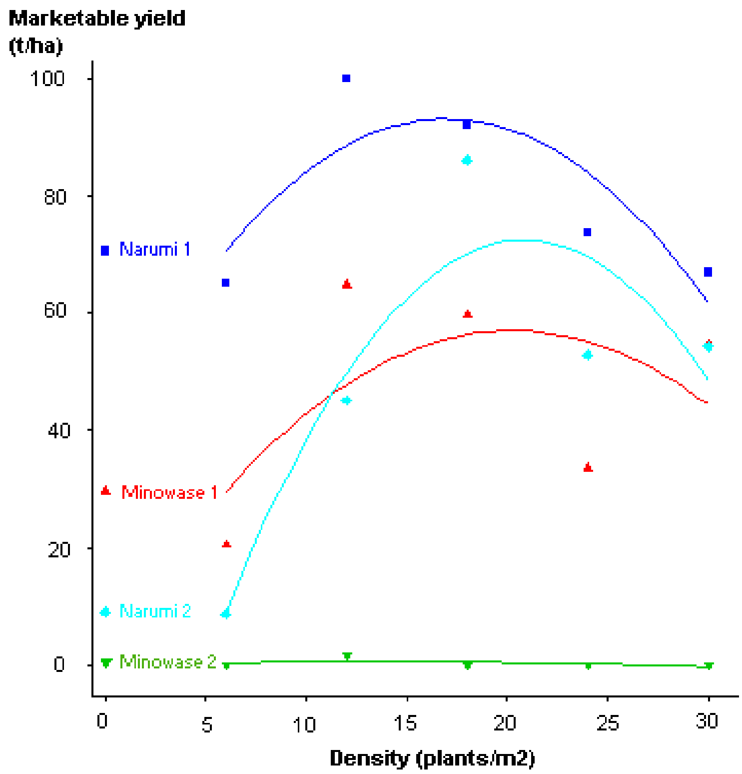

Figure 34: The effect of plant density and time of harvest (1=65, 2=80 days after sowing) on the marketable yield of Narumi and Minowase daikon (R^2 = 0.80).

65 DAS Narumi	$y1 = 39.4 + 6.32x - 0.186x^2$
65 DAS Minowase	$y2 = 1.8 + 5.44x - 0.134x^2$
80 DAS Narumi	$y3 = -52.4 + 11.95x - 0.286x^2$
80 DAS Minowase	$y4 = 0.0 + 0.09x - 0.003x^2$

Root weight, length and diameter

Weight measurements were transformed to $\log_e$ weights prior to analysis as they appeared to display a log distribution. There were no variety effects on weight but harvest, density and interactions of harvest and density were significant (Table 59).

From Figure 35, both Minowase and Narumi harvested 65 days after sowing had significantly the same weight. As to be expected, the first harvest had a significantly lower root weight than roots harvested at a later date. Similarly, those roots planted at a lower density had higher root weights than those planted at a higher density.

Table 59: The effect of plant density and harvest time (days after sowing) on root weight (g) of both Narumi and Minowase daikon.

Density (plants/m^2)		65 DAS	80 DAS
6	$\log_e$ wt	7.79	8.17
	*retransformed**	*1463.8*	*2587.0*
12	$\log_e$ wt	7.66	7.74
	*retransformed**	*1158.0*	*1338.8*
18	$\log_e$ wt	7.49	7.60
	*retransformed**	*810.0*	*1059.8*
24	$\log_e$ wt	7.37	7.48
	*retransformed**	*627.8*	*822.7*
30	$\log_e$ wt	7.27	7.36
	*retransformed**	*456.9*	*602.6*
Significance			
Harvest		<0.001	
l.s.d. (p=0.05)		0.070	
Density		<0.001	
l.s.d. (p=0.05)		0.033	
Harvest * Density		<0.001	
l.s.d. (p=0.05)		0.093	

* means in grams can only be compared using l.s.d's on the log scale

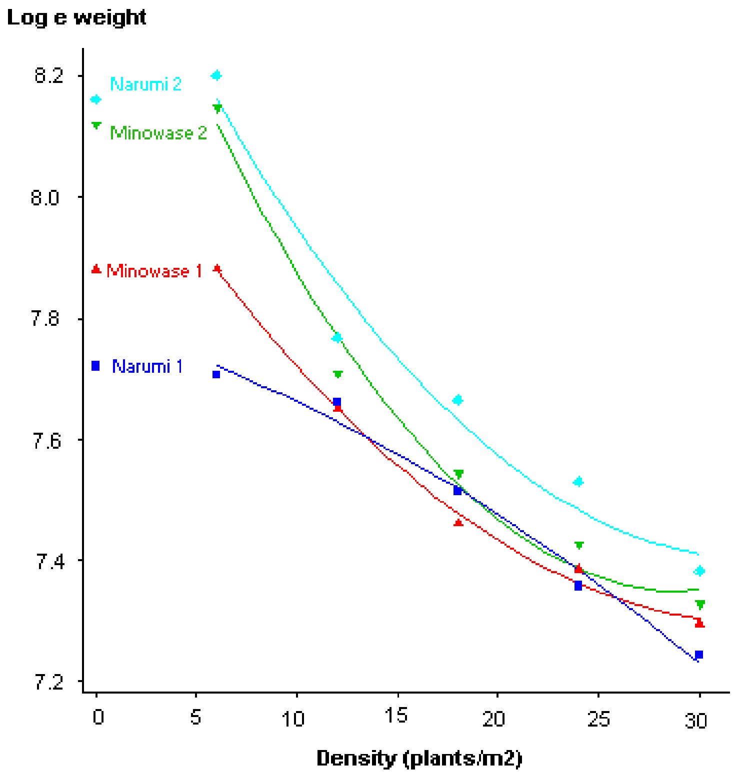

Figure 35: The effect of plant density and harvest time (1=65, 2=80 days after sowing) on root weights ($\log_e$) of Narumi and Minowase daikon (R^2 = 0.96).

65 DAS Narumi	**$y1 = 7.793 – 0.0102x – 0.000285x^2$**
65 DAS Minowase	**$y2 = 8.166 – 0.0524x + 0.000790x^2$**
80 DAS Narumi	**$y3 = 8.541 – 0.0698x + 0.001072x^2$**
80 DAS Minowase	**$y4 = 8.572 – 0.0841x + 0.001447x^2$**

Root length is influenced by harvest, variety and density effects with significant interaction with harvest and density. As to be expected, a delay in harvesting results in longer daikon roots. For example, Narumi harvested 65 days after sowing, planted at a density of 6 plants/m^2, had a length of 364.0 mm. Harvested later at 80 days after sowing, the root length was 499.7 mm. There was also a variety effect. Minowase recorded longer root lengths than Narumi with an average increase of 24% longer. With regards to density, daikon planted closer together results in shorter root lengths. Minowase harvested 60 days after sowing with a density of 30 plants/m^2 had lengths of 338.0 mm which increased to 552.5 mm when planted at 6 plants/m^2 (Figure 36). Table 60 shows the means of length and the slightly significant interaction between harvest and density. For any given density, root length increased with later harvest.

Table 60: The effect of plant density and harvest time (days after sowing) on root length (mm) of both Narumi and Minowase daikon.

Density (plants/m²)	65 DAS	80 DAS
6	473.2	560.9
12	424.0	435.0
18	371.4	382.4
24	332.9	338.9
30	292.4	296.1
Significance		
Harvest	0.013	
l.s.d. (p=0.05)	17.35	
Density	<0.001	
l.s.d. (p=0.05)	27.58	
Harvest * Density	0.018	
l.s.d. (p=0.05)	37.82	

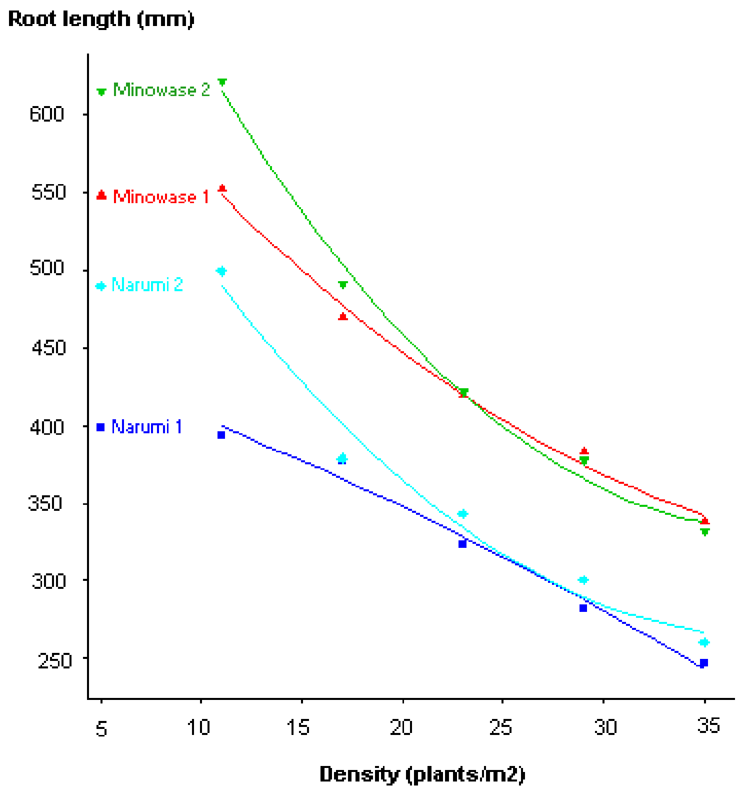

Figure 36: The effect of plant density and harvest time (1=65, 2=80 days after sowing) on root lengths (mm) of Narumi and Minowase daikon (R^2 = 0.98).

65 DAS Narumi $y1 = 429.2 – 4.67x – 0.051x^2$

65 DAS Minowase $y2 = 631.8 - 14.95x + 0.177x^2$
80 DAS Narumi $y3 = 600.9 - 20.34x + 0.307x^2$
80 DAS Minowase $y4 = 755.2 - 25.56x + 0.388x^2$

Diameter has significant main effects of harvest, variety and density. There was also a significant harvest by density interaction (Table 61). Maximum diameter was achieved at a density of 6 plants/m^2 at the second harvest. There were also variety effects with Narumi recording a maximum diameter of 100.0 mm.

Table 61: The effect of plant density and harvest time (days after sowing) on root diameter (mm) of both Narumi and Minowase daikon.

Density (plants/m^2)	65 DAS	80 DAS
6	75.1	94.9
12	70.5	74.8
18	63.3	70.3
24	57.1	63.4
30	51.5	56.9
Significance		
Harvest		<0.001
l.s.d. (p=0.05)		1.80
Density		<0.001
l.s.d. (p=0.05)		3.13
Harvest * Density		<0.001
l.s.d. (p=0.05)		4.23

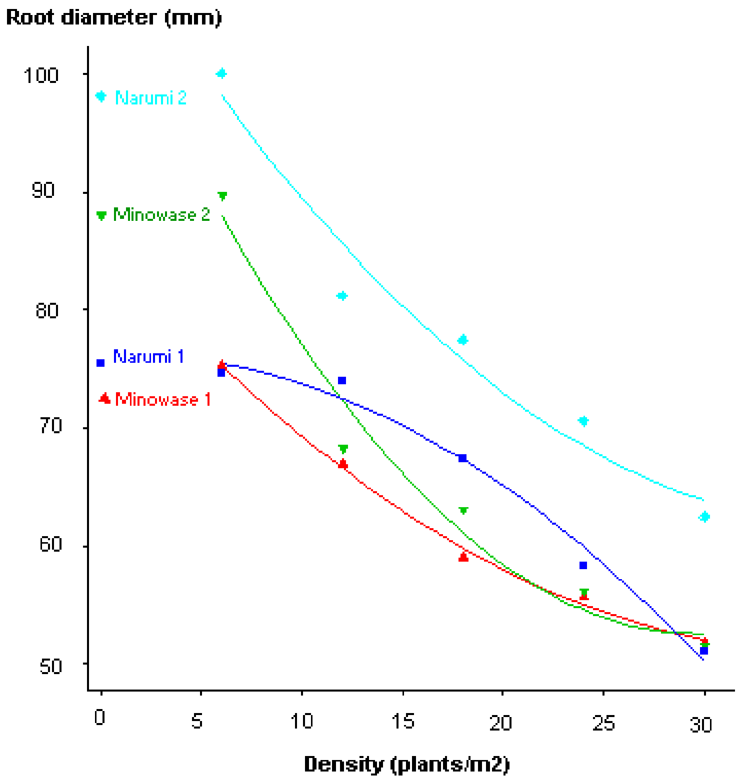

Figure 37: The effect of plant density and harvest time (1=65, 2=80 days after sowing) on root diameter (mm) of Narumi and Minowase daikon (R^2 = 0.95).

65 DAS Narumi	**$y1 = 76.22 + 0.069x – 0.0311x^2$**
65 DAS Minowase	**$y2 = 86.03 – 1.938x + 0.0269x^2$**
80 DAS Narumi	**$y3 = 113.26 – 2.739x + 0.0364x^2$**
80 DAS Minowase	**$y4 = 108.34 – 3.763x + 0.0635x^2$**

Pithiness, rots and blemishes and quality ratings

Variety and density significantly affected pithiness ratings (Table 62). Minowase had a higher severity of pithiness than Narumi. Generally, pithiness ratings increased as density decreased. Minowase planted at 6 plants/m^2 had a moderate to severe pithiness ratings while at 30 plants/m^2, pithiness decreased to slight to moderate (Figure 38). Similarly with Narumi, pithiness was higher at the lower densities than the higher densities. However, Narumi had only slight pithiness. At 65 days after sowing, Narumi had no density effects on pithiness as very little pithiness was recorded in this variety.

Table 62: The effect of plant density and variety on pithiness ratings (1 = none, 5 = very severe) of daikon roots

Density (plants/m^2)	Narumi	Minowase
6	1.37	3.65
12	1.13	2.99
18	1.17	2.80
24	1.09	2.70
30	1.08	2.35
Significance		
Variety		<0.001
l.s.d. (p=0.05)		0.13
Density		<0.001
l.s.d. (p=0.05)		0.15
Variety * Density		<0.001
l.s.d. (p=0.05)		0.22

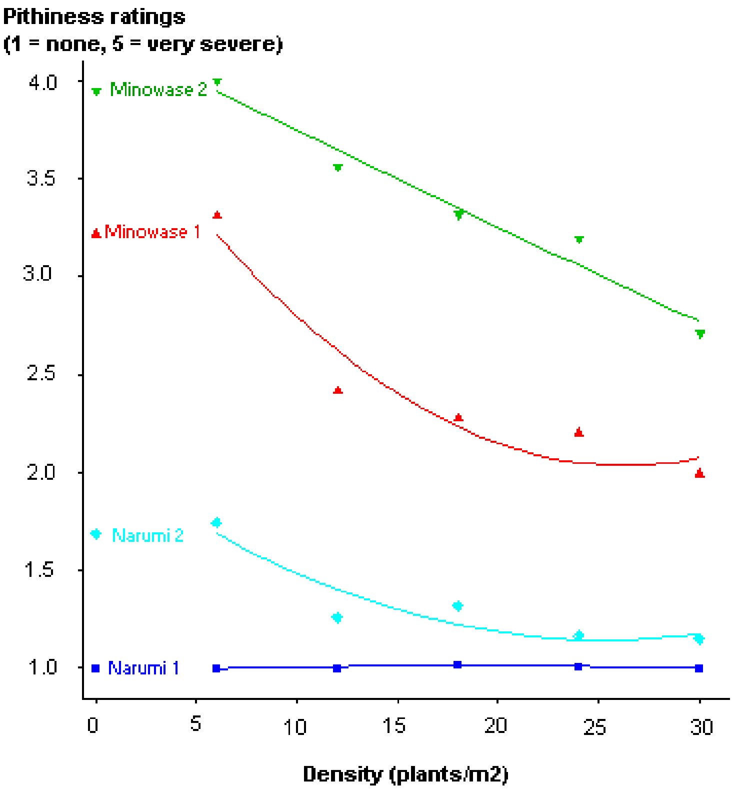

Figure 38: The effect of plant density and harvest time (1=65, 2=80 days after sowing) on pithiness ratings of Narumi and Minowase daikon (R^2 = 0.98).

65 DAS Narumi **$y1 = 0.982 + 0.0031x – 0.00008x^2$**

65 DAS Minowase $y2 = 4.010 – 0.1498x + 0.00284x^2$
80 DAS Narumi $y3 = 2.072 – 0.0730x + 0.00144x^2$
80 DAS Minowase $y4 = 4.254 – 0.0513x + 0.00006x^2$

There was no qradratic response of density on the ratings of rots and blemishes, hence the linear function (Figure 39). There was no interaction except for harvest by variety interaction (Table 63). Minowase had more severe rots and blemishes than Narumi for both harvests for any given density. Narumi harvested at 65 days after sowing recorded the lowest ratings of rots and blemishes with the lower densities recording higher rots and blemish ratings than the higher densities.

Table 63: The effect of harvest and variety on rots and blemish ratings (1 = none, 5 = very severe) of daikon roots

Harvest (DAS)	Narumi	Minowase
65	1.65	2.06
80	2.71	4.69
Significance		
Variety		<0.001
l.s.d. (p=0.05)		0.30
Harvest		<0.001
l.s.d. (p=0.05)		0.30
Variety * Harvest		<0.001
l.s.d. (p=0.05)		0.43

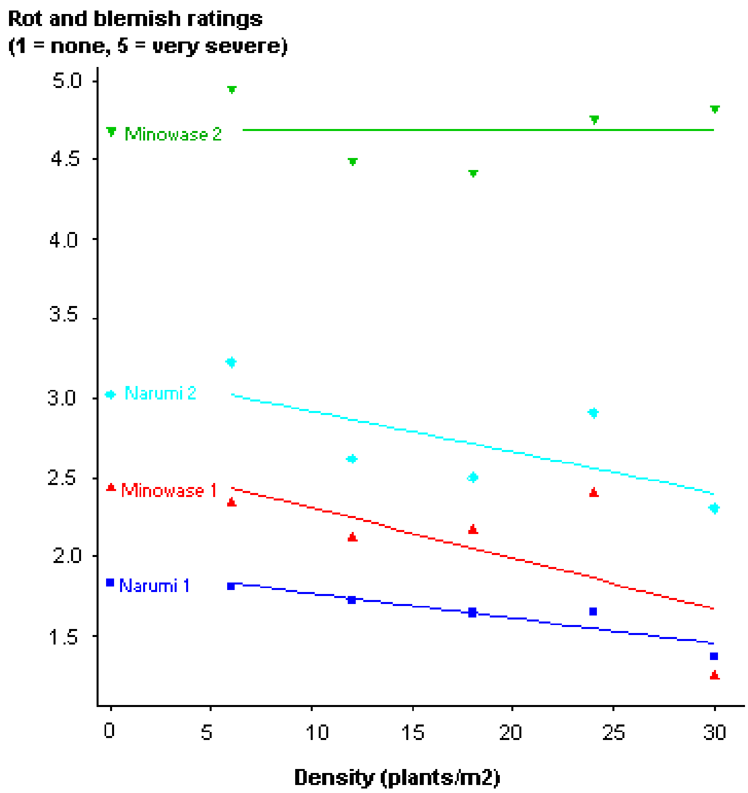

Figure 39: The effect of plant density and harvest time (1=65, 2=80 days after sowing) on rots and blemish ratings of Narumi and Minowase daikon (R^2 = 0.95).

65 DAS Narumi	**y1 = 1.930 – 0.158x**
65 DAS Minowase	**y2 = 2.625 – 0.0317x**
80 DAS Narumi	**y3 = 3.175 – 0.0257x**
80 DAS Minowase	**y4 = 4.682 + 0.0003x**

Quality ratings had no significant density effects and no interaction occurred except for harvest by variety (Table 64). Minowase from both harvests showed quality ratings between good marketability and reject, while Narumi had a better quality ratings of good marketability at both harvests.

Table 64: The effect of harvest and variety on quality ratings (1 = excellent export standard, 5 = reject) daikon roots

Harvest (DAS)	Narumi	Minowase
65	3.31	3.70
80	3.11	4.86
Significance		
Variety		<0.001
l.s.d. (p=0.05)		0.23
Harvest		0.002
l.s.d. (p=0.05)		0.23
Variety * Harvest		<0.001
l.s.d. (p=0.05)		0.33

For export markets, particularly Taiwan, there are preferred weight, length and diameter specifications. The preferred specifications for daikon exported to Taiwan are 1000 – 1500 g root weight, 280 – 300 mm root length and 80 – 90 mm root diameter.
With regards to root weight, the recommended densities and harvest time to achieve the desired export weight is 6 plant/m^2 at 65 DAS, 12 plants/m^2 65 and 80 DAS and 18 plants/m^2 at 80 DAS. However, to achieve higher total and marketable yields, a density of 18 plants/m^2 (14.5 cm x 29 cm) harvested at 65 days after sowing is better for both varieties.

To achieve a recommended root length of 280 – 300 mm, a density of 30 plants/m^2 at both harvests is suitable. However, at this high plant density and at the later harvest, yield and quality are reduced. Diameter of 80 – 90 mm was also difficult to achieve from the densities used. All treatments except for a density of 6 plants/m^2 harvested 80 days after sowing, were all under 75 mm in diameter. Further research needs to done to determine a suitable variety, density and harvest time for the summer period to achieve the preferred export standards for root length and diameter. From this trial, the majority of daikon were considered too long and too narrow for export market which could have been caused by the time of year the trial was grown, the fertilisers applied and the varieties grown.

Density did not have any major effect on pithiness, rots and blemish and quality ratings. These attributes were mainly affected by variety and harvest. Pithiness occurred more severely in Minowase than Narumi in both harvests, while rots and blemishes occurred more in those roots that were harvested later. Quality deteriorated rapidly for Minowase harvested 80 days after sowing, while Narumi harvested at both harvest times had good marketability.

In conclusion, daikon can grow very rapidly during the summer months. Both varieties grew very large when harvested at 80 day after sowing which suggests the later harvest was not suitable for both varieties at this time of year. With regards to yield, a density of 17 – 22 plants/m^2 is suitable for both varieties at an earlier harvest (65 DAS). This density produced root lengths of 309 – 337 mm for Narumi and 392 – 435 mm for Minowase and root diameters of 62 – 64 mm for Narumi and 56 – 62 mm for Minowase.

7.0. NEW EXPORT VEGETABLES STUDY TOUR TO JAPAN

As part of the Developing New Export Vegetables project, a study tour to Japan was completed from the 9 to 16 December 2001. The tour delegates consisted of two Department of Agriculture staff, Ms Vynka McVeigh, Project Officer, and Dr. Soon Chye Tan, Principal Research Scientist, and one industry representative, Mr Jeff Hastings of Xylem International.

Following is a summary of the study tour report which is located at Appendix One. The summary will include details of the company's visited, results of discussions, and the outcomes and findings of the study tour. The recommendations made by the study tour report are found at section '12.0. Recommendations' of this Final Report.

7.1. Objectives

The objectives of the study tour were:

- To visit burdock growers to determine their growing and handling methods for burdock and to gather information on crop agronomy.
- To visit vegetable importers, wholesalers and processors to discuss prospects of exporting fresh and/or semi-processed burdock to Japan.
- Visit wholesale market and inspect local and imported burdock quality and determine wholesale price.
- Obtain up-to-date monthly volume throughput and wholesale price of local and imported burdock particularly from China and Taiwan.
- Identify other potential export vegetables for the Japanese market.

All objectives were achieved. One of the major conclusions that was reiterated during our discussions with growers, importers and processors was that China in recent years have become very competitive in the Japanese market. Not only have Chinese imports of burdock increased but other vegetable imports from China have increased as well.

As a result, Western Australia may not be able to compete against China in the Japanese fresh burdock market. At the time the study tour report was written, there was still a potential to export a semi-processed burdock product to Japan. This opportunity was based on the assumptions that a shelf life of 20 days or more can be achieved from the semi-processed burdock product, that burdock flavour and texture is as good as the Japanese and Chinese products and that the price of these products are competitive.

A detailed economic analysis of exporting minimally processed burdock is discussed in section 8.0. Unfortunately, this study indicated that the opportunity of exporting a semi-processed burdock product to Japan was not viable based on the figures and information received from the study tour and from a local vegetable processing company in Perth, Western Australia.

7.2. Summary of discussions

7.2.1. Growers

Two growers of burdock were visited during the tour. Mr Hideo Takishima was a small conventional burdock grower and rotated his crops with carrots and daikon. Mr

Takishima discussed the importance of good soil structure to grow good quality burdock. Six months before planting burdock, sorghum is ploughed into the soil to increase organic matter and improve soil structure. Mr Takishima believes that practising this type of green manure, the burdock becomes 'softer' and has better texture.

Eighty percent of all burdock grown in Japan is the variety Yanagawa Riso, however, the hundred day burdock or Hyakunichi gobo is becoming popular with consumers because it is shorter and easy to handle.

The second grower was an organic grower who grew mainly burdock, carrot and daikon. He has a family business and operates ten hectares of land which is slightly larger than other organic growers. From Mr Koshikawa's experience, organic burdock does not go brown or discolour after cutting. He believes that conventionally grown burdock has a lot of nitrates in the roots. The nitrates reduce enzyme production and the health of the plant which in turn causes more discolouration than the organically grown produce.

The main problems with organic growing are pests and weeds. He uses pheromones, Bacillus thuringiensis (biological insecticide) and companion planting using garlic for insect control.

Mr Koshikawa said that yields using organic methods tend to be lower than conventional methods, but organic products receive a price premium of 20%. It has taken Mr Koshikawa ten years to reach this point of producing such high quality vegetables. He has now established a good reputation and brand to supply high quality organic produce and he can sometimes achieve prices that are 2 – 3 times higher than conventionally grown products.

7.2.2. Agricultural contractor

Due to the small area of farms in Japan and with the majority of growers having multiple incomes, many growers use agricultural contractors. Mr Tammio Takayangi is an agricultural contractor whose operations includes planting and trenching of burdock, lifter ploughing for burdock, ploughing and levelling of paddy field, ploughing and harvesting sweet potato and mowing uncultivated fields. Mr Takayangi, his son and his brother run the family business.

Mr Takayangi owns a Kawabe four row chain trencher, one of only two in Japan, a rotary trencher and over twenty tractors including a 140 HP Massey Ferguson which is used to pull the four row trencher. The four row trencher has better balance, cultivates the soil to a finer tilth and can work more area in less time than the two row chain trencher or the rotary trencher. However, the chain trencher has higher maintenance costs as the chain needs to be replaced often. The four row chain trencher is valued at about ¥ 4 million or A$62,000.

Mr Takayangi has regular customers with property size ranging from 0.5 – 3 hectares. He has a few larger growers with 12 – 20 hectares. Mr Takayangi is paid by the area he is working and payment is usually made at the end of the year. He charges ¥ 70,000 to ¥100,000 (A$1,080 – A$1,530) per hectare of ploughing.

7.2.3. Processors

As part of the study tour, four burdock processors were visited. Shonan Company Ltd. was a large processing company that mainly cut burdock into kimpira cut or stick-like cut. Shonan was established 11 years ago and sources burdock from all over Japan such as Kagoshima, Aomori, Hokkaido and Chiba prefectures. Shonan also imports burdock from China. The company's customers actually prefer Chinese burdock as opposed to local product because the price is low and quality is reasonably good. Shonan has established relationships with particular Chinese importers from which they buy fresh Chinese burdock. Shonan can source burdock all year round either locally or from China or Taiwan.

The contract price of the fresh burdock varies depending on which prefecture the burdock is grown. The bought price (including transport costs) from growers in Kagoshima is ¥160/kg and ¥120/kg from Hokkaido. Chinese burdock delivered to the factory can range from ¥50 - ¥120/kg. According to Mr Matsuo, Taiwan sometimes sell fresh burdock to Japan below costs because China is so competitive. Shonan sells their 150 gram burdock and carrot packs for ¥100- ¥150 per pack or ¥660 - ¥990/kg (A$1.50 - $2.20 per 150 grams or $10.00 - $15.00/kg)

When discussions about Australian burdock opportunities arose, Mr Matsuo said that the supply of burdock is excessive all year round, therefore for Australia to compete, a market niche would be needed. He said this would be difficult under the current market climate, particularly with fresh burdock.

Kanehatsu Foods Company Ltd., located in Nagoya, was a larger processor than Shonan, however, no operations were shown. Kanehatsu either buy fresh burdock from China or buy the semi-processed burdock from an associated company that buys fresh burdock from China. Kanehatsu then use the semi-processed product, usually kimpira cut, in mayonnaise salad mixes. Fresh burdock from China is bought all year round for about ¥170/kg (A$2.60). The highest demand for processed burdock in Japan is March – May.

The third processor visited was Osaka Delica Foods Corporation. The company processes fresh vegetables and repacks processed vegetables that are bulk-packaged and distributes to food service, retail and delicatessen companies. Osaka Delica not only processes burdock but other vegetables such as onion, daikon, kabocha, carrot, capsicum and even aloe vera for the food service industry.

The bulk-packaged processed burdock that Osaka Delica buys consists of 5 kg of burdock with 2 kg of water. The company pays for the net weight, not the weight of the water. Prices of bulk-packaged sasagaki cut burdock from different origins are as follows:

Local burdock cut in Japan	¥260 per kilo	A$4.00/kg
Chinese burdock cut in Japan	¥150 per kilo (approx.)	A$2.31/kg
Chinese burdock cut in China	¥100 per kilo (approx.)	A$1.50/kg

Osaka Delica are currently looking at setting up a processing plant in China to vacuum cook burdock and other vegetables. The company recognises there can be a risk with bad quality burdock but it is cheaper to set up a processing plant in China than in Japan.

Proximity to Japan is also an advantage as it only takes 4 – 5 days to sea freight product from China.

The fourth processing company visited was Sato Restaurant Systems Company Ltd. Sato act as a food distributor to major restaurants in Japan. They also have their own restaurant chain. Sato deal with sasagaki cut burdock, kabocha and other vegetables depending on customer demands. Sato is buying sasagaki cut burdock from local processors for ¥90 per 150 gram net pack (A$1.40) or ¥600 per kilo ($A9.20/kg). This buying price is quite high which may be due to their small volume and package size. The processed burdock is from China. Sato buy about 181,400 packs (150 grams) per year or about 27 tonnes per year.

7.2.4. Importers/Wholesalers

During the study tour two importers, Meika Corporation and S. Ishimitsu and Company Ltd. and one wholesaler, Daika Osaka Seika Co. Ltd. were visited. Meika Corporation is one of the largest fresh fruit and vegetable importers in Japan and part owns a processing company called Central Foods. The movement in processing is to set up operation in China with the view to leave the wastage in China as it is expensive to remove the waste product produced with processing in Japan. China is a major produce supplier for retail/supermarket as well as food service. China is already supplying fresh cut vegetable products. The demand for burdock is mainly in winter which is supplied by China, but Meika import burdock all year round. Meika buys fresh burdock from China at ¥90 per kilogram landed at the market.

Ishimitsu is an importer of food and non food items. Ishimitsu is working with processed burdock in sasagaki cut in conjunction with Osaka Delica. Ishimitsu's price structure for burdock processed into kimpira cut is as follows:

C & F from China	¥ 50/kg (US$400/tonne)
Price to processors	¥ 70/kg
Actual processors price counting wastage	¥ 80/kg
Price of kimpira cut, bulk pack	
Good volume purchase	¥ 170/kg
Medium volume purchase	¥ 200/kg
Small volume purchase	¥ 350/kg

Sasagaki cut price would be 20% higher.

As part of the study tour we also visited the Osaka Wholesale Markets. There we met with staff of Daika Osaka Seika and viewed the burdock auction within the markets. Daika Osaka Seika is a primary wholesaler that auction vegetables to secondary wholesalers. Daily volume of fresh burdock handled at the Osaka Wholesale Market has declined to 53 tonnes from over 200 tonnes a couple of years ago. The reason for this is that the Osaka wholesale market does not deal with imported products and there have been dramatic increases of imported burdock from China.

Current prices of imported burdock are US$3 – 5.00 / 10 kg (¥0.22 – 0.37 per kg) carton depending on specification and quality. Local burdock price is ¥120 - ¥130 / kg depending on specification. As a general rule, if the product is 20 – 30% cheaper than local product then trading companies will buy the imported product.

7.2.5. Supermarkets

Various supermarkets were visited such as Jusco, one of the leading supermarket chains in Japan, and Daimaru. Prices of burdock did not vary all that much between supermarkets. Packaged fresh burdock (two washed halves) from China was ¥198 each. The same product from Japan was ¥398 each. The majority of the burdock seen in the supermarket was fresh burdock. Even in the pickled vegetable section of the Jusco supermarket, pickled burdock was not seen. Pickled daikon appears to be more popular as there were many forms of pickled daikon. Frozen kimpira cut burdock was seen in the freezer section of the Jusco supermarket.

7.3. Commercial implications and opportunities for Australian burdock into Japan

As part of Mr Jeff Hastings participation in the study tour and his contractual obligations, Mr Hastings has written a report on the study tour from his point of view as an industry representative.

Mr Hastings also has the view that Australia is not competitive in the supply of fresh burdock in Japan as China is too great a threat in its ability to supply high quality fresh burdock at a very cheap price. However, the report does suggest that Australia has a real opportunity to produce and supply a range of semi-processed burdock (kimpira or sasagaki cut) directly into the food service and wholesaling sectors of the Japanese market. Mr Hastings also outlines the assumptions and success factors of such an industry, if it were to occur. Those factors are as follows:

1. Securing and implementing the technology necessary to provide at least 28 days shelf life of cut burdock. This allows the burdock to be sea freighted, maximising our competitiveness.
2. Commitment from one or more Australian processing companies prepared to work with growers and grower support organisations will be essential for the development of a burdock industry in Australia. They will need to be the ones that develop supply relationships with companies in Japan, send product samples etc. and gradually establish the capacity and confidence to supply this semi processed product over the long term.
3. Further production trial work throughout different growing regions to prove up all agronomic parameters and maximise grower returns and product quality.
4. Further financial analysis is required in determining accurate production and processing costs in Australia and distribution/logistics costs once landed in Japan for semi processed burdock to ensure our competitiveness.

5. Careful and purposeful marketing of Australian burdock as an industry, and the advantages that we can offer the Japanese market.
6. Positioning Australian semi processed burdock in an effective distribution system within Japan, such that cool chain maintenance can be assured and maximum shelf life and product quality can be obtained.

8.0. PROCESSING OF FRESH-CUT BURDOCK

The Department of Agriculture approached Food Science Australia (FSA) in Werribee, Victoria and discussed the prospects of conducting research on the processing of fresh-cut burdock. FSA responded with a project proposal and the trials were completed in April/May 2001. The aim of the research done by FSA was to conduct a preliminary observation on fresh-cut burdock and provide a written report on the findings, including conclusions on likely factors that limit the shelf-life together with recommendations for remedial actions.

In April 2001, 15 kg of burdock from two different sources were sent to Ms Mala Gamage of FSA. Yanagawa Riso and Takinogawa Long were the varieties sent from the Department of Agriculture burdock trials. Due to the lack of burdock available for the trials, burdock was also sourced from Sumich Vegetable Exporters. Unfortunately the burdock variety was not known.

Below is a summary of the report written by Ms Mala Gamage and Mr Thu Vu of FSA. The full report can be located at Appendix Two.

8.1. Objectives

The objectives of the study conducted by FSA was to identify the possibilities of processing burdock into a fresh-cut form suitable for transport to Japan. This was done by conducting three experiments. Experiment one was simply observing browning of burdock roots at ambient temperatures after three dipping solutions were used. Experiment two involved using a combination dipping solutions and packaging. Experiment three used dipping solutions and barrier bags either vacuum-sealed or sealed with normal air inside and stored for 10 days at 4°C.

8.2. Experiment one

In this experiment, colour change of burdock pieces at room temperature (22°C) was studied. Burdock lengths of six centimeters were cut into quarters, longitudinally. One quarter was exposed to air at ambient temperature. The second quarter was dipped in either distilled water, ascorbic and citric acid for 10 minutes then exposed to air at ambient temperature. The third quarter was dipped in the solutions for 20 minutes and exposed to air at ambient temperatures. The fourth quarter was left in the solutions at ambient temperatures.

The experiment was duplicated on the same day using a second burdock root (variety unknown). The colour of the burdock pieces was recorded using a Minolta colorimeter at 5, 35, 65, 155 and 295 minutes after exposure to air. The colour was also observed visually and recorded for all treatments.

A difference in browning pattern was observed on the inner cut surface and peel side of burdock piece. Therefore the colour of the peel side and the inner side were measured separately (refer to Figures 1 and 2 of the full report in Appendix 2). Hue value was calculated using a and b values obtained with the Minolta Colorimeter. A hue value of 100 represents a yellowish white colour and a decrease in hue value was noted with the browning of samples. At a hue value of 80 – 85 the browning was very prominent and the colour became unacceptable when hue values were less than 95. At this stage the colour was noted as light brown.

Except for samples treated with ascorbic acid at pH 2.5, all other treatments reached a hue value below 95 after 35 minutes exposure to air. Colour change on the inner surface was slower than on the skin side. The hue value of the cut surface in treated samples showed distinctive differences from the control samples during 5 to 295 min exposure periods. Samples treated with ascorbic acid at pH 2.5 for 10 and 20 min showed the best colour retention when compared to all other treatments. The difference in dipping times was not very prominent.

8.3. Experiment two

The burdock sample used for this experiment was of very poor quality as the tissues were brown and dry. Four 6 cm long pieces were cut from each burdock root and were marked 1 to 4 starting from the crown end (leaf bearing end) of the root. Each piece was then cut into quarters along the longitudinal axis and dipped in dipping solutions described in Table 65 for 20 minutes. This was repeated for all four pieces obtained from one root. After removing from the dipping solution, burdock pieces were packed in bags. Each bag contained four quarters, one from each piece (no. 1 to 4). This procedure was repeated for all twelve treatments.

Table 65: Treatment combinations used in experiment two.

Treatment No.	Dipping solution	Type of packaging	Storage temperature °C
T1	1% Vitamin C	Barrier bag	1
T2	2% Vitamin C	Barrier bag	1
T3	Control – distilled water	Barrier bag	1
T4	1% Vitamin C	Barrier bag	4
T5	2% Vitamin C	Barrier bag	4
T6	Control – distilled water	Barrier bag	4
T7	1% Vitamin C	Polyethylene bag	1
T8	2% Vitamin C	Polyethylene bag	1
T9	Control – distilled water	Polyethylene bag	1
T10	1% Vitamin C	Polyethylene bag	4
T11	2% Vitamin C	Polyethylene bag	4
T12	Control – distilled water	Polyethylene bag	4

This experiment failed because of the poor quality of the burdock roots. However, the visual observations showed that when cut burdock was stored in polyethylene bags, the roots first turned pink and then brown during storage. The pink colour development was more prominent with the ascorbic acid treated samples. Colour retention was good when stored in barrier bags.

When comparing the storage temperatures, storage at 1°C resulted in browning for all samples when compared to the samples stored at 4°C for 10 days.

8.4. Experiment Three

Burdock roots (cv. Takinogawa Long) were peeled using a kitchen peeler under water and then submerged into dipping solution 1 (Table 66) until further processing. The peeled roots were then cut into 6 cm long pieces and fed through a food processor (Anlikaer, Switzerland) which cut the pieces into julienne strips (3-4 mm wide x 1-6 cm long). The julienne burdock strips were then put into dipping solution 2 (Table 66). After dipping the burdock strips, they were drained for one minute and packed into barrier bags. The barrier bags were purchased from Cryovac – W.R. Grace Australia Ltd. with the following specifications:

- size: 180 mm x 305 mm
- structure: EVA-PVdc-EVA
- thickness: 50 micron
- OTR: typically 25 mL/m^2/24 h/atm
- WVTR: typically 10-15 ml/m^2/24 h/atm

The bags were either sealed with vacuum or air. Samples were vacuum packed using a vacuum packing machine (Webomatic, Germany) at 0.8 bar vacuum and heat sealed. Samples packed in air were sealed using a heat sealer (Venus, Australia). Samples were stored at 4°C and evaluated on 4, 8 and 10 days for colour and texture using the Kramer cell with Instron (series 4400, USA).

Table 66: Dipping solutions used in Experiment three.

Treatment	Dipping solution 1	Dipping solution 2	Type of packaging
Control 1 – air	Distilled water	Distilled water	Barrier bag + air
Control 1 – vacuum	Distilled water	Distilled water	Barrier bag + vacuum
Control 2 – air	0.35% citric acid	Distilled water	Barrier bag + air
Control 2 – vacuum	0.35% citric acid	Distilled water	Barrier bag + vacuum
T1000 – air	0.35% citric acid	1.0% Ascorbic acid	Barrier bag + air
T1000 – vac	0.35% citric acid	1.0% Ascorbic acid	Barrier bag + vacuum
T2000 – air	0.35% citric acid	2.0% Ascorbic acid	Barrier bag + air
T2000 – vacuum	0.35% citric acid	2.0% Ascorbic acid	Barrier bag + vacuum
T2025 – air	0.35% citric acid	2.0% Ascorbic acid + 0.25% citric acid	Barrier bag + air
T2025 – vacuum	0.35% citric acid	2.0% Ascorbic acid + 0.25% citric acid	Barrier bag + vacuum
T2035 – air	0.35% citric acid	2.0% Ascorbic acid + 0.25% citric acid	Barrier bag + air
T2035 - vacuum	0.35% citric acid	2.0% Ascorbic acid + 0.25% citric acid	Barrier bag + vacuum

In terms of colour, samples packed under vacuum and air both showed a similar trend in hue value change during storage at 4°C for 10 days.

The two controls, which were only treated with a water dip (control 1) or 0.35% citric acid (control 2) after peeling showed a hue value lower than the treatments which had a second dipping treatment to prevent browning. The hue value showed a slight increase on day 4 and remained constant during storage.

Among the samples that had a second dip with 2% ascorbic acid or a combination of 2% ascorbic acid and citric acid, had hue values in the same range and the values remained above 95. The samples treated with (second dip) 1% ascorbic acid had a hue value at or below 95 and was slightly lower than the samples treated with 2% ascorbic acid or a combination of 2% ascorbic acid with citric acid.

Texture of the burdock pieces did not show a definite trend under the conditions studied in this experiment. Further replication and detailed study on texture analysis of this product is necessary before comparing the treatment effects.

8.5. Discussion

Observations made in this study on fresh cut burdock shows that the browning was very rapid after peeling or cutting of the root. Although the results of this study show that storage of peeled roots in water was superior to storage in 0.35% citric acid solution, the effect of this pre-dip and its duration has to be studied in detail. This will provide information that can be useful in handling pre peeled roots, under a commercial processing situation where delays are usually encountered.

Packaging with or without vacuum did not show much effect on the colour of burdock. This may be due to the high barrier properties of the bags used in experiment three. A balance between prevention of browning and anaerobic respiration is important for prevention of flavour changes and to retain the microbiological safety.

8.6. Conclusions

Colour of fresh cut burdock can be retained for a short period (2.5 hours) under ambient conditions, using a 2% ascorbic acid dip. However, the retention of colour during storage depends on the barrier properties of the packaging material used and storage at refrigerated temperature (4°C). In this study, 2% ascorbic acid treatment together with storage in barrier bags has enable the storage of burdock pieces without significant colour change for 10 days at 4°C. Taste and microbiological quality of the stored product were not investigated in this study.

Food Science Australia recommended further studies on fresh cut burdock, which are outlined in the full report (Appendix 2). However, due to the findings of the economic analysis of the semi-processed burdock, no further work was done.

9.0. AN ECONOMIC ANALYSIS OF SUPPLYING WESTERN AUSTRALIAN SEMI-PROCESSED BURDOCK TO JAPAN

9.1. Introduction

Findings gathered from the study tour to Japan indicated that exporting fresh burdock into Japan was not a viable option for Western Australia, mainly because of the marginal prices received for imported burdock and strong competition from China. The study tour also investigated the prospects of exporting a semi-processed burdock product to Japan. This option initially seemed favourable providing that quality burdock could be grown and a shelf life of about 21 days of the value added product could be achieved.

With these assumptions, an economic analysis of supplying semi-processed burdock to Japan was conducted based on figures and information obtained from processing companies in Japan as well from a local vegetable processing in Perth, Western Australia. Mr Alexander Rahmig compiled the information in a report which is located in Appendix Three. Below is a summary of the full report. Recommendations from the analysis will be outilined in section '12.0 Recommendations', of this Final Report.

9.2. Japanese market

Japan is the largest market for burdock worldwide and has a value of around ¥40 billion or A$573 million at Japan's wholesale markets. Japan has a consumption of approximately 230,000 – 300,000 tonnes of burdock each year. On average the Japanese consumer eats approximately 58 kg of fresh vegetables per annum. Included in this is 2 kg of burdock consumed per person per year (Gartrell, Pasqual and Tan, 1997).

Food consumption in Japan are affected by three significant trends; one is the growing consumption of processed food, two is the westernisation of the Japanese diet and three is the response of the first two trends, Japan is experiencing a health food boom (Rahmig, 2002). With more working women, busier work schedules for working people and more people living alone has meant less time to prepare meals. Therefore, Japanese consumers are looking for faster and more convenient ways to eat. This has resulted in increased sales of processed foods such as microwave dinners and other ready to heat and eat meals. This trend would support the export of semi-processed burdock to Japanese market because the use of this product helps the customer to reduce preparation time and reduce waste for both processors and consumers.

Westernisation could be a threat to the use of burdock in the Japanese diet. However,burdock is used in the fast food industry where burdock is used in Japanese style hambugers. This use would only compensate for part of the decreasing consumption of burdock in traditional Japanese diets. The general consumption of burdock in Japan is slightly decreasing (Rahmig, 2002).

In 2001 Japan imported approximately 88,283 tonnes of burdock. This does not include the processed burdock packed and imported with other processed vegetables such as carrots. China is the largest burdock supplier for the Japanese market with a share of 76,565 tonnes or 86% of the total imported quantity in 2001. The other 13% of the imports are sourced from Taiwan and only 1% comes from countries like Vietnam, Korea, Indonesia, France, USA and Australia. The burdock imported from Australia is insignificant and was approximately 185 tonnes or 0.2% of the total quantity imported in 2001 (Rahmig, 2002).

From the 88,283 tonnes of burdock imported to Japan, a share of 7,600 tonnes or 8.6% was imported in a processed form in 2001. This is an increase of 12% compared to 2000 in which approximately 6,768 tonnes of processed burdock were imported to Japan. (Japan Tariff Association). China recorded a rapid market share growth over the last three years from 78% or approximately 60,389 tonnes in 1999 to a market share of 86% in 2001. Due to competitive prices and increasing quality of Chinese burdock this trend is likely to continued. The production of burdock for export to Japan is concentrated in the Laiyang, Laixi, Cangshan, Jinan, Taian, Pizhou, Fengxian and Xuzhou regions of China.

The main reasons for the rising imports into Japan are the improving quality of Chinese products and the following circumstances in Japan (Hastings, 2002):

- Increasing land prices due to the expansion of Japan's cities
- The rapid aging of the agricultural population
- The rural youth don't want to take over the farms
- Pressure on domestic prices, because of cheaper imports
- Food service sector and processors tend to invest in off-shore joint ventures for the production and processing of burdock

9.3. Landed price per kilogram of semi-processed burdock

Based on figures collected from various sources (refer to Appendix 3 for full details on landed price per unit), the landed price of one kilogram of kimpira cut (matchstick cut) burdock is approximately A$8.69 per kilogram. The processing involved vacuuming packing the semi-processed burdock into one kilogram bags.

This price would not prove profitable if the achievable price at the Tokyo wholesale markets is in a range from A$4.00 – A$6.50 per kilogram. This price indication was taken from the *New Export Vegetable Study Tour to Japan* report completed in December 2001. However, the only way to get an indication or quotation for semi-processed burdock from Western Australia is to send a sample of the product to a Japanese importer/processor. The criteria for the quality assessment are texture, colour and flavour. These criteria and the current supply and demand determine the achievable price for the product.

The landed price calculation shows that the major part of the cost structure is direct processing and packaging costs. This part makes up approximately 63% (A$5.52 per kg) of the total landed price. For Australian semi-processed burdock to become profitable and competitive, the emphasis should focus on the processing and packaging costs. The best opportunities for reducing costs and making savings are in this stage of production. For example the costs of skinning and trimming are responsible for nearly half of the direct processing of burdock. In the end this makes up A$2.70 of the final saleable product.

Jeff Hastings of Xylem International Pty Ltd. provided the following costs for two alternative methods of processing burdock. These costings are based on small scale commercial testing but do claim much lower processing costs than estimated in the current study.

The first alternative is to apply edible coatings to fresh cut burdock. The second option is to use the IQF-method (Individual Quick Frozen). The costs for these alternatives is suggested to be A$0.58 per kg and A$0.63 per kg respectively. This source further mentioned that the recovery of processed burdock is 74% compared with approximately 61.7% used in this analysis. The figures were based on labour input of forty man days to produce 20 tonnes of IQF product. The market price for frozen burdock and the market acceptance of burdock with edible coatings need to be investigated before any detailed assessment of the feasibility of exporting these products is made.

9.4. Conclusion

The Japanese market for fresh burdock is very hard to penetrate for the Australian vegetable industry. China is well positioned with increasing quality and low prices.

The opportunities for a semi-processed product from Australia are also limited. The landed price per unit calculation shows a landed price per unit of A$8.69 per kilogram. With a focused price range of A$4.00 - 6.50 at the Tokyo wholesale markets the enterprise would not be profitable.

Mechanisation and economies of scale are possibilities to reduce the processing costs significantly. A cost reduction of 50% would result in a landed price per unit of A$5.43 per kilogram. Even then, the enterprise would still not prove profitable, given that the exporter/processor and importer margins are not included in this analysis.

10.0. ASSESSMENT OF OTHER POTENTIAL EXPORT VEGETABLES FOR WESTERN AUSTRALIA

Over the life of the project, less research was conducted on daikon and burdock due to unfavourable market pressure in Japan. During the last year of the project, other potential export vegetables for Western Australia were investigated. Four export vegetables were chosen as having potential in Western Australia's growing conditions. Those vegetables were: Japanese taro, Japanese yam, vegetable green soybean (Edamame) and Japanese broad bean (Soramame).

Two small trials of Japanese taro were planted in October 2002 at Medina Research Station and Manjimup Horticultural Research Institute. The trials were strictly observation trials to determine if Japanese taro could be successfully grown at the two sites. Details of the trials can be found at section 10.2. Information such as production in Australia, export market potential and growing potential in WA was gathered for the other vegetables as well as Japanese taro. This section covers the information obtained for the four potential export vegetables and the details of the Japanese taro plantings.

10.1. Japanese taro (Sato imo)

Japanese taro (*Colocasia esculenta* var. *antiquorum*) is native to South-central Asia and is a member of the Araceae family. It is primarily grown for the corm or swollen stem base (Figure 40). It is known as sato imo in Japan.

C. esculenta var. *esculenta* or the dasheen type taro produce larger primary corms which are popular among Pacific countries. The Japanese market has the greatest potential for sato imo but this market prefers the eddoe type or small corms.

Sato imo usually takes about 6 – 10 months to grow depending on climactic conditions. Although it is mainly grown in tropical and sub-tropical areas of Australia, it can tolerate cooler temperatures of the south. Sato imo is propagated vegetatively and prefers a well drained, fertile soil. It is a warm temperate crop (15°C minimum, 25°C - 30°C for maximum growth), usually planted in October/November and harvested April/May. Sato imo does not tolerate wind or frost during the growing period (Hicks, 2002).

10.1.1. Production in Australia

Australian taro producers from Queensland, New South Wales and Northern Territory are becoming more focused on exporting taro with the assistance of a project jointly funded by Rural Industries Research Development Corporation, Central Queensland University and NSW Agriculture. The project is looking to develop product specifications, determine suitable production and postharvest methods and to facilitate the development of export supply chains (Newman, 2003) Although, Western Australia is not part of the project, information can be sought from the project when released and can be adapted to WA conditions.

Taro is sold mainly through specialty agents in Brisbane, Sydney and Melbourne. Taro prices are around $3-4/kg for the larger pacific variety corms. However, there is an increase in demand for smaller corms (Chay-Prove and Goebel, 1999).

Figure 40: Japanese taro in Japan (Source: Vinning 2002a)

10.1.2. Export market potential

Lee (1996) and Vinning (1995) suggested that sato imo has potential to develop a fresh export market. Japan currently imports more than 25,000 t of fresh taro with a further 60,000 t imported frozen. The majority of taro imported to Japan is sourced from China, but there is a window of opportunity for Australian producers from June through to August (Newman, 2003)

Planting area and production of sato imo in Japan has decreased over the past five years with a slight increase in 1999 (Figure 41). Consumption of sato imo in Japan is currently at 3 kg/person/year (Otsubo 1996) and is increasing due to use in Japanese restaurants and consumer awareness in dietary fibre (JETRO 2001). Therefore imports have increased and the trend is likely to increase further.

In 2000, China was the largest importer of fresh sato imo into Japan at 20,345 t (99.9% of total taro imports into Japan) fetching a price of ¥51/kg (Nguyen, 2001). Monthly import data shows a seasonal decrease in throughput in May and August with also an increase in price (White, 2001). This coincides with Australian production with harvesting occurring from April to June. In 2000, the price per kilogram of taro imported to Japan was ¥120 or about A$1.70 per kilo (FAO, 2000) (Figure 42). In 2002, research indicated that medium term prices will be $2.20 per kilo, providing quality meets expectations (Doolan, 2002).

Being a root vegetable, taro must be completely free of soil and no evidence of insect or disease damage on corms. To export sato imo to Japan, a phytosanitary certificate is required with an additional declaration stating either "Grown on a farm that has been inspected by soil sampling (prior to their planting or during the growing season) and found to be free from *Radopholus similis*", (burrowing nematode) or "found free from *Radopholus similis* as a result of inspection during the growing season".

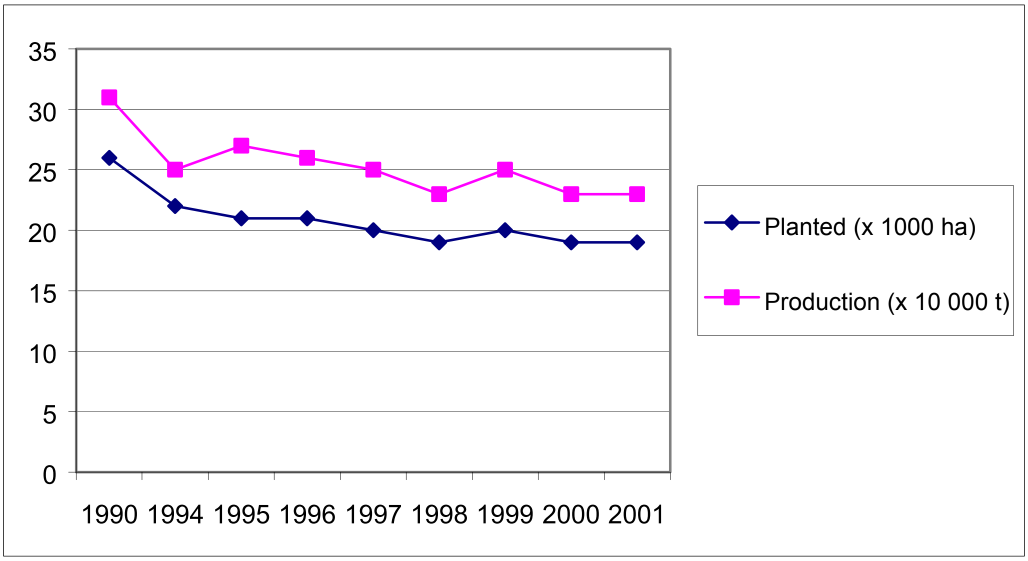

Figure 41: Japanese production of taro (t) and area planted (ha) (MAFF 2001).

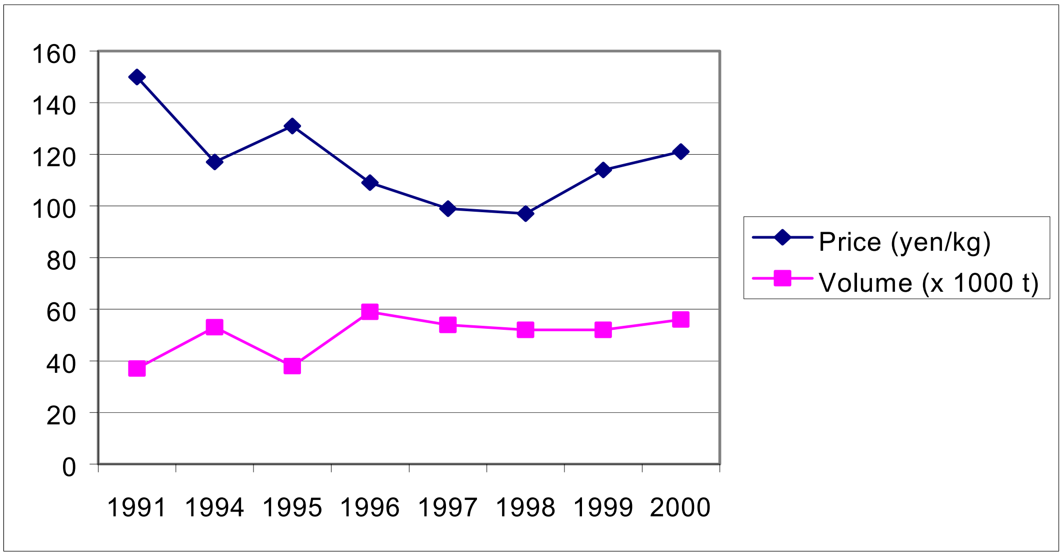

Figure 42: Japanese imports of fresh sato imo (FAO 2000)

10.1.3. Potential for Western Australia

Previously, the dasheen type of taro had been grown in WA but in small volumes. Currently, there is no known commercial planting of taro. A small observation trial of sato imo is to be planted in late October 2002 to determine if the market preferred variety (Ishikawa – wase) can grow in WA conditions.

According to Vinning (1995) of Asian Market Research, sato imo has good prospects for Australia, providing mechanisation is developed for more profitable production.

Opportunities for sato imo in WA

- WA has experience with export to Japan
- Two RIRDC projects are investigating agronomy and mechanics of planting and harvesting.
- May be able to have WA grown taro sent to Eastern States and then have it shipped to Japan under their label (RIRDC project has a Japnese customer interested in buying "Australian sato imo"
- Creates diversity for the WA horticultural industry

Limitations for sato imo in WA:

- WA does not have domestic market unlike Eastern States
- No current commercial production (lack of growing experience)
- Difficult to break into Japanese market
- Mechanisation for planting and harvesting yet to be developed

10.2. Japanese taro trials

Rotation crops are needed to maintain ecologically and economically sustainable horticultural production in metropolitan and south-west production areas. Part of the HAL funded ‘Developing New Export Vegetables’ project is the assessment of potential export vegetable crops for WA. Japanese taro or sato imo, as it is known in Japan, may be one such potential vegetable.

The aim of this unreplicated trial was to observe the growth of Japanese taro under WA growing conditions and to observe the effect of three different plant spacings on yield and quality.

10.2.1. Materials and method

The trial was planted at the Medina Research Station. The planting material came from Central Queensland University and were 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°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°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, potassium sulphate 200 kg/ha and trace element mix at 150 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. Potassium sulphate at 19 kg/ha and ammonium nitrate at 41 kg/ha was 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).

Table 67: Japanese taro grading system (Source: G. Vinning)

Grade	Weight of corm (g)
S	Less than 40 g
M	41 – 60 g
L	61 – 80 g
2L	81 – 100 g
3L	0ver 101 g

10.2.2. Results and discussion

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.

Figure 43: Japanese taro plants at Medina Research Station 13 weeks after transplanting.

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 was 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 (Hicks, 2002). 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 68 shows the average number of corms per plant and the cormel yield (kg/plant) for each spacing. As to be expected the wider the intra-row spacing, the greater the number of corms and cormel yield per plant.

Table 68: Average number of corms per plant and cormel yield for each spacing

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

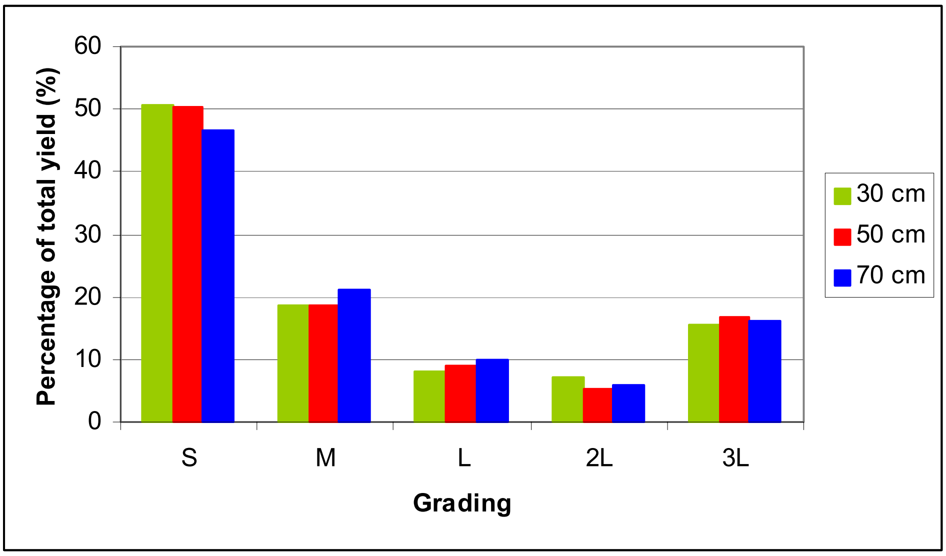

Figure 44: The percentage of total yield that fall into each grade for each spacing

The percentage of total yield that fell into each size grade category for each spacing is shown in Figure 44. All spacings showed a similar pattern 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 (Figure 45). Japanese market prefers 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.

Figure 45: A sample of taro harvested at the Medina Research Station in May 2003

10.2.3. Taro observation at the 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 1.5 m x 6 m. This observation trial was smaller than that planted at the Medina 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.

10.3. Japanese yam

Yam also known as Chinese yam or common yam, is a herbaceous vine which produces an underground tuber of varying size and shape depending on species and variety. Some edible species of yam include: *Dioscorea esculenta*, the lesser or potato yam preferred in Chinese cuisine, *Dioscorea alata* L., the greater yam, orginated in South East Asia. *D. cayenensis* Lam, the yellow yam and *D. rotundata* Poir, the white yam are native to Africa (O'Hair 1990).

The species which have export potential, particularly to the Japanese market, is *Dioscorea batatas*, which has three types; naga imo (long shaped), yamata imo (round, irregular shaped) and icho-imo (hand shaped) (Nguyen, 2001).

Figure 46: One of the many varieties of Yam (*Dioscorea* spp) (Source: South Pacific Commission)

The growing requirements of yam are similar to sato imo in that it prefers a deep, fertile and well drained soil. Minimum temperature required for growth is 20°C, the optimum is 25 - 30°C. Yam is frost susceptible and needs to be well watered. Yam takes about 6 – 10 months to mature depending on climactic conditions and may need to be trellised for higher yields.

10.3.1. Production in Australia

In Australia, yam is grown commercially in Queensland and Northern New South Wales. It is usually planted in September and harvested in April/May. Domestic wholesale prices for yam at the Sydney market in 1999 were between $1.50 - $6.00/kg with the higher prices received in August-September. Two main varieties sold domestically are

D. esculenta with purplish/brown skin and indented shapeand *D. alata*, which has brown skin with a more even corm shape and is preferred by Pacific Islanders (Moody, 2000)

The Rural Industries Research and Development Corporation (RIRDC) in conjunction with Central Queensland University and Agriculture NSW are conducting a project known as ‘Development of taro, yam bean, yam and sweet potato exports to Japan and the USA’. Trials on yam are continuing mainly in Queensland with planting material from Japan due to be released from quarantine in August 2002. Nguyen (2001) believes that the yam variety, yamato imo, should be grown in Australia rather than nago imo. Yamato imo can grow in shallow soils and usually fetch a higher price than nago imo in Japan.

10.3.2. Export market potential

The RIRDC project UCQ-13A chose four potential vegetables, Japanese taro, yam, yam bean and sweet potato, to investigate markets, define required quality attributes, and establish a supply chain for the successful export of these vegetables (University of Central Queensland, 2001). Although, the project is directed at growers in NSW and Queensland, WA growers could learn form their experiences.

The production of yam has increased slightly over the past eight years (Figure 47) with a slight decrease in 1999. Although, planted area has not changed since 1997 (8880 ha), yields have increased by 4%.

It is difficult to comment on the annual volume and price of naga imo (long shaped) taro except that when volumes are high, prices are low and vice versa. Therefore it is difficult to determine a preferred market window (White, 2001). The Tokyo wholesale market had a throughput of 11,732 t of naga imo in 2000, which fetched an average annual price of ¥270/kg (Vinning, 2002b).

Since the late 1980’s, yamato imo (round, irregular shaped) annual volume has decreased. From January to December, there is a general downward trend in volume figures with annual average prices generally increasing (Vinning, 2002b). The Tokyo wholesale market had a throughput of 4036 t of yamato imo in 2000, and at an average annual price of ¥576/kg, yamato imo is twice the price of naga (Vinning, 2002b).

Similar to sato imo, the majority of imported yam into Japan comes from China. In 2000, 3321 tonnes of fresh yam was imported into Japan, 92% of that came from China at ¥94/kg and about 7% came from Vietnam at ¥214/kg (Nguyen, 2001). China also dominates frozen yam imports into Japan. In 2000, 1543 tonnes of frozen yam was imported into Japan. China imported 96% of frozen yam at ¥129/kg and the Phillippines imported 4% at ¥179/kg (Nguyen, 2001).

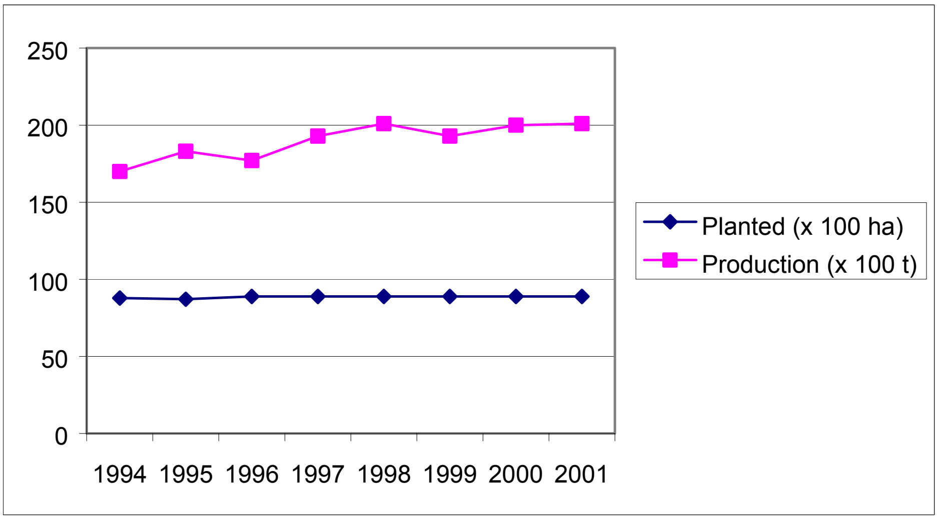

Figure 47: Japanese production of yam (t) and area planted (ha) (MAFF 2001).

10.3.3. Potential for Western Australia

Although yam has not been grown in commercial quantities in WA previously, it still has export potential to the Japanese market. Similarly to sato imo, mechanisation would need to be developed for more profitable production.

Opportunities for yam in WA
- WA has experience with export to Japan
- China imports only a small amount of yam into Japan which may create a window of opportunity for WA
- Creates diversity for the WA horticulture industry

Limitations for yam in WA
- No current commercial production (lack of growing experience)
- Difficult to break into Japanese market
- Mechanisation for planting and harvesting yet to be developed

10.4. Vegetable green soybean (edamame)

Vegetable green soybean (*Glycine max* L.) is a nutritious bean that is high in protein and has a sweet nutty flavour. In Japan it is known as edamame (pronounced "eh-dah-MAH-may") and is consumed as a snack food usually accompanied with beer. Edamame is the same species as field soybean (Miles, Lumpkin and Zenz, 2000) and cultural practices are identical except that edamame is harvested at the mature green stage when the pods have almost filled out (Nguyen 1998b).

a)

b)

Figure 48: a) Edamame plants in the field b) Frozen edamame (Source: Carol Miles, Washington State University)

Edamame is a summer-grown crop with a planting time from November to early January and harvested 68 – 86 days after sowing (Nguyen 1998b). It is important to choose a variety that has good eating quality, have 2 – 3 seeds per pod, pods should be a fresh green colour (2.5 – 3.0 g fresh weight per pods), white pubescence (hair outside the pod) and colourless hilum (Nguyen 1998b).

The seeds need to be innoculated with *Bradyrhizobium japonicum*, a beneficial bacterium that will ensure the formation of nitrogen-fixing nodules on the roots (Miles, Lumpkin and Zenz, 2000). Edamame is a legume and is a plant that lives in association with soil bacteria. If the bacterium is not present in the soil, then plants will become stunted with pale leaves and poor yields (Simmul 2002a).

Edamame also requires large amounts of water, particularly during the vegetative stage, flower bud formation and pod development. It also prefers well-drained soils and weed control is important in the early stages of the crop as high weed incidence affect both yield and quality (Nguyen 1998b).

10.4.1. Production in Australia

From recent trials, edamame can be grown in New South Wales and Victoria for the January to April markets in Japan when throughput of edamame in the Tokyo Wholesale Market is low (Nguyen 1998b). Domestic market is limited with a demand of only 150kg/week with the attached type being preferred (Nguyen 1995). The attached type is when whole plants with leaves, pods, stems and roots are packed in bundles. The attached type is also popular in Japan where it is believed this type keeps the pods fresher for longer (Nguyen, 1998b).

Due to Japanese quarantine restrictions, fresh edamame from mainland Australia cannot be shipped to Japan. Japanese quarantine believe that fresh edamame may be a fruit fly host. Only Tasmania, considered fruit fly free, is allowed to export fresh edamame to Japan.

10.4.2. Export market potential

According to Nguyen (1998b) and Pan (1995), market opportunities exist for Australia to export frozen edamame to Japan. However, improved quality of frozen edamame imports from China has significantly lowered wholesale prices (Table 69). Taiwan is the main competitor with total frozen imports of 27,350 tonnes in 1995 with a landed price of ¥173/kg.

Edamame should be frozen using Individual Quick Frozen (IQF) technology. IQF involves using carbon dioxide and nitrogen liquids and produces a highly satisfactory quality of frozen pods (Nguyen, 1998b).

Table 69: Imports of frozen edamame and landed prices for 1985 – 1995. (Source: Nguyen 1998).

	1985	1990	1991	1992	1993	1994	1995
Total import (t)	31,044	40,071	42,621	44,621	51,249	56,700	52,608
Taiwan (t)	30,959	38,825	40,629	39,128	38,229	30,661	27,350
Landed price ¥/kg		323	237	238	201	201	163

Although prices are decreasing, frozen edamame may still be a viable option for Australia. According to Nguyen (1998b), the breakeven price for Australian frozen edamame is A$1.55/kg.

10.4.3. Potential for Western Australia

As with all new crops, edamame is another crops that has not been planted commercially in Western Australia. Therefore, small scale plantings would have to be planted to determine if edamame is suited to WA growing conditions. Then the process of fine tuning agronomy would be needed to achieve high quality, 2 – 3 seed pods for the Japanese market. In addition to IQF technology and establishing a share in the Japanese market, including food service sector, frozen edamame could be a be viable option.

Opportunities for edamame in WA
- WA has experience in export to Japan
- Less perishable product when frozen
- Opportunity to promote WA's 'clean and green' image as an advantage over main competitors Taiwan and China.
- Creates diversity for the WA horticulture industry
- Edamame can be harvested mechanically using a fresh bean harvester

Limitations for edamame in WA
- No current commercial production (lack of growing experience)
- IQF technology required for high quality pods
- Market bias against a 'non-Asian' country producing an "Asian vegetable" to be sold in an Asian market.
- Exchange rate changes can have a significant affect on returns for WA.

10.5. Japanese broad beam (Soramame)

Japanese broad bean, also known as soramame in Japan, is similar to the broad bean (*Vicia faba*). Soramame has a similar taste to that of fresh green peas but it is mainly used in the pickled form in Japan (Simmul 2002a).

Figure 49: Soramame or Japanese broad bean. (Source: Burgmans 1996)

Soramame is a winter grown crop and is usually sown any time from April to August. Mature beans begin to form about mid November (Simmul, 2002a). Extensive trials have been conducted in Tasmania. Similar to edamame, only Tasmania can export fresh soramame to Japan. Soramame from mainland Australia must be frozen to be exported to Japan.

Similar to edamame, soramame is a legume and requires certain soil bacteria to be present so the plant can produce nitrogen fixation nodules on the roots. Soramame will grow in most soils providing the soil pH is greater than 6.0 (Simmul 2002a). Unfortunately, soramame does not adapt well to mechanical planting or harvesting. Small plantings are better done by hand and harvesting is best done using hand labour with 2 – 3 selective pod harvests. For export, pods need to have 3 – 4 beans and should be straight with no surface blemishes (Simmul 2002a).

10.5.1. Production in Australia

As mentioned previous, the Department of Primary Industries, Water and Environment (DPIWE) in Tasmania has been trialing soramame for the past three years. The trials were conducted mainly for seed multiplication, so enough seed could be produced to send a small sample of fresh soramame to the target market, Japan (Simmul 2002b). It is not known if soramame has been grown commercially in other states of Australia.

10.5.2. Export market potential

In 2000, the Tasmanian Institute of Agricultural Research (TIAR) coducted extensive trials on density and time of harvest of soramame. Results showed that yields of high grade soramame was low. Then in 2002 , a trial shipment was sent to Japan with unfavourable outcomes as cost recovery was barely achievable due to very low prices (Simmul 2002b). The surplus soramame was then trial marketed in Tasmania, again with disappointing results (Simmul 2002b).

According to Simmul (2002b), exporting fresh soramame to Japan is considered high risk. It is assumed that the frozen product would be considered high risk as well, particularly with China as a major importer of frozen soramame into Japan (Table 70).

Table 70: Quantity and value of "Other beans, uncooked or cooked by steaming or boiling in water, frozen"* for 1998 and 1999 imported into Japan from various countries. (* Soramame is classified under this category) (source: Yamamoto, 2001)

Country	**1998** Quantity kg	Value ¥/kg	**1999** Quantity kg	Value ¥/kg
World	5,086,753	226	6,159,587	199
China	4,512,538	215	5,702,990	196
Chile	525,187	328	412,830	246
New Zealand	12,408	122	43,767	149

10.5.3. Potential for Western Australia

Further investigations should be conducted on the potential of frozen soramame to Japan.

11.0. TECHNOLOGY TRANSFER

11.1. Publications

As mentioned in the Summary Report of this project, in March 2001 the Department of Agriculture published a Bulletin called 'Burdock production in Western Australia'. The release of the bulletin was announced on local radio and articles were written in industry newsletters advertising its availability. As a consequence, over 25 interested people were sent a copy of the burdock Bulletin. Copies were also handed out to people at field walks and seminars.

11.2. Industry magazines, newsletters and newspapers

Several articles were published in various industry magazines, newsletters and newspapers. The articles are listed chronologically below:

11.2.1. Industry magazines

- McVeigh, V. (2001) 'Developing New Export Vegetables'. VegeLink in WA Grower, March 2001, Vol 32, No. 1, p. 3.
- Manning, L. (2002) 'New Export Vegetables Field Walk'. WA Grower, March 2002, Vol 33, No. 1, pp. 10 –11.

11.2.2. Industry newsletters

- McVeigh, V. (2001) 'Burdock and Daikon Research Extended'. Access to Asian Vegetables, January 2001, Issue 36, Department of Natural Resources and Environment, Rural Industries Research and Development Corporation.
- McVeigh, V. (2001) 'Developing New Export Vegetables'. Access to Asian Foods, February 2001, Issue 8, Department of Natural Resources and Environment, Rural Industries Research and Development Corporation.
- McVeigh, V. (2001) 'A Grower's Manual for Burdock Production in Western Australia'. Access to Asian Vegetables, May 2001, Issue 39, Department of Natural Resources and Environment, Rural Industries Research and Development Corporation.

11.2.3. Newspaper articles

- Mayo, A. (2001) 'The changing face of vegetable exports from Western Australia'. Good Fruit and Vegetables, July 2001, Vol. 12, No. 2, pp. 11 – 16.
- McVeigh, V. (2002) 'Field walk to reveal Asian vege niches'. Countryman, January 17, 2002, p. 12
- Shardlow, M. (2002) 'White radish helps cash flow'. Countryman Horticulture, July 4, 2002, p. 12
- Shardlow, M (2002) 'Japan tough target'. Countryman Horticulture, July 4, 2002, p. 12.

11.3. Radio interview and television broadcast

- McVeigh, V. ABC Radio Rural Report 3rd April 2001.
- Limb, J. (2001) Asian Vegetable Exports in Western Australia . Landline program, ABC national television. Televised16 December 2001.

11.4. Field walk, seminars and conferences

- Consolidating the Asian Vegetable Industry, RIRDC project meeting and growers seminar, 6 – 8 May 2001, Murwillumbah, New South Wales.
- Department of Agriculture Horticulture Program Biennial Conference (internal) – Leading today, shaping tomorrow. 18 – 19 September 2001, Mandurah Quays Resorts, Western Australia.
- 2001 Horticultural and Forestry Expo, 15 November, Manjimup, Western Australia.
- New Export Vegetables Field Walk. 25 January 2002, Medina Research Station, Western Australia.
- Consolidating the Asian Vegetable Industry, RIRDC project meeting and growers seminar, 18 – 23 June 2002, Melbourne/Geelong, Victoria

12.0. RECOMMENDATIONS

12.1. Burdock research

From the burdock agronomy and postharvest trials, the following recommendations were developed:

- A rate of 400 – 600 kg N/ha should be applied to increase total yields when planting in spring.

- Further research needs to be conducted on why marketable yields are less from a spring sown crop (8t/ha or less) compared to a summer sown crop (20 – 22 t/ha) before an optimum N rate can be determined.

- Pre-emergent herbicides, Kerb® at 4.4 L/ha and trifluralin at 2.0 L/ha, had slight effects (minimal stunting and chlorosis) on burdock seedlings sown in January and November. As at May 2003 no herbicides were registered for burdock in Australia.

- Intra-row spacing of spring-sown burdock is recommended at 5 – 8 cm (16.7 – 26.4 plants/m^2) if harvested at 20 weeks to achieve total yields of 31 – 36 t/ha.

- Priming burdock seed (in water for 12 hours) does not have any significant benefit on the germination rate of summer-sown burdock, therefore it is recommended to sow natural, untreated burdock seed.

- Higher germination (96 – 97%) and marketable yields (8 – 9 t/ha) were achieved when summer sown burdock was sown on a flat bed or a flat bed with furrow compared to the hilled bed formation. Therefore, it is recommended to sow burdock on a flat bed for summer planting.

- Although, 0 - 1°C is the preferred storage temperature for burdock, it is a challenge to maintain this temperature in transit to export markets. Storage of burdock in L213 LifeSpan® bags at 0 - 9°C for 28 days had minimal effects on burdock quality, therefore this barrier bag may be suitable to maintain quality during transit to export market. However, further research should be done after the storage period as differences in quality may be more noticeable when the product is on the supermarket shelf at ambient temperatures for 2 – 3 days, particularly if the product has experienced high temperatures during in-transit storage.

12.2. Shallot research

- Although, yields from the variety evaluation planted at the Medina Research Station were low, it showed that shallot varieties Ambition and Matador are the most suited varieties for Medina.

- The varieties Ambition and Matador also showed the greatest potential in terms of yields at the Manjimup Horticultural Research Institute, with total yields of 73.4 t/ha and 52.9 t/ha respectively.

- The optimum density for Ambition and Matador is 90.6 plants/m^2 and 160.3 plants/m^2 respectively. This corresponds to a seed spacing of 9.02 and 3.12 cm when an eight row air seeder with a distance of 40 cm between each pair of double-rows is used.

- Small bulbs (up to 20 mm maximum diameter) can be used to propagate shallots vegetatively, thus giving an outlet for otherwise waste product. Medium (21 – 45 mm maximum diameter) and large (46 – 65 mm maximum diameter) bulbs tended to flower prematurely, and produced more small bulbs. Vegetatively propagated plants matured approximately one month earlier than seeded shallots.

- A detailed economic analysis should be conducted on exporting shallots to Indonesia and other markets.

12.3. Daikon research

- The preferred root weight of daikon exported to Taiwan is 1000 – 1500 g. The recommended densities and harvest time to achieve the desired export weight is 6 - 12 plant/m^2 at 65 days after sowing (DAS), and 12 - 18 plants/m^2 at 80 DAS. However, to achieve higher total and marketable yields, a density of 18 plants/m^2 (14.5 cm x 29 cm) harvested at 65 DAS is better for both daikon varieties, Narumi and Minowase Summer Cross No. 3 as this achieved an average root weight of 810 grams.

12.4. New export vegetables study tour

- A study tour to Japan in December 2001 concluded that Western Australia could not viably export fresh burdock to Japan due to burdock imports from China. Therefore, more emphasis was placed on the viability of developing a higher value semi-processed burdock product with an extended shelf life.

- From the study tour report, it was recommended to conduct economic feasibility analysis on the prospects of processed burdock into the Japanese market.

12.5. Processing fresh-cut burdock

- Preliminary studies to prevent browning in fresh-cut burdock were conducted by Food Science Australia. The recommendation from the report was to study the microbiological and sensory properties of the product under current experimental conditions to understand or predict the shelf life of burdock.

- It was also recommended to select suitable packaging material based on respiration rate and browning of the product.

- Unfortunately, due to the unfavourable findings of the initial economic analysis of semi-processing burdock for export to Japan, no further research was conducted.

12.6. Economic analysis of supplying semi-processed burdock to Japan

- According to Rahmig (2002), the opportunities for a semi-processed burdock product from Australia is limited. The price calculation shows a landed price per unit of A$8.69 per kilogram. With a focused price range of A$4.00 - $6.50 per kilogram for imported semi-processed burdock, the enterprise would not be profitable.

- From the economic analysis, other recommendations were given (Rahmig, 2002):
  - i) Conduct further research on the processing costs based on the findings in this analysis and on the figures provided by Jeff Hastings to build up a Western Australian semi-processed burdock industry into Japan.
  - ii) Gather information about the production practices in China. Find out if there are imminent disease or pest problems or unsustainable production practices which could lead to supply problems in future years.
  - iii) Further analysis of the general demand trend for burdock. Who will demand burdock in the future (international and domestic) and who will pay a premium for the product.
  - iv) Investigate opportunities for Western Australian growers to establish joint-ventures with Japanese companies to grow burdock in WA and to export the product to the Japanese market.

12.7. Other potential export vegetables

- Continue agronomic trials of Japanese taro in the Perth area.

- Monitor studies conducted by Central Queensland University and Taro Growers Australia Inc. and remain involved in agronomic trials as part of the national project.

- Detailed market analyses need to be completed on other potential export vegetables, Japanese yam, vegetable green soybean and Japanese broad bean, before conducting any agronomic trials in WA.

13.0. ACKNOWLEDGMENTS

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15.0. APPENDICES

15.1 APPENDIX ONE - Report on the New Export Vegetables Study Tour To Japan

15.2 APPENDIX TWO - Report of Fresh-Cut Burdock (*Arctium lappa* L.)

15.3 APPENDIX THREE - An economic analysis of supplying Western Australian semi-processed burdock to Japan

Report on the

New Export Vegetables Study Tour to Japan

9 – 16 December 2001

Written by

Vynka McVeigh and Soon Chye Tan

CONTENTS

1.0 MEDIA SUMMARY

As part of the Horticulture Australia Ltd. (HAL) funded project 'Developing New Export Vegetables', a study tour to Japan has been completed. The tour delegates consisted of two Department of Agriculture staff, Ms Vynka McVeigh, Project Officer, and Soon Chye Tan, Senior Research Officer (Postharvest), and one industry representative, Mr Jeff Hastings of Xylem International. The objectives of the study tour were:

- To visit burdock growers to determine their growing and handling methods for burdock and to gather information on crop agronomy.
- To visit vegetable importers, wholesalers and processors to discuss prospects of exporting fresh and/or semi-processed burdock to Japan.
- Visit wholesale market and inspect local and imported burdock quality and determine wholesale price.
- Obtain up to date monthly volume throughput and wholesale price of local and imported burdock particularly from China and Taiwan.
- Identify other potential export vegetables for the Japanese market.

All objectives were achieved. One of the major conclusions that was reiterated during our discussions with growers, importers and processors was that China in recent years have become very competitive in the Japanese market. Not only have Chinese imports of burdock increased but other vegetable imports from China have increased as well.

As a result, Western Australia may not be able to compete against China in the Japanese fresh burdock market. However, there still appears to be potential to export a semi-processed burdock product to Japan. This opportunity is based on the assumptions that a shelf life of 20 days or more can be achieved from the semi-processed burdock product, that burdock flavour and texture is as good as the Japanese and Chinese products and that the price of these products are competitive. A detailed economic analysis of exporting minimally processed burdock is required.

2.0 RESULTS OF DISCUSSIONS

2.1 Growers

On the study tour, we visited three burdock growers. The first grower Mr Hideo Takishima had a 3.6 hectare property on which he grew burdock and rotated with carrots. Discussions with Mr Takishima revealed that growing burdock in Japan is quite different to the methods of growing burdock in WA. One point that was reiterated was that to achieve good quality burdock you need good soil management. Six months before burdock is sown, Mr Takishima ploughs in a crop of sorghum into the soil. This is done to increase organic matter in the soil and improve soil structure which in turn assists the burdock root in absorbing nutrients. The sorghum absorbs nitrogen when it grows then when it is ploughed into the ground, the sorghum breaks down making nitrogen available to the burdock. By practicing this form of green manuring, the burdock also becomes 'softer' and has better texture.

Mr Takishima believes that pH is very important as it affects the fragrance of burdock which is an important factor with fresh burdock. On Mr Takishima's property, the pH is 5.5 – 6.25 (1:5 water*)* before the application of inorganic fertilisers. Burdock grown in the sandy soils of Japan has a pH of 6.5. According to Mr Takishama and Dr Seki, soil agronomist, high pH may be causing root twisting which WA grown burdock can have. Root twisting is also caused by the lack of soil cultivation, or in our sandy soils, due to compaction during growth. Twisting is not a problem in Japan as the soils are very light, volcanic ash and when cultivated forms a light, friable tilth with a soil penetrometer reading of 10 – 12 kg/m^2 at 15cm deep.

In areas of sandy soil in Japan, the use of the trencher tends to bring up acidic soil, therefore to increase the pH they use inorganic fertiliser. Through the translation, it was difficult to establish the name of this fertiliser but the composition was 4.0 kg silica, 3.4 kg phosphate and 2.4 kg potassium (45% alkaline). The bag was a 10 kilogram bag and when applied to sandy soils at the rate of 1200 kg/ha, the fertiliser increases the pH by 1 unit.

The main burdock variety grown (80% of all burdock grown) in Japan is Yanagawa Riso and grows for 150 days. Depending on variety, the shortest growing time is 100 days. Mr Takishima uses a rotary trencher at a depth of 1 – 1.2 metres. After trenching, a tape seeder is used to sow the seeds. The tape seeder has a press wheel on the back of it to slightly compress the soil after sowing. This slight compaction is known to improve germination.

Depending on the time of the year, burdock is either harvested after the 150 days or is ground stored. Ground storage of burdock usually occurs from December to April. With the colder months the leaves die off and regrow when the climate is warmer. The burdock is allowed to regrow until the leaves are 15 cm long then the roots are harvested. Mr Takishima uses a Sugano plough lifter to loosen the burdock roots out of the ground (Figure 1). The lifted roots are then tied into bundles of 10 kg and wrapped with newspaper or cardboard carton and put into the coolroom (0 - 2°C) until sold. Depending on market demands some burdock is washed. However, this is not done on Mr Takishima's property. The wholesaler/distributor has a burdock washing machine.

One variety that is becoming more popular with consumers is the short variety or 'Hyakunichi gobo' or hundred day burdock. It is a salad variety grows to 55cm in length and 2.2 cm in diameter. Consumers like this variety as it is the same diameter down the length of the root and it is easier to take home than the standard longer burdock.

The burdock inspected on Mr Takishima's property was planted on 25 May 2001 and was still being harvested.

The second grower was an organic burdock grower Mr Yoshio Koshikawa (Figure 2). Mr Akio Ito from International Nature Farming Research Centre (INFRC) was also met and his role is to improve organic growing methods amongst organic growers. Mr Ito is currently researching the effects of Effective Microorganisms (EM) on burdock.

Mr Koshikawa has a 10 hectare property on which he grows 17 different organic vegetables. His main crops are daikon, carrot and burdock. In terms of size, he is a larger than average grower as most organic growers have about 5 hectares. His family often help with harvesting.

Mr Koshikawa grows organic burdock under contract. He is a member of the supply group known as Centre of Japanese Organic Farmers Group (CJOFG). In this group there are seven partners or members all of whom are organic growers. There are 2700 growers that are certified organic growers in Japan but they only produce 0.4% of the total vegetable production sold in Japan. Organic growers are now certified under a relatively new regulatory body known as Japanese Agricultural Standards or JAS. The role of JAS is to set the organic standards for organic produce in Japan. Since the introduction and enforcement of JAS there are less organic growers in Japan. JAS recognises the Australian organic standards such as Biological Farmers of Australia Co-operative Ltd. (BFA) and National Association for Sustainable Agricultural (Aust.) Ltd. (NASAA).

From Mr Koshikawa's experience, organic burdock does not go brown or discolour after cutting. He believes that conventionally grown burdock has a lot of nitrates in the roots. The nitrates reduce enzyme production and the health of the plant which in turn causes more discolouration than the organically grown produce.

The main problems with organic growing are pests and weeds. He uses pheromones, *Bacillus thuringiensis* (biological insecticide) and companion planting using garlic for insect control.

Mr Koshikawa said that yields using organic methods tend to be lower than conventional methods. But organic products receive 20% higher in price than inorganic produce. It has taken Mr Koshikawa 10 years to reach this point of producing such high quality vegetables. He has now established a good reputation and brand to supply high quality organic produce and he can sometimes achieve prices that are 2 – 3 times higher than conventionally grown products.

2.2 Agricultural contractor

Due to the small area of farms in Japan and with the majority of growers having multiple incomes, many growers use agricultural contractors. Mr Tammio Takayangi is an agricultural contractor whose operations includes planting and trenching of burdock, lifter ploughing for burdock, plough and levelling of paddy field, ploughing and harvesting sweet potato and mowing uncultivated fields. The family business is run by Mr Takayangi, his son and his brother.

Mr Takayangi owns a Kawabe four row chain trencher, one of only two in Japan, a rotary trencher (Figure 3) and over twenty tractors including a 140 HP Massey Ferguson which is used to pull the four row trencher. The four row trencher has better balance, cultivates the soil to a finer tilth and can work more area in less time than the two row chain trencher or the rotary trencher. However, the chain trencher has more maintenance cost as the chain needs to be replaced often. The four row chain trencher is valued at about ¥ 4 million or A$62,000.

Mr Takayangi has regular customers with property size ranging from 0.5 – 3 hectares, he has a few larger growers with 12 – 20 hectares. Mr Takayangi is paid by the area he is working and payment is usually made at the end of the year. He charges ¥ 70,000 to ¥100,000 (A$1,080 – A$1,530) per hectare of ploughing. On an average farm, 20 - 30% of costs are for contractors. Mr Takayangi outlined a break-up of the basic costs involved in growing burdock using contractors for trenching and harvesting (see Table 1). The average marketable yield of burdock is 20 – 30 tonnes per hectare and the lowest gross margin for burdock in Japan is about ¥500,000/ha or A$7,690, according to Mr Takayangi.

Table 1: Approximate costs for burdock production in Japan using contractors for trenching and harvesting.

Operation	Cost per 1 hectare in Yen (¥)	Cost per 1 hectare in A$
Seed	¥200,000	$3,080
Chemicals and fertilisers	¥400,000	$6,150
Contract trenching	¥200,000	$3,080
Contract lift ploughing (harvesting)	¥250,000	$3,850
Hand weeding	¥200,000	$3,080
TOTAL	**¥1,250,000**	**$19,240**

A$1 = ¥65

Based on a marketable yield of 25 tonnes per hectare and a gross margin of ¥500 000, the lowest price per kilogram received by the grower would be ¥70 per kilogram or A$1.08/kg.

2.3 Burdock harvesting and handling process

During the visit in the Chiba and Ibaraki prefectures, we visited another small grower, one of Mr Takayangi customers. In the field we saw a demonstration of burdock harvesting using the Kawabe root digger (Figure 4). The digger loosens the burdock roots from the ground and roots were lifted by the crown using two soft rubber belts (Figure 5). The roots were then put in a wire cradle until 10 – 15 roots were harvested. The cradle then gently placed the bundle of roots on the ground (Figure 6). No evidence of damage by the machine was seen on the roots. The Kawabe root trencher was worth about ¥ 2,600, 000 or A$ 40,000. A 72 HP tractor was used to pull the root digger.

Out of the harvested roots, 80% was marketable. The total yield was about 20 – 25 tonnes per hectare. The burdock we saw was planted in mid May and a flail mower was used to cut the dried burdock leaves for a clean field for harvesting. With the onset of winter the leaves die off, at other times the green leaves are usually cut off after 150 days. The variety was Yanagawa Riso. The plant density of the burdock was 75 cm between the rows, 6 cm between plants and 1.3 m depth was achieved using a chain trencher.

After the root digger places bundles of burdock on the ground, a person gathers and loosely ties up the bundle of roots and loads the bundle of roots in an open frame on a small truck. Once the truck is loaded, it is driven to the grading and packing shed.

After delivery to the shed, the open frame on the truck, into which the bundles of roots are placed, is unloaded. The bundles are untied and each individual root is topped by a circular saw (Figure 7) leaving 1-2 cm of stalk at the crown of the root. After topping, the roots are then placed on a conveyor up to the grading machine. The grading machine is a simple machine that grades the root by weight (Figure 8). The main grades are S, M and L. The graded roots are then placed on the floor in large separate piles (Figure 9). Each pile is treated separately as not to mix up the grades. The roots are then individually put through another machine that brushes the excess dirt from the root and removes the small lateral roots off the main taproot (Figure 10). The brushed whole burdock is then packaged and sold mainly to supermarkets. The grower was getting ¥235 per kilogram of fresh burdock (A$3.60/kg).

After seeing the field demonstration, we saw the grower's Kawabe double row trencher (Figure 11). The trencher is fixed with two probes which applies a soil fumigant to the soil whilst trenching. It was difficult to establish the name of the actual chemical used but it sounded similar to metham sodium or Nemacur® as it was used to control nematodes. After trenching and the application of this fumigant, burdock is planted two weeks later using a tape seeder.

2.4 Processors

2.4.1 Shonan Company Ltd.

As part of the study tour, we also visited processors of burdock. The first processor was a fairly large factory known as Shonan Company Ltd. We met with Mr Raito Matsuo, Managing Director, and his brother Mr Kazufusa Matsuo, Superintendent, and we discussed their operation with particular reference to burdock.

Shonan was established 11 years ago and mainly process burdock. The company also act as vendors to supermarkets in country areas. The large supermarket chain Daiei is Shonan's biggest customer. Shonan buy fresh burdock directly from the grower and then sell various processed burdock products to the supermarket.

The company sources burdock from all over Japan such as Kagoshima, Aomori and Hokkaido. They have contracts with individual growers as well as grower cooperatives. Shonan also imports burdock from China. The company's customers actually prefer Chinese burdock as opposed to local product because the price is low and quality is reasonably good. Shonan has established relationships with particular Chinese importers from which they buy fresh Chinese burdock.

According to Mr Matsuo 220,000 to 230,000 tonnes of fresh and processed burdock is sold per year in Japan. About 43% or 100,000 tonnes of this is imported from China, with a small amount being imported from Taiwan. Mr Matsuo illustrated a table showing the areas where burdock can be sourced at what months of the year. Burdock is available all year round (Table 2).

Table 2: Availability of the burdock from Japan, China and Taiwan

Country/Prefecture	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**
Japan - Kagoshima				#	#	#	#	#	#			
Chiba	#	#	#								#	#
Aomori											#	#
Hokkaido								#	#	#	#	#
China	*	*				*	*	*	*	*	*	*
Taiwan		*	*	*	*							

- harvest * - supply

Shonan process burdock mainly in the kimpira cut or stick-like cut. They also cut burdock in the sasagaki cut which is a half moon wedge (Figure 12). The kimpira cut burdock is usually packed into 150 gram packs with cut carrot (Figure 13). The shelf life of these fresh cut packs is 3 – 5 days under 10°C. Shonan also pack washed and unwashed burdock halves (Figure 14 and 15).

Before the burdock is delivered to Shonan processing plant, the growers must grade the roots which is condition of their contract with Shonan. The burdock is then delivered to the plant in refrigerated trucks (Figure 16). The roots are then transferred to mobile bins for easy maneuverability. Depending on market demands, the roots are either processed into kimpira, sasagaki cut or semi-processed into halves. The roots for the kimpira and sasagaki cut are washed by machine (Figure 17) and peeled by scraping with a knife. During these stages, the roots are almost continuously submerged in water. After peeling, each root is fed into a cutter machine which either cuts the burdock into kimpira cut (Figure 18) or sasagaki cut (Figure 19). The cut burdock is then packaged in bulk or packaged in 150 gram retail packs.

The contract price of the fresh burdock varies depending on which prefecture the burdock is grown. The bought price (including transport costs) from growers in Kagoshima is ¥160/kg and ¥120/kg from Hokkaido. Chinese burdock delivered to the factory can range from ¥50 - ¥120/kg. According to Mr Matsuo, Taiwan sometimes sell fresh burdock to Japan below costs because China is so competitive. Shonan sells their 150 gram burdock and carrot packs for ¥100- ¥150 per pack or ¥660 - ¥990/kg (A$1.50 - $2.20 per 150 grams or $10.00 - $15.00/kg)

When discussions about Australian burdock opportunities arose, Mr Matsuo said that the supply of burdock is excessive all year round, therefore for Australia to compete, a market niche would be needed. He said this would be difficult under the current market climate particularly with fresh burdock. However, he said that a semi-processed product would be easier to market. When Mr Matsuo was asked about Australian technology into extending the shelf-life of fresh cut burdock, he believed the potential to be quite large particularly during March, April and May, providing the quality is good and price is competitive. However, China is already selling semi-processed and frozen products on the Japanese market.

2.4.2 Kanehatsu Foods Company Ltd.

The second processor visited was Kanehatsu Foods located in Nagoya. This company was a larger processor than Shonan, however, no operations were shown. We met with Mr Yoshi Aoki, Manager and Mr Yoshinori Ishii, Director, of Kanehatsu Foods.

Kanehatsu Foods deal with a range of processed foods. They have recently been trying to specialise in New Year gift packs which have a range of fresh and semi-processed products. Kanehatsu Foods processes burdock into the kimpira cut which is then packaged with mayonnaise and other vegetables such as carrot.

Kanehatsu either buy fresh burdock from China or buy the semi-processed burdock from an associated company that buys fresh burdock from China. Kanehatsu then use the semi-processed product in the mayonnaise salad mixes. Fresh burdock from China is bought all year round for about ¥170/kg (A$2.60).

The most demand for processed burdock is March – May. Kanehatsu indicated that they would like to receive a sample of kimpira cut burdock from Western Australian grown burdock. They said that if Australian semi-processed burdock has good quality and a competitive price, Kanehatsu would consider buying Australian products as opposed to Chinese product during March – May. Mr Ishii did mention that one problem that would need to be overcome is shelf life as it takes only one week to deliver burdock from China to the factory when it takes 17 – 20 days to sea freight from Australia.

The dimensions of the kimpira cut that Kanehatsu process or buys is typically 2.5mm in width and height and 45 mm in length. Sometimes 3 mm x 3 mm x 35 mm is accepted.

The fragrance of the burdock is not that important for semi-processed products. As Kanehatsu manufacture burdock salad, they are looking for the correct colour (cream to white), no discolouration, and suitable texture or 'bite'. Texture was difficult to describe. The only way to achieve the correct burdock texture would be to continually send samples until the processors are satisfied with the Australian product.

2.4.3 Osaka Delica Foods Corporation

Osaka Delica is a processing company located in Osaka. Osaka Delica is a smaller company than Kanehatsu Foods. The company processes fresh vegetables and repacks processed vegetables that are bulk-packaged and distributed to food service, retail and delicatessen companies. We met with Mr Kazuo Okada, Executive Director, and Mr Keiji Yoshimi, Product Development.

The company deals with three sources of burdock, Chinese burdock processed in China, Japanese burdock processed in Japan and Chinese burdock processed in Japan. The company does not process a lot of burdock, about 100 kg per day or 300 tonnes per month but they have a good customer for sasagaki cut burdock. They believe that the Japanese burdock has better flavour than the Chinese product but Japanese burdock is more expensive than the Chinese burdock therefore they mix both products together in the final product. Osaka Delica buy burdock that is already processed in the kimpira cut with dimensions of 3 mm x 3 mm x 50 mm. This cut is re-packed into 500 gram packs with other vegetables (Figure 20) or packaged with added flavours such as burdock with sesame oil or mayonnaise.

Osaka Delica is testing sasagaki cut burdock to mix with other vegetables. The company is going to process sasagaki cut burdock in deionised water to prevent discolouration and bacterial growth. Three grams of sesame oil will be added to 200 grams of sasagaki cut burdock.

The company is also trying to develop products that are in the middle of the processing stage, ie. not dealing with fresh vegetables nor the final product, but with products they call 'one-step prior to final'. To do this they are using vacuum cooking technology. Vacuum cooking is cooking a product already vacuum sealed in water held at a certain temperature for a certain period of time. For example, cut burdock is vacuum packed and cooked at 92°C for about 18 minutes so that cellulose fibre within the pieces breaks down but still leaves the product crunchy and flavoursome. The product then needs to be cooled down to a core temperature of 3°C within 90 minutes to prevent bacterial growth.

The bulk-packaged processed burdock that Osaka Delica buys is 5 kg of burdock with 2 kg of water. The company pays for the net weight, not the weight of the water. According to Mr Yoshimi, prices of bulk-packaged sasagaki cut burdock from different origins are as follows:

Local burdock cut in Japan	¥260 per kilo	A$4.00/kg
Chinese burdock cut in Japan	¥150 per kilo (approx.)	A$2.31/kg
Chinese burdock cut in China	¥100 per kilo (approx.)	A$1.50/kg

Osaka Delica are currently looking at setting up a processing plant in China to vacuum cook burdock and other vegetables. Mr Yoshimi recognises there can be a risk with bad quality burdock but it is cheaper to set up a processing plant in China than in Japan. Proximity to Japan is also an advantage as it only takes 4 – 5 days to sea freight product from China.

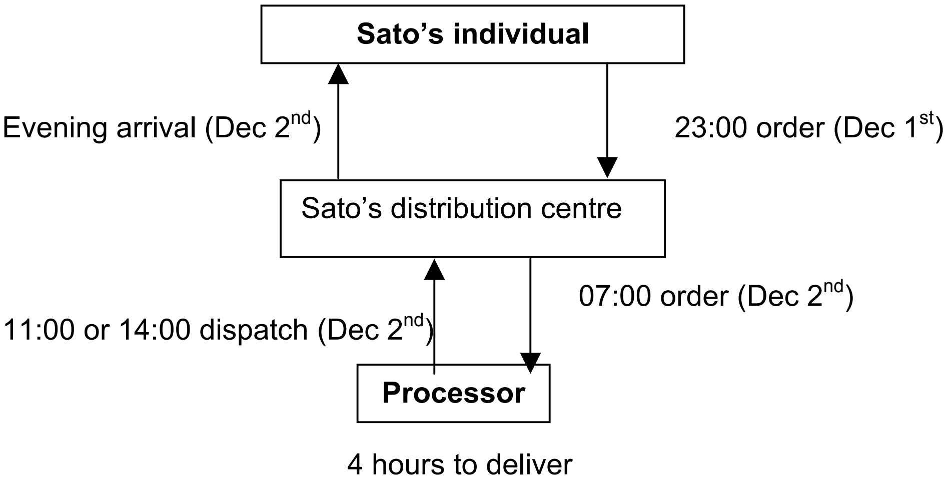
Osaka Delica also indicated that they would like to receive a sample of semi-processed Western Australia burdock. However, for the company to be truly interested in an Australian product the quality must be of superior quality to Chinese products.

2.4.4 Sato Restaurant Systems Company, Ltd.

Sato act as a food distributor to major restaurants in Japan. They also have their own restaurant chain. Sato deal with sasagaki cut burdock, kabocha and other vegetables depending on customer demands. Mr Kenichi Inui discussed mainly burdock and kabocha with us.

Sato is buying sasagaki cut burdock from local processors for ¥90 per 150 gram net pack (A$1.40) or ¥600 per kilo ($A9.20/kg) (Figure 21). This buying price is quite high which may be due to their small volume and package size. The processed burdock is from China. Sato buy about 181,400 packs (150 grams) per year or about 27 tonnes per year. The burdock packs are filled with normal water to prevent oxidation and only the net weight of the burdock pack is paid for. Sato focus on four quality aspects of sasagaki cut burdock, i) number of bacteria (total plate counts of salmonella, E. coli), ii) colour (natural white colour not bleached), iii) flavour and iv) texture. Flavour and texture are the two most difficult to determine as these are subjective aspects.

Sato's food chain is sketched below. Processors must deliver the150 gram packs within 4 hours from the time of order received from Sato Distribution Centre everyday. Processors need to assume the volume to be ordered from Sato before the actual order is received. This is so the processors can deliver within 4 hours. By doing this they need to take into account a percentage of wastage caused by approximating the volume that may be ordered.



Currently, Sato is also looking to set up operations overseas. Sato are looking for a processing company in China to produce Japanese pickles. They also process kabocha slices for tempura fry from local processors. The fresh kabocha is mainly imported from New Zealand and Mexico. The processors sell sliced kabocha in 200 gram packs, twenty slices per pack and sell for ¥135 per 200 gram pack (A$2.10 /pack). Sato's annual volume of kabocha is 314,500 packs or about 60 tonnes. Mr Inui believes that frozen kobocha is not suitable for tempura fry but it has been argued that Individual Quick Freezing or IQF technology is suitable for Sato's needs.

2. 5 Importers/Wholesalers

2.5.1 Meika Corporation

Meika Corporation is one of the largest fresh fruit and vegetable importers in Japan. At Meika, we met with Mr Eiji Ohta, Chief, and Mr Toshio Nagai, Managing Director.

Meika part owns a processing company called Central Foods. The movement in processing is to set up operation in China with the view to leave the wastage in China as it is expensive to remove the waste product produced with processing in Japan. China is a major produce supplier for retail/supermarket as well as food service. China is already supplying fresh cut vegetable products. The demand for burdock is mainly in winter which is supplied by China, but Meika import burdock all year round. Meika buy fresh burdock from China at ¥90 per kilogram landed at the market.

Meika showed us samples of burdock from China. Mr Nagai said that for processing, food service industries prefer the 2L grade of burdock (3 – 3.5 cm in diameter) while supermarkets for fresh burdock prefer the 2M grade (1.8 – 2.2 cm diameter). When asked about fragrance, they said fragrance is not much an issue. The burdock is of good quality when texture is 'soft' but not stringy and no hollow or pithiness inside the root. When asked about the meaning of 'soft' texture, they could not explain.

Mr Ohta believes that fresh burdock would be very difficult to sell in Japan with such competition from China. He believes there would be better opportunity with sweet corn. There is no domestic supply of sweet corn in Japan during March to May. Meika indicated they would like to receive another test shipment of controlled atmosphere (CA) sweet corn from Western Australia. Dr. Soon Chye Tan would coordinate the trial shipment which is planned to be carried out in March/April 2002.

2.5.2 S. Ishimitsu and Company Ltd.

Ishimitsu is an importer of food and non food items. Their company is based in Kobe. We met with Mr Kazuo Yoshihara, Deputy Manager, and Ms Sonia Kusumoto, Senior Manager.

Ishimitsu import only fresh burdock mainly from China. According to Mr Yoshihara, the total supply of fresh burdock in 2000 was 240,000 tonnes, out of which 80 000 tonnes were imported (65,000 tonnes from China and less than 15,000 tonnes from Taiwan). Total burdock imports have increased 10% from last year.

Ishimitsu's specifications and prices are outlined in the table below. The first three sizes S, 2M and M, are mainly used for retail or the fresh market and L and 2L are the preferred sizes for processing. Out of total imports, 20% of imports are the S, 2M and M sizes while 80% of imports are for processing (L and 2L)

Size	Diameter (mm)	No of roots per 10 kg carton	C & F (US$ / tonne)	C & F (A$ / tonne)
S	15 – 17	85 –100		
2M	17 – 20	60 –70	500	960
M	20 – 24	48 – 55		
L	25 – 30		400 – 450	770 - 865
2L	30 – 35			

Ishimitsu's price structure for burdock processed into kimpira cut is as follows:

C & F from China	¥ 50/kg (US$400/tonne)
Price to processors	¥ 70/kg
Actual processors price counting wastage	¥ 80/kg
Price of kimpira cut, bulk pack	
Good volume purchase	¥ 170/kg
Medium volume purchase	¥ 200/kg
Small volume purchase	¥ 350/kg

Sasagaki cut price would be 20% higher.

Ishimitsu is working with processed burdock in sasagaki cut in conjunction with Osaka Delica. Ishimitsu also indicated that they would be interested in Australian semi-processed burdock if we are able to extend the shelf life of fresh cut burdock and obtain preferred flavour and texture within a competitive price.

2.5.3 Daika Osaka Seika Co. Ltd.

As part of the study tour we also visited the Osaka Wholesale Markets. There we met with staff of Daika Osaka Seika and viewed the burdock auction within the markets. Daika Osaka Seika is a primary wholesaler that auction vegetables to secondary wholesalers. The company has a trade division that import vegetables. Mr Koji Yamada is the director of vegetables and Mr Yukio Monoe is the director of trade.

Total fresh vegetable supply in 2000 was 2,810,000 tonnes and imported fresh vegetable supply was 925,000 tonnes. Out of the total imported fresh vegetables 80% were brown onion, broccoli, kabocha and asparagus.

Daily volume of fresh burdock handled at the Osaka Wholesale Market has declined to 53 tonnes from over 200 tonnes a couple of years ago. The reason for this is that the Osaka wholesale market does not deal with imported products and there have been major increases of imported burdock from China. Not only with burdock imports but other vegetables imports are increasing particularly from China. These imports are cheaper than local market prices therefore the volume of local product has declined significantly.

Current prices of imported burdock are US$3 – 5.00 / 10 kg (¥0.22 – 0.37 per kg) carton depending on specification and quality. Local burdock price is ¥120 - ¥130 / kg depending on specification. As a general rule, if the product is 20 – 30% cheaper than local product then trading companies will buy the imported product.

The burdock auction is relatively simple. One 10 kg carton of burdock from a pallet of burdock is placed on the floor. One person points to the carton sample being auctioned and another man auctions the burdock. The buyers bid their price by using hand signals which only the auctioneer can see as the buyer gestures behind his coat to prevent other buyers seeing what price he has bided (Figure 30). The price per kilo, the amount bought and the buyer is recorded and the carton is put back on the pallet of burdock. Most of the time the burdock is bought is taken to supermarkets or processors. Sometimes the fresh burdock recently sold is cut in halves and packaged or processed into sasagaki cut on the market premises.

2.6 Supermarkets

Various supermarkets were visited such as Jusco, one of the leading supermarket chains in Japan, and Daimaru. Prices of burdock did not vary all that much between supermarkets. Packaged fresh burdock (2 washed halves) from China was ¥198 each. The same product from Japan was ¥398 each. The majority of the burdock seen in the supermarket was fresh burdock (Figure 23 and 24). Even in the pickled vegetable section of the Jusco supermarket, pickled burdock was not seen. Pickled daikon appears to be more popular as there were many forms of pickled daikon. Frozen kimpira cut burdock was seen in the freezer section of the Jusco supermarket.

3.0 COMMERCIAL IMPLICATIONS AND OPPORTUNITIES FOR AUSTRALIAN BURDOCK INTO JAPAN

As part of Mr Jeff Hastings participation in the study tour and his contractual obligations, Mr Hastings has written a report on the study tour from his point of view as an industry representative. In the report, Mr Hastings focuses on the commercial implications of developing a burdock industry in Australia to supply direct into the Japanese market. The report covers a brief market overview, purchasing trends and a list of opportunities and recommendations to develop a semi-processed burdock industry in Australia.

Mr Hastings also has the view that Australia is not competitive in the supply of fresh burdock in Japan as China is too great threat in its ability to supply high quality fresh burdock at a very cheap price. However, the report does suggest that Australia has a real opportunity to produce and supply a range of semi-processed burdock (kimpira or sasagaki cut) directly into the food service and wholesaling sectors of the Japanese market. Mr Hastings also outlines the assumptions and success factors of such an industry, if it were to occur. Those factors are as follows:

7. Securing and implementing the technology necessary to provide at least 28 days shelf life of cut burdock. This allows the burdock to be sea freighted, maximising our competitiveness.
8. Commitment from one or more Australian processing companies prepared to work with growers and grower support organisations will be essential for the development of a burdock industry in Australia. They will need to be the ones that develop supply relationships with companies in Japan, send product samples etc. and gradually establish the capacity and confidence to supply this semi processed product over the long term.
9. Further production trial work throughout different growing regions to prove up all agronomic parameters and maximise grower returns and product quality.
10. Further financial analysis is required in determining accurate production and processing costs in Australia and distribution/logistics costs once landed in Japan for semi processed burdock to ensure our competitiveness.
11. Careful and purposeful marketing of Australian burdock as an industry, and the advantages that we can offer the Japanese market.
12. Positioning Australian semi processed burdock in an effective distribution system within Japan, such that cool chain maintenance can be assured and maximum shelf life and product quality can be obtained.

For further detail of Mr Hastings report, see Appendix 1.

4.0 ITINERARY

Day and Date	Time	Visit/Meeting
Sun 9 December	20:30 22:10	• **Tan, Hastings and McVeigh meet at Departure Lounge** • **Depart Perth on Qantas QF 79**
Monday 10 December	08:30 08:50 10:00 10:30 12:00 13:00 14:30 15:00 18:00 18:30	• Arrive Narita Int. Airport Terminal 2 • Meet Mr Key and Japanese attendants (Mr Kon, Mr Kono, Dr Seki) at Arrival Gate • Leave Narita Airport • Visit Mr Hidoe Takishima, grower of burdock and carrot (about 1 hour) and technical advisor from Sugano Machinery Corp. • Move to next visit. On the way have lunch • Visit organic burdock grower, accompanied by another grower Mr Yoshio Koshikawa and Mr Akio Ito, representative of organic groups. • Move to next visit • Arrive Keisei Narita Station for Mr Hastings to go to Tokyo. Leave for Makuhari City, Chiba Pref. • Check into Hotel Alpha The Tsuchiura, Ibaraki Pref. • Welcome Dinner – Some growers and parties concerned in the region be present
Tuesday 11 December	08:00 08:30 10:30 12:00 14:00 15:30 17:30 18:00	• Leave hotel • Visit Mr Tammio Takayanagi, a contractor for burdock • Visit burdock grower in Tamatsukuri City • Move to Kichijou City and have lunch on the way • Visit Mr Raita Matsuo, president of Shounan Corp, a burdock processor and vendor. • Leave for hotel • Back to Hotel Alpha The Tsuchiura • Have dinner with a wrap-up meeting. Delegates to stay at hotel and attendants to go back to Tokyo.
Wednesday 12 December	07:30 08:00 09:03 10:56 11:30 13:20 14:00 16:30	• Depart Tsuchiura Station on rapid train • Arrive Tokyo Station • Depart Tokyo Station on Hikari 117 (Shinkansen) • Arrive Nagoya train station • Early check in at Nagoya Marriot Associa • Meet with Mr Denis Zolin on 2nd floor of Marriot Associa • Meeting Marushin ABS Co. (fresh vegetable importer) *Meeting cancelled due to personal reasons.* • Back to Marriot Associa
Thursday 13 December	07:20 08:00 10:00 13:30 14:40 15:00 16:00 18:00	• Meet with Mr Denis Zolin on 2nd floor of Marriot Associa • Meeting with Meika Corp., Mr Eiji Ohta (importer) and Meika (market dealer) (1 hour) • Meeting with Kanehatsu Foods (processor), Mr Yoshio Aoki • Depart Nagoya on Hikari 215 (Shinkansen) • Arrive Shin-Osaka station • Kaz Kuroda to meet us at central exit of Shin-Osaka station • Meeting with Osaka Delica Foods (processor), Mr Keiji Yoshimi • Check into Hotel Granvia, Osaka

Friday 14 December	08:30 09:00 11:00 15:00 17:30 21:30	• Pick up at Hotel Granvia • Visit Osaka Central Wholesale Markets, meet with Mr Kanada • Meet with Sato Restaurant Systems, Mr Kenichi Inui • Meet with S. Ishimitsu & Co. Ltd., Mr Morimoto • Debriefing • Hastings departs Osaka for Brisbane
Saturday 15 December	09:00 13:16 16:16 17:03 17:55 2045	• Visit supermarkets and convenience stores • Depart Osaka on Hikari 120 • Arrive Tokyo Station • Depart Tokyo Station on Narita Express No.37 • Arrive Narita Airport Terminal 2 • Depart Narita Int. Airport on QF 70
Sunday 16 December	06:00	• Arrive Perth Int. Airport

5.0 RECOMMENDATIONS

As a result of the study tour, it was concluded that Western Australia may not be able to compete against China in the fresh burdock market in Japan. Therefore, more emphasis will be placed on the viability of developing a semi-processed burdock product with an extended shelf life. From the study tour, the following recommendations were made:

1. Conduct economic feasibility analysis on the prospects of processed burdock into the Japanese market.
2. On the basis on the analysis, continue research with Food Science Australia to:
    i) develop a semi-processed burdock product (ie. kimpira cut or sasagaki cut)
    ii) identify necessary processing machines required to produce fresh cut burdock and the cost of these machines
    iii) investigate packaging (i.e. vacuum) and product treatments (i.e. absorbic acid, coatings) to extend the shelf life of the semi-processed product (greater than 20 days).
3. Send samples of semi-processed burdock products to interested importers and processors met during the study tour to confirm preferred flavour, colour and most importantly texture. Also to get an indication of price.
4. Disseminate research and gauge interest in such a venture with potential growers and processors in Western Australia.
5. Continue current burdock agronomy trials to improve marketable yields and maximise returns for growers. Also, continue trials using the variety Yanagawa Riso, the most widely used burdock variety in Japan for both fresh and processing markets.
6. Investigate and/or continue research on other potential export vegetables such as sweet corn, kabocha (Japanese pumpkin) and soramame (broad bean).

6.0 ACKNOWLEDGEMENTS

Horticulture Australia Ltd. funded the study tour and their contribution is gratefully appreciated.

The Department would like to thank Mr Jeff Hastings of Xylem International for his participation and contribution to the study tour. Many thanks goes to Mr Kichinori Kon, President of Agricultural Technology Communications for his valuable time and driving skills. Our thanks also go to Mr Yoshihiro Asakawa for organising our itinerary whilst in the Chiba/Ibaraki area and to Mr Tomohiro Kono for interpreting during our meetings. Thanks to Mr Bernard Key from the Western Australian Government Office for accompanying us for the first two days of our tour. The organising of our itinerary and transport by Mr Denis Zoiln of Austrade Nagoya and Mr Kazuya Kuroda of Austrade Osaka, is gratefully acknowledged. Finally, many thanks to all the growers, machinery operators and manufacturers, importers, wholesalers and processors who agreed to meet with us.

7.0 APPENDICES

Appendix 1 - Jeff Hastings Report – Commercial implications and opportunities for Australian burdock into Japan.

Appendix 2 - Contact List

Appendix 3 - Photographs of study tour (Figures 1 – 24)

APPENDIX 1

COMMERCIAL IMPLICATIONS AND OPPORTUNITIES FOR AUSTRALIAN BURDOCK INTO JAPAN

Jeff Hastings
Xylem International
Email: jeff.hastings@bigpond.com

Date: 4 January 2002

Introduction

This report focuses on the commercial implications of developing a burdock industry in Australia to supply directly into the Japanese market. It also discusses some real and current commercial opportunities for Australian growers, food processing companies and industry support organisations, to develop a burdock industry capable of producing and supplying into Japan on a profitable basis.

The suggestions and strategies offered in this report have been developed by the author over many years of working on burdock in the Japanese market, culminating in a recent visit (December 2001) to Japan with Department of Agriculture personnel to solidify market assessment and identify opportunities for a possible Australian burdock industry. They are offered to provide further understanding of the Japanese burdock market and for the Western Australian horticultural industry to consider burdock as a commercial alternative to existing crops currently grown throughout the State.

Market Overview

A detailed market overview will be covered in detail in the accompanying Department of Agriculture report. However a few key observations set the scene for this report.

Japan consumes approximately 230,000 – 300,000 tonnes of burdock each year. Nearly half of this annual demand is imported, while the balance is grown in Japan. This balance is changing every year in favour of increased imports, due to pressures on local production and the cheap but improving quality of the Chinese imports.

Local production is concentrated around 3 distinct regions being 1. Aomori/Hokkaido prefectures (north Japan) 2. Ibaraki/Chiba prefectures (around Tokyo) and 3. Kagoshima in the south of Japan. Increased pressures are being felt by Japan's burdock growers due to;

- Increasing urban encroachment forcing land prices higher,
- The reluctance for rural youth to remain 'on the farm', with the average farmer age now over 60 years,
- Lowering domestic prices due to cheaper imports and
- The recent trend by the food service sector and processors alike to actively pursue off shore joint venture investments into burdock production and processing.

Of the imported burdock, approximately 80% currently is sourced in from China, with 15% from Taiwan and 5% from other countries, including a very small volume from

Australia. The volume being imported from Taiwan is rapidly decreasing each year in favour of Chinese imports.

The total volume of burdock imported from China is increasing, despite a gradual decrease in the overall consumption by Japanese consumers. This is an indication of China having a lower price than all alternative suppliers and the increasing quality of their burdock, particularly over the last 2 years. China has also increased its supply window to being able to supply into Japan for almost 12 months per year. However, despite this strong position that China has, many Japanese buyers continue to be frustrated with the way business is conducted with Chinese companies. The main issues of reliability and consistency have not been solved. The increasing trend for joint venture operations by Japanese companies in China (discussed below) may help to alleviate this situation.

As a fresh product burdock is very price sensitive and will be a very difficult market for Australia to penetrate. However, the market for processed and semi processed burdock has a completely different structure to it, with a different target market than fresh burdock. The opportunities that can be developed for semi processed burdock, grown and processed in Australia are discussed in detail below.

Purchasing Trends

Recent Japanese Department of Finance figures show the total volume of burdock imported into Japan in the year 2000 was 175,130 tonnes, with 655 tonnes of this coming from Australia. Of this total only 47% were imported as fresh burdock, showing the high demand for processed or semi processed burdock.

Although the majority of all burdock traded by wholesalers in Japan is done as 'fresh' burdock, an estimated 70% of all burdock purchased at the retail level is purchased in a processed or semi processed form. This trend is thought to be increasing, indicating a growth period for the food processing and food service sector, both in Japan and off shore as more and more Japanese companies look to outsource their processing needs.

This means that irrespective of whether burdock is being sold into Japan as fresh or processed, most of it will be processed before it reaches the consumer, and this is where the future opportunities to supply could lie.

The evolution of Japanese purchasing trends for fresh burdock can be broken into 5 broad evolutionary stages as, shown in Table 1.

Table 1: Evolution of Purchasing Trends for Burdock

Stage	Description	Time Period
1	Local production	Continuing
2	Imported from Taiwan (now almost non existent)	Continuing but Decreasing
3	Imported from China (Low quality and low price)	Pre 2000
4	Imported from China (High quality and low price)	2000 – Current
5	Joint venture companies in China with Japanese interests	2001 – Current

Product Quality Issues
Japan demands high quality in all their vegetable products. They also seek to purchase vegetables that have been produced in a 'clean and green' environment with high nutritional value.

Perception is reality with burdock, as it is with most food sold in Japan. This is one area where a future Australian burdock industry could position itself at the forefront of Japanese quality preferences, due to our perceived clean environment, fresh running water, favourable climate and efficient farming practices.

Any burdock purchased from Australia would be perceived as having a higher quality than China and perhaps matching that of Taiwan. This quality advantage should result in a higher purchase price than that of China.

Domestic production, although decreasing in volume, is perceived as having the highest quality. Japanese consumers generally would prefer to buy locally produced burdock if available, although price will always be an important criterion to purchasing.

The issues relating to semi processed burdock internal eating quality are no different to that of fresh burdock. The colour needs to be naturally white (not bleached white), the flavour sweet, the texture should resemble a soft crispy crunch with minimal fibre and it must be free of any bacterial contamination.

Opportunities for Australia

The following list of opportunities and recommendations on a possible direction for an Australian burdock industry reflect the views and opinions of the author, and each would require further development work to fully ascertain their viability.

1. Fresh or Semi Processed

Recent developments in Chinese produced burdock have rendered Australia non competitive in the supply of 'fresh' burdock into Japan. A Japanese wholesaler can purchase high quality fresh imported burdock from China nearly all year round at typically AUD$0.80 - $1.15/kg landed in his warehouse. In the same market semi processed burdock (fresh-cut into bulk bags) will typically sell for AUD$4.00 - $6.50/kg, depending on the target market and the distribution system used.

Semi processed burdock can come in a number of forms, as follows;

1. Kimpira cut (julienne shape typically 2.5 x 2.5 x 45 mm or 3 x 3 x 35 mm)
2. Sasagaki cut (thin scallop shape)
3. Angle sliced
4. IQF frozen
5. Pickled
6. Extended shelf life by using a water or brine solution in the packaging.

The highest demand is for either kimpira or sasagaki cut in as fresh a form as possible. The typical existing supply chain in Japan sees fresh burdock either imported or purchased locally and sent to a processing company for cutting into either kimpira or sasagaki styles. It is then sold to the food service or retail industry for sale to consumers. The shelf life of cut burdock is only 3-4 days when stored at the correct temperature. Processed in either a water or brine solution will provide an additional 1-2 days shelf life. For Australia to penetrate this semi processed market it must rely on newly developed extended shelf life technology such as that recently developed by Food Science Australia. This will be discussed in the Technology section below.

Allowing for the wholesalers modest margin, the difference in pricing between 'fresh' and semi processed is dramatic and suggests that if we can prove up the technology required to extend the shelf life for sea freighting purposes, an opportunity may exist for Australia to export semi processed burdock into the Japanese market at a competitive rate.

There are 2 other key factors that could further support this opportunity.

1. The cost of waste removal in Japan is very high and is a key consideration for all food processing and food service companies. If they can purchase burdock in a semi processed form then they eliminate their waste problems, with all the waste being removed by the processor in Australia.
2. Japanese food processors generally are looking to outsource parts of their processing operations that have either high waste problems, high labour components or large space requirements in their factories. This very recent trend opens an opportunity for Australian growers and processors.

2. Market Segment

The market segment suggested for the supply of semi processed burdock is to the following sectors;

- Food service companies
- Supermarket and convenience store chains
- Wholesalers

While many of these companies will only purchase through a trading company, some will deal direct and the others can be developed in combination with their preferred importer. This is now common practice in exporting fruit and vegetables into Japan.

The advantages offered to this market in purchasing Australian semi processed burdock, would include;

- Price and quality competitiveness
- Extended shelf life of product once landed in their depot
- Perception of clean and fresh production region, resulting in high quality burdock
- Mode of doing business as reliably, continuous, high quality supplier.

3. Joint Ventures

Recent developments by Japanese companies in joint venturing with Chinese counterparts to secure long term supply arrangements could see the same arrangements available to Australia. The technological, climatic, environmental and business advantages that Australia has could provide a valid and viable alternative for Japanese importers. The general perception that Japanese consumers have of Australia is very conducive to the development of this argument.

4. Technology Advantage

To offer a competitive semi processed burdock product into the Japanese market, it will require the use of technology sufficient to extending the shelf life of the cut burdock by a minimum of 28 days. A shelf life of 32-35 days would be preferred to counter any distribution problems that can occur and to give the customer a shelf life advantage over competitive products, once it lands in his depot.

Department of Agriculture and the author have been developing extended shelf life technology with Food Science Australia, throughout 2001 and results to date indicate that the required shelf life extension may be possible with this technology. Further verification trials will be required to validate this technology and ensure its commercial rigour.

Summary

Australia is not competitive in the supply of fresh burdock into Japan, even after considering the potential seasonal advantage that Australia has over its Northern Hemisphere competitors. China is too great a threat, at least for the next few years, due to their ability to supply high quality fresh burdock at a very cheap price, nearly all year round. In addition, the current trend of forming Japanese/Chinese joint ventures to secure supply arrangements from China, looks to be continuing. However it will be worth monitoring the Chinese burdock production and supply security into Japan in a few years time when China may be facing greater internal migration issues, and the need to provide sufficient volumes of food to feed these populations could become the major market for domestically produced burdock.

There is however a very real opportunity for Australia to produce and supply a range of semi processed burdock directly into the food service, retail supermarket and wholesaling sectors of the Japanese market. The preferred style of cut is either the kimpira or sasagaki cut burdock, packaged in either bulk packs or possibly directly into retail packs using Japanese labelling.

Current pricing in Japan shows kimpira or sasagaki cut burdock wholesaling for AUD$4.00-$6.50/kg compared to AUD0.80-$1.15/kg for fresh burdock in the same market. While further analysis is required on the cost of processing in Australia and on the various costs and margins associated with getting from a C&F position through to wholesale selling price in Japan, there is enough evidence to suggest that the supply of semi processed burdock could be profitable for Australian growers and industry alike.

The current trend for Japanese processors to outsource aspects of their processing operations to improve efficiencies in waste management, space utilisation and labour costs, further enhances the opportunity for Australia to develop and secure a burdock industry based on a semi processed product.

The success of such an industry would be reliant on a number of factors, namely;

1. Securing and implementing the technology necessary to provide at least 28 days shelf life of cut burdock. This allows the burdock to be sea freighted, maximising our competitiveness.
2. Commitment from 1 or more Australian processing companies prepared to work with growers and grower support organisations will be essential for the development of a burdock industry in Australia. They will need to be the ones that develop supply relationships with companies in Japan, send product samples etc and gradually establish the capacity and confidence to supply this semi processed product over the long term.
3. Further production trial work throughout different growing regions to prove up all agronomic parameters and maximise grower returns and product quality.
4. Further financial analysis is required in determining accurate production and processing costs in Australia and distribution/logistics costs once landed in Japan for semi processed burdock to ensure our competitiveness.
5. Careful and purposeful marketing of Australian burdock as an industry, and the advantages the we can offer the Japanese market.
6. Positioning Australian semi processed burdock in an effective distribution system within Japan, such that cool chain maintenance can be assured and maximum shelf life and product quality can be obtained.

APPENDIX 3

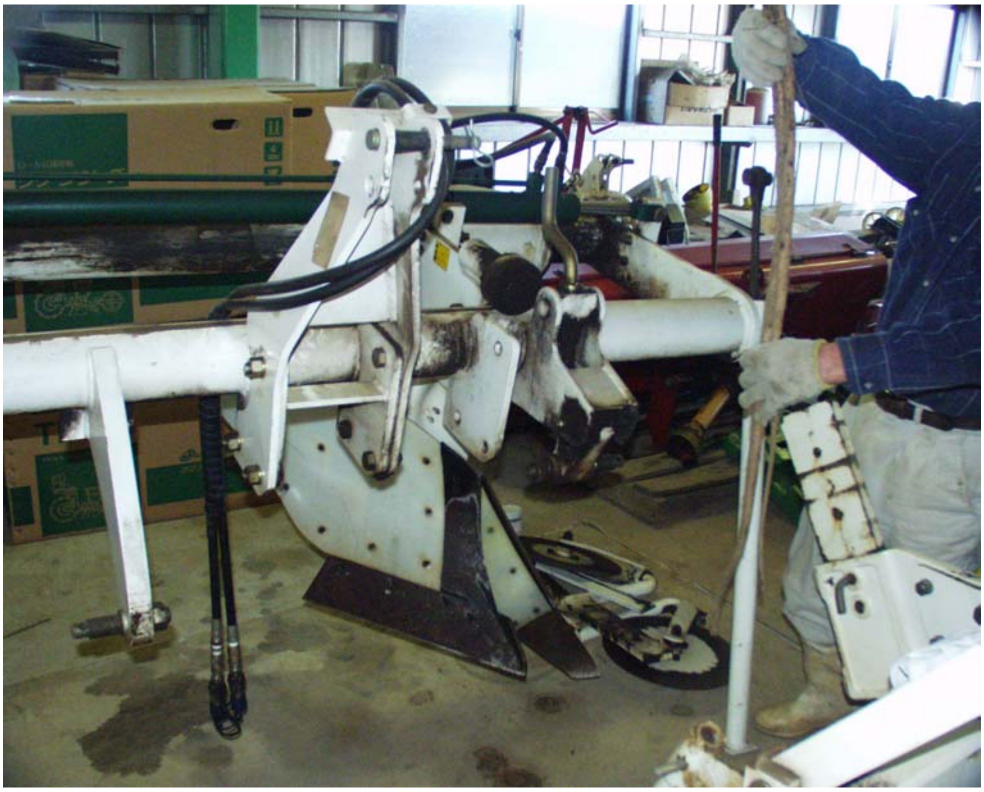


Figure 1: Sugano plough lifter used to harvest burdock roots

Figure 2: Jeff Hastings, Mr Koshikawa, Soon Chye Tan and Vynka McVeigh

Figure 3: Rotary trencher used to cultivate soil for burdock planting

Figure 4: Kawabe root digger

Figure 5: The belts used to lift the burdock root by the crown out of the ground

Figure 6: Mr Takayangi and Kawabe root digger with cradle of burdock roots

Figure 7: Cutting the stalk off the burdock root using a circular saw.

Figure 8: Burdock grading machine

Figure 9: Burdock roots, graded and brushed.

Figure 10: Brush machine for burdock

Figure 11: Trencher fixed with probes that applying soil fumigant deep into the soil whilst trenching

Figure 12: Burdock processed in sasagaki cut

Figure 13: Kimpira cut burdock and carrot at Shonan Co. Ltd.

Figure 14: Unwashed burdock halves ready for packaging.

Figure 15: Washed burdock halves packaged ready for the supermarket

Figure 16: Refrigerated truck loaded with fresh burdock

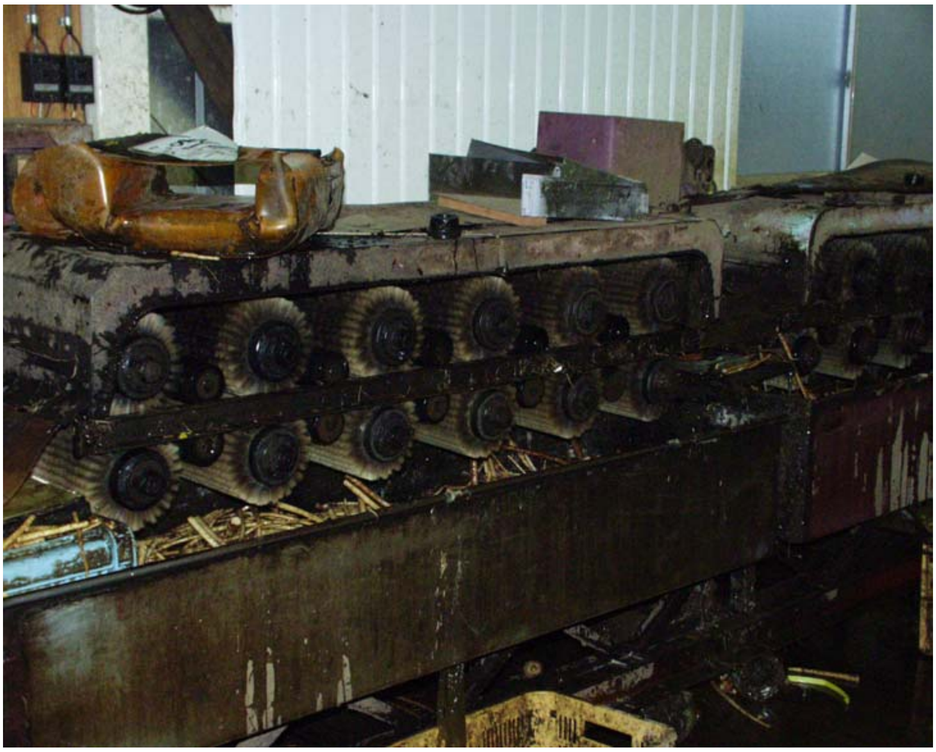


Figure 17: Burdock washer at Shonan Co. Ltd.

Figure 18: Kimpira cutter machine

Figure 19: Sasagaki cutter machine

Figure 20: Vacuum packed burdock, carrot and daikon processed by Osaka Delica

Figure 21: Sasagaki cut burdock in 150g pack distributed by Sato Restaurants

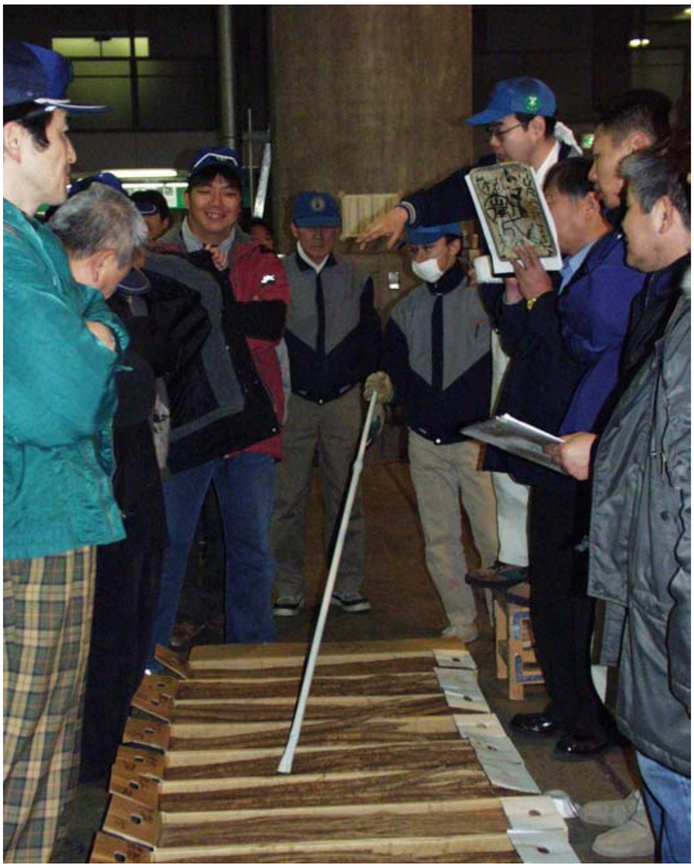


Figure 22: Fresh burdock auction at Osaka Wholesale Markets

Figure 23: Whole washed burdock (2 pieces) from China

Figure 24: Vacuum packed burdock pieces at small supermarket in Nagoya

FOOD SCIENCE AUSTRALIA
A JOINT VENTURE OF CSIRO AND AFISC
CSIRO
Afisc Australian Food Industry Science Centre
ABN: 78 695 101 514

Confidential Project Report

PROCESSING OF FRESH-CUT BURDOCK (Arctium Lappa L.)

Project Number 103248

Report for:
Agriculture Western Australia
Dr S.C. Tan

Prepared by: Mala Gamage and Thu Vu

EXECUTIVE SUMMARY

This study was conducted to assess the possibility of minimally processing burdock roots. In this study the browning behaviour of the root was observed. Root segments were treated with citric acid and ascorbic acid solutions at pH 2.5 and 3.0 and were exposed to ambient conditions and the browning patter of the roots was observed. Browning prevention was studied at two levels of processing, immediately after peeling and at intervals during storage of the packaged product at 4°C.

Burdock roots are highly susceptible to browning and change the colour, within a few minutes (5 min) after peeling. Browning is very rapid near especially the peel where it is more than in the inner tissues. A dipping treatment with ascorbic acid at pH 2.5 was effective in controlling the browning for 2.5 hr (150 min) at 22°C at ambient conditions Storage of peeled roots in water or 0.3% citric acid was essential to prevent browning, prior to further processing.

Cut burdock (julienne cut) was treated with 2% ascorbic acid and packed in low density polyethylene (LDPE), developed a pink colour and turned into brown during storage. Treated product when stored in barrier bags with or without vacuum, retained the whitish colour during a 10-day storage trial at 4°C.

Further studies on minimal processing unit operations, evaluation of varieties, harvesting time and post-harvest storage conditions are necessary to launch a commercially viable fresh cut burdock product to the export market.

CONFIDENTIAL PROJECT REPORT
PROCESSING OF FRESH-CUTBURDOCK (ARCTIUMLAPPA L.)

FOR Agriculture Western Australia Dr S.C. Tan

INTRODUCTION

Burdock (Arctium lappa L.) is a new crop introduced to Western Australia. It has been assessed by the Centre for New Industries Development, Agriculture Western Australia as a product with very high market potential in Japan. It is a widely consumed vegetable in Japan. Currently burdock is exported in un-processed form in bulk container packs at 4' - 7'C. In Japan this product is marketed in the form of "Julienne cuts" packed in flexible packages and is available in 100g retail and 5Kg wholesale packages. If the product is exported from Australia in processed form the profit margin may be increased up to 6-7 fold. Hence, Agriculture Western Australia approached Food science Australia to identify the possibilities of processing burdock into fresh-cut form suitable for transport to Japan.

PROJECT AIM

Conduct preliminary visual observations on fresh-cut burdock and identify factors likely to limit shelf life.

Stage 1

- To conduct a literature search and review related literature.
- Investigate peeling and cutting methods of burdock and identifying suitable equipment.
- Measure pH and texture (penetrometer) and monitor colour changes at room temperature to finalise experimental conditions at Stage 2.

Stage 2 Preliminary storage study

Based on the initial investigations and interpretation of the literature, conduct experiments on the prevention of browning in fresh-cut burdock.

Based on results of this preliminary study provide a detailed project proposal to the Project Manager, Centre for New Industries Development Agriculture Western Australia.

LITERATURE REVIEW

Enzymatic browing of fruit and vegetable products are caused bythe oxidation of polyphenols by oxidative enzymes (Gallezzi et al, 1981). Studies conducted by Muro et al (1993) on polyphenol oxidase enzyme (PPO) activity of edible burdock (Arctium lapa L.) revealed that this enzyme has a very high oxidative activity specific to pyrogallol. The optimum pH is reported to be 7.0 and the enzyme is sable at pH 7.0 - 9.0, It is reported that burdock contain about 0.78% of polyphenols such as caffeic acid and chlorogenic acit etc. (Munro et al, 1993).

It is reported that treatment with 0.3-0.35% citric acid (pH = 3.0) and 0.07-0.1 1% sodium 6-metaphosphate (pH 3-6) could prevent browning in burdock root (Liu et al, 1997). Lee-kim and Hwang (1 997) studied the inhibition of crude and purified PPO from burdock. This study reported that 4-hexylresorcinol (HR) has inhibitory effects on crude PPO extracts of burdock. The effect of ascorbic acid (AA) was reported to be lower than that of HR but was comparable to bisulfites. The effect of binary mixtures of I-IR + AA, HR + citric acid (CA) and AA + CA on purified PPO was reported and the effectiveness was in the decreasing order. However, it is reported that the binary mixture of AA + CA was more effective than the separate use of each compound.

A study conducted on heat inactivation of purified PPO of burdock revealed that heating for about 1 0 min at 60'C could cause 50% loss in enzyme activity (Leekim et al, 1995). Polyphenol oxidase and peroxidase in edible burdock were reported to be inactivated by heat treatment at 98 ' +2 ' C for 8 min and prevented browning during frozen storage (Ming, 1995).

Two Japanese patents on cut burdock indicated the use of vacuum packaging in barrier bags on prevention of browning in cut burdock during processing (JP 11 187812-A, JP03004763-A).

MATERIALS AND MEETHODS

Burdock roots:

Burdock roots were sent from Agriculture Western Australia by refrigerated transport to Melbourne fruit and vegetable markets. Roots were transported to Food Science Australia at room temperature and stored at 4'C immediately after arrival. Three batches were received from western Australia: Batch 1 - variety Yanagawa Riso R2,
Batch 2 - variety unknown form a commercial grower, Batch 3 - variety Takinogawa.

Chemical ragents:

Food grade ascorbic and citric acid (Langdon, Australia) were used in all experiments.

Measurement of pH:

Three representative burdock root samples from variety Takinogawa (100 g) were homogenised with equal weight of deionised water and the pH of the resulting puree was measured at 20'C using a pH meter (Activon 2 1 0, Australia) calibrated with buffers at pH 4 and 7 (BDH, Australia).

Measurement of colour:

The browning of peeled burdock was very rapid therefore visual judgement was only used to identify the point of un-acceptability. Colour of the samples was measured using a Minolta colouremeter (CR 200, Japan). Colour was measured as L, a and b. Change in hue values related well with the visual observation of colour. Therefore hue values were selected to represent the colour change in fresh cut burdock.

Hue Value - Tan^{-1} (a/b)

Peeling method:

Peeling experiments were conducted with the variety Yanagawa Riso R4 (first batch).
Peeling of the burdock roots was conducted immediately after removal from 4°C and heat treated as follows.
1 - 75°C water-bath for 3 minute and submerged in atater at 22°C.

2 - 95° C water-bath for 30 seconds and submerged in water at 22°C.
After heat treatment roots were peeled and submerged in tap water or in 0.35% (pH 2.5) citric acid. The colour of the roots was observed visually.

It was not possible to measure the texture of the roots with the penetrometer. Texture measurements were conducted using Instron (Series 4400, USA) with Kramer cell.

Experiment 1 - Observation of browning at ambient conditions

Colour change at room temperature (22°) was studied in this experiment Five, 6 cm long pieces were cut from each burdock root (second batch, variety unknown) and each piece was then cut into quarters along the longitudinal axis.

From each six cm long piece

1. One quarter was left on a plastic dish and was exposed to air at ambient temperature.
2. The second quarter was dipped in the relevant solution for 10 min and then exposed to air on a plastic dish at ambient temperature.
3. The third quarter was dipped in the relevant solution for 20 min and then exposed to air on a plasticdish at ambient temperature.
4. The fourth quarter was left in the solution at ambient temperature.

The dipping solutions used in this experiment were distilled water, citric acid solution at pH 2.5 and 3.0, and ascorbic acid solution at pH 2.5 and 3.0 (Table 1). Storage in air at ambient temperature (22'C) was used to accelerate the browning reactions.

This experiment was duplicated on the same day using a second burdock root. The colour of the burdock pieces was recorded using a Minolta colouremeter at 5, 35, 65, 155 and 295 min after exposure to air. The colour was also observed visually and recorded for all treatments.

Table 1 - The pH and concentration (w/w %) of dipping used in experiment I.

Type of solution	**pH of the solution**	**Acid % w/w**
Distille water		
	2.5	2.11
	3.0	0.19
Citric		
	1	2.5
	1	3.0

Experiment 2 - Preliminary processing experiment

Burdock roots from the second batch (variety unknown) were used in this experiment. This sample was of very poor quality and on arrival the inner tissues were brown and dry. Four 6 cm long pieces were cut from each burdock root and were marked 1 to 4 starting from the shoulder end (leaf bearing end) of the root. Each piece was then cut in to quarters along the longitudinal axis and dipped in dipping solutions described in Table 1, for 20 min. This was repeated for all 4 pieces obtained from one root. After removing from the dipping solution burdock pieces were packed in bags. Each bag contained four quarters, one from each piece (no 1 to 4). This procedure was repeated for all twelve treatments.

Table 1 - Treatment combinations used in experiment 2

Treatment	**Dipping solution**	**Type of packaging**	**Storage temperature °C**
Tl	1 % Vitamin C	Barrier bag	1
T2	2% Vitamin C	Barrier bag	1
T3	Control - Dist Water	Barrier bag	1
T4	1% Vitamin C	Barrier bag	4
T5	2% Vitamin C	Barrier bag	4
T6	Control Dist Water	Barrier bag	4
T7	1% Vitamin C	Polyethylene bag	1
T8	2% Vitamin C	Polyethylene bag	1
T9	Control Dist Water	Polyethylene bag	1
T10	1 % Vitamin C	Polyethylene bag	4
Tll	2% Vitamin C	1 Polyethylene bag	4
T12	Control Dist Water	1 Polyethylene bag	4

Experiment 3

Burdock roots from variety Takinogawa were used in this study. Roots were peeled using a kitchen peeler under water and peeled roots were submerged in dipping solution 1 as described in table 2 until further processing. Peeled roots were cut into 6 cm long pieces and fed into a food processor (Anlikaer, Switzerland) and cut into julienne cut (3-4 mm side and 1 -6 cm long). The cut pieces were collected directly from the food processor into a container with dipping solution 2 as described in Table 2.

Table 2 - Dipping solutions used in experiment 3

Treatment	**Dipping solution** 1	**Dipping solution** 2	**Type of packaging**
Control 1- air	Distilled Water	Distilled water	Barrier bag + air
Control 1 - vac	Distilled Water	Distilled water	Barrier bag + Vacuum
Control 2 - air	0.35% citric acid	Distilled water	Barrier bag + air
Control 2 - vac	0.35% citric acid	Distilled water	Barrier bag + Vacuum
T1000 - air	0.35% citric acid	1.0 % Ascorbic acid	Barrier bag + air
T1000 - vac	0.35% citric acid	1.0 % Ascorbic acid	Barrier bag + Vacuum
T2000 - air	0.35% citric acid	2.0 % Ascorbic acid	Barrier bag + air
T2000 - vac	0.35% citric acid	2.0 % Ascorbic acid	Barrier bag + Vacuum
T2025 - air	0.35% citric acid	2.0 % Ascorbic acid + 0.25% citric acid	Barrier bag + air
T2025 - vac	0.35% citric acid	2.0 % Ascorbic acid + 0.25% citric acid	Barrier bag + Vacuum
T2035 - air	0.35% citric acid	2.0 % Ascorbic acid + 0.25% citric acid	Barrier bag + air
T2035 - vac	0.35% citric acid	2.0 % Ascorbic acid + 0.25% citric acid	Barrier bag + Vacuum

After dipping the cut burdock in the relevant solutions they were drained on a plastic strainer for 1 min and packed in barrier bags. Samples sealed with vacuum were packed using a (Webomatic, West Germany) vacuum packing machine at 0.8 bar vacuum and heat sealed. Samples packed in air were sealed using a heat sealer (Venus, Australia). An samples were stored at 4'C and evaluated on 4, 8 and 10 days for colour and texture using Kramer cell with Instron (Series 4400, USA). Barrier bags were purchased from Cryovac -W.R. Grace Australia Ltd with the following specification:

- size: 18Omm x 305 mm
- structure: EVA-PVDC-EVA
- thickness: 50 micron
- OTR: typically 25 MI/M2 /24 hrs/atm
- VJVIR: typically 10-15 MI/M2 /24 hrs/atm

RESULTS

Peeling of burdock roots:

In our study heat treatment was not very effective in controlling browning of burdock root after peeling. Browning in heat-treated samples was faster than in the samples peeled at 4'C. Submerging roots in tap water or in 0.35% citric acid after peeling helped in delaying the browning on peeled surface of both heat-treated and untreated roots.

pH of the burdock roots:

The pH of Takinogava burdock roots was 6.03 $\pm$ 0.08, (N = 3).

Experiment 1

A difference in browinng pattern was observed on the inner cut surface and peel side of burdock piece. Therefore the colour of the peel side and inner side were measured separately and are presented in two graphs (Fig 1 & 2). Hue value was calculated using a and b values obtained with the Minolta Colorimeter. A hue value of 100 represents a yellowish white colour and a decrease in hue value was noted with the browing of samples. At a hue value of 80 - 85 the browning was very prominent and the colour became unacceptable when hue values were less than 95. At this stage the colour was noted as light brown.

Fig 1 & 2 show the colour change of burdock pieces on the peel side after subjecting to various dipping treatments for 10 min and 20 min respectively and exposed to air for 5 hrs. The control samples were left in air untreated from the time of cutting and showed a rapid reduction in hue value and was unacceptable, 5 min after cutting or peeling. Except for the samples treated with ascorbic acid at pH 2.5 all the other treatments reached a hue value below 95 after 35 min exposure to air. Samples treated in ascorbic acid at pH 2.5 for 20 and 10 min showed a similar pattern in colour change after exposure to air. These samples had a hue value above 95 for 155 min.

Fig 3 & 4 show the colour change of burdock pieces on the cut surface after subjecting to various dipping treatments for 1 0 and 20 min respectively and exposed to air for 5 hrs. Colour change on the inner cut surface was slower than on the skin side. In control samples, the hue value of the cut surface after exposure to air for 5 hrs, was ≈83 where as the hue value of skin surface was < 80. The hue value of cut surface in treated samples showed distinctive difference from the control samples during the 5 to 295 min exposure periods. Samples treated with ascorbic acid at pH 2.5 for 1 0 and 20 min showed the best colour retention when compared to all the other treatments. The difference between dipping times was not very prominent.

Visual observations made on the colour of the samples left in solution showed that, only the samples stored in ascorbic acid solutions at pH 2.5 and 3.0 were able to retain the white colour for 2.5 hrs (1 *50* min).

Experiment 2:

This experiment failed because of the poor quality of the burdock roots. However, the visual observations showed that when cut burdock was stored in polyethylene bags, the roots first turned pink and then turned brown during storage. The pink colour development was more prominent with the ascorbic acid treated samples. Colour retention was good when stored in barrier bags.

When compare the storage temperature, storage at I'C resulted browning in all samples when compared to the samples stored at 4'C for 1 0 days.

Experiment 3:

Colour.

The sample was comprised of matchstick size julienne cut pieces (2mm X 2 mm). Therefore the colour difference between peel side and the inner part of the root was not apparent. Samples packed under vacuum and air both showed a similar trend in hue value change during storage at 4' for 1 0 days (Fig 5&6).

The two controls, which were only treated with a water dip (control 1) or 0.35% citric acid (control 2) after peeling showed a hue value lower than the treatments which had a second dipping treatment to prevent browning. The hue value showed a slight increase on day 4 and remained at constant during storage.

Among the samples that had a second dip samples treated with 2% ascorbic acid or a combination of 2% ascorbic acid with citric acid had hue values in the same range and the values remained above 95. The samples treated with (second dip) 1% ascorbic acid had a hue value at or below 95 and was slightly lower than the samples treated with 2% ascorbic acid or a combination of 2% ascorbic acid with citric acid.

According to visual observations all samples treated with a second dip with 2% ascorbic acid or a combination of 2% ascorbic acid with citric acid had an acceptable whitish colour where as the controls were light brown in colour.

Texture:

Texture was measured as the load at the highest point in kilo newtons. Texture of the burdock pieces did not show a definite trend under the conditions studied in this experiment. Further replication and detailed study on texture analysis of this product is necessary before comparing the treatment effects.

DISCUSSION

Observations made in this study on fresh cut burdock shows that the browning was very rapid after peeling or cutting of the root. The browning was intense and more rapid near the peel than at the inner part of the root. Therefore, it was essential to conduct the peeling and cutting under a stream of running water. Another approach was to store the peeled root in water or in 0.35% citric acid. Although the results of this study show that storage of peeled roots in water was superior to storage in 0.35% citric acid solution, the effect of this pre-dip and its duration has to be studied in detail. This will provide information that can be useful in handling pre peeled roots, under a commercial processing situation where delays are usually encountered.

The heat inactivation of browning enzymes was not successful in this study. This may be due to the lower temperatures and short exposure times used in this study. Ming (1995) reported that PPO and peroxidase activity of burdock could be inhibited by heat treatment at 98' $\pm$ 2'C for 8 min.

Results of the first experiment showed that the type of acid used to lower the pH of dipping solution was more important than actual effect of pH. By exposing the treated samples to ambient conditions browning was accelerated, to observe the relative effectiveness of the treatment solutions. At pH 2.5 and 3.0 only ascorbic acid was able to delay browning. This shows that the anti-oxidant property of ascorbic acid is more important than the lowering of pH.

Experiment 3 showed that there was no significant difference in colour, of the samples treated with 2% ascorbic acid or a combination of 2% ascorbic acid with citric acid. However, this observation contradicts with the results reported by Leekim and Hwang (1 997) on crude and purified PPO extracts of burdock. It was reported that the mixtures of ascorbic acid and citric acid were more effective in inhibiting PPO, than the separate use of ascorbic acid or citric acid.

Packaging with or without vacuum did not show much effect on the colour this may be due to the high barrier properties of the bags used in experiment 3. Vacuum was used to reduce the amount of air present in headspace and thereby reduce the amount of oxygen available within the package. When samples were packed in low density polyethylene (LDPE) bags (experiment 2), samples became brown gradually (data not shown). This may be due to the high oxygen content in headspace, which relates to the comparatively high permeability of LDPE. Therefore packaging in LDPE was not investigated further. However, it is essential to find the correct type of packaging material so that the samples remain under aerobic condition while retaining the whitish colour. A balance between prevention of browning and anaerobic respiration is important for prevention of flavour changes and to retain the microbiological safety. Under anaerobic conditions harmful micro-organisms could proliferate and leading to health hazards. The atmosphere in the head space was not monitored in this experiment.

In general the colour change of the varieties supplied to our laboratory showed a difference. (Trials on variety evaluation were not conducted under this contract.) Also the maturity or the age at harvesting might affect the browning pattern.

In the first experiment it was noted that when samples were stored in acid solutions for a period of 8 hr the root pieces were softer than the samples stored in water. When texture measurements were made using Instron texture measuring device a continuous trend was not observed.

CONCLUSIONS

Colour of fresh cut burdock can be retained for a short period (2.5 hr or 150 min) under ambient conditions, using a 2% ascorbic acid dip. However, the retention of colour during storage depends on the barrier properties of the packaging material used and storage at refrigerated temperature (40C). In this study, 2% ascorbic acid treatment together with storage in barrier bags enabled the storage of burdock pieces without a significant colour change for 10 days at 40C. Taste and microbiological quality of the stored product were not investigated in this study.

RECOMAUNDATION

It is important to study the microbiological and sensory properties of the product under current experimental conditions to understand or predict the shelf life of this product. It is recommended to select the suitable packaging material based on respiration rate and browning of the product.

FURTHER WORK

Further work has to be conducted on following aspects:

1. Conduct further work on unit operations on fresh cut burdock processing.
2. Select suitable burdock varieties for fresh cut processing.
3. Study the effect of climatic and agronomic factors on the quality of fresh cut burdock.
4. Study the effect of harvesting time and pre processing storage conditions.

Please see the attached project proposal.

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Dr Mala Gamage

(pH D in Food Science, UNSW)

Detailed Project proposal for further Studies

Stage 1 - Developing a commercially viable fresh cut burdock processing method.

Laboratory scale trials are necessary for the selection of a washing system, inactivation of browning enzymes using physical methods, selection of suitable packaging material, microbiological quality evaluation, organoleptic evaluations and estimation of maximum shelf life at refrigerated and near freezing temperatures.

Stage 2 - Selecting suitable burdock varieties for fresh cut processing.

Literature on potato and other fruit and vegetables demonstrate that different varieties of a crop could show difference in browning potential. Therefore it is important to identify varieties that are less susceptible to browning. It is also important to identify varieties having "high aroma properties" to result in a fmal product with considerable level of aroma after processing. There may be other desirable qualities that are important to traditional consumers of this product.

Stage 3 - Studying the effect of climatic and agronomic factors on the quality of fresh cut burdock.

Browning susceptibility of some vegetable crops change with the seasonal differences and the agronomic conditions such as fertiliser applications and irrigation etc. Similar changes could be expected in burdock and these changes would affect the quality of final product during year round production. It is important to understand the patterns of these changes so that the treatment conditions are changed accordingly to obtain a consistent quality of final product throughout the year.

Stage 4 - Studying the effect of harvesting time and pre processing storage conditions.

During the lifetime of a burdock crop the browning and aroma properties could change. Immature

stages may be more susceptible to browning than mature stages. Therefore it is important to identify the correct harvesting stage for fresh-cut processing.
Harvested burdock will have to be stored to continue processing in between harvesting times. Storage conditions could affect the aging process and / or the deterioration of the stored unprocessed roots and also the quality of the processed end product.

Stage 5 - Address the issues relating to intellectual property.

There is a possibility of developing patentable intellectual property during the life of this project.

Stage 6 - Scaling up laboratory procedures to pilot and commercial scale

In a commercial fresh cut vegetable processing line, a number of unit operations are involved. Unit operations have to be identified and processing conditions have to be optimised from harvesting of burdock roots to transporting the fresli-cut product to the market outlets. Quality control parameters will have to be identified for raw material and fmal product.

The total estimated projec cost: **$ 150,000 - 200,000 depending on the agreed research protocols**

Project duration: **2- 3 years**

Collaborative partners: **Agriculture Western Australia & Food Science Australia**

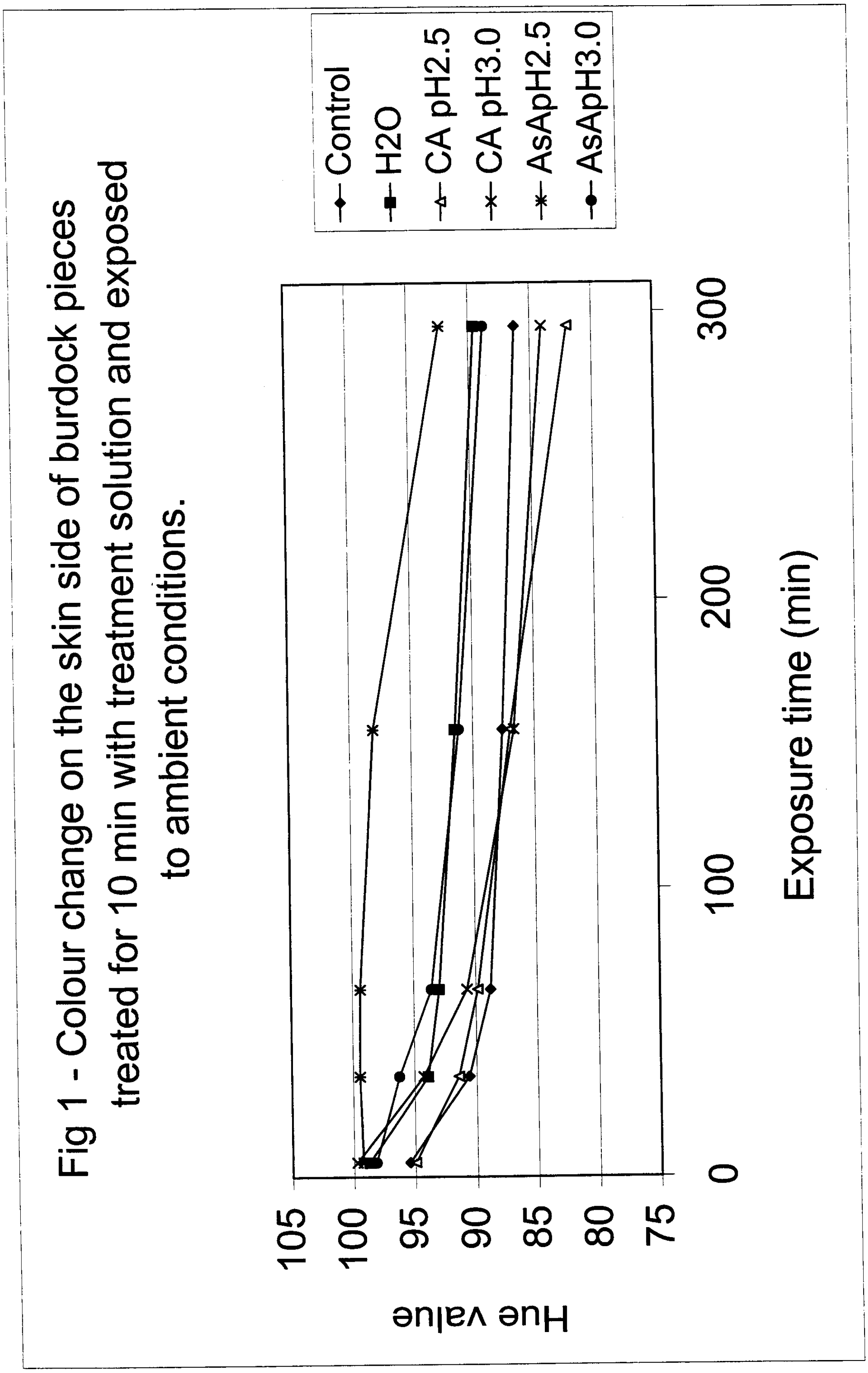
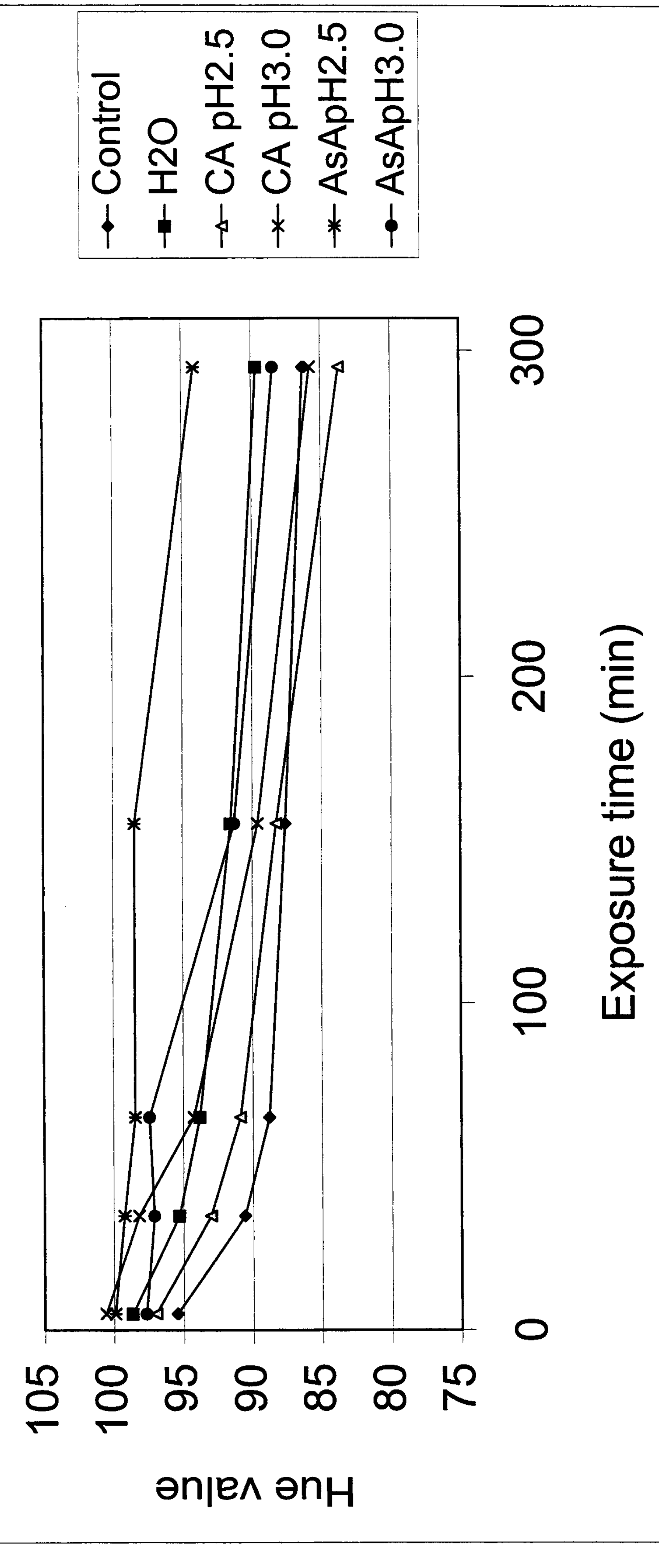


Fig 1 - Colour change on the skin side of burdock pieces treated for 10 min with treatment solution and exposed to ambient conditions.

Fig 2 - Colour change on the skin side burdock pieces treated for 20 min with treatment solution and exposed to ambient conditions.



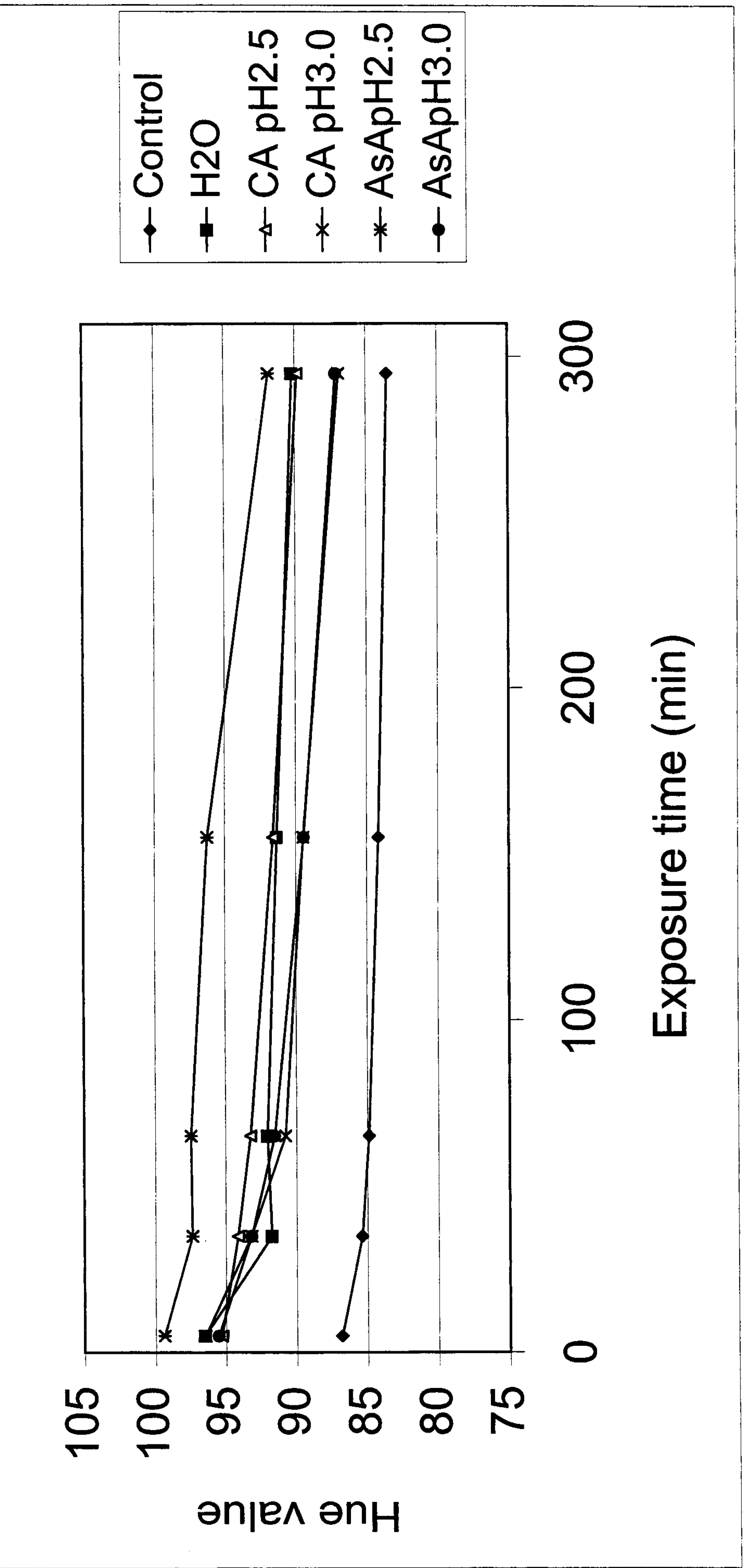


Fig 3 - Colour change on the cut side of burdock pieces treated for 10 min with treatment solution and exposed to ambient conditions

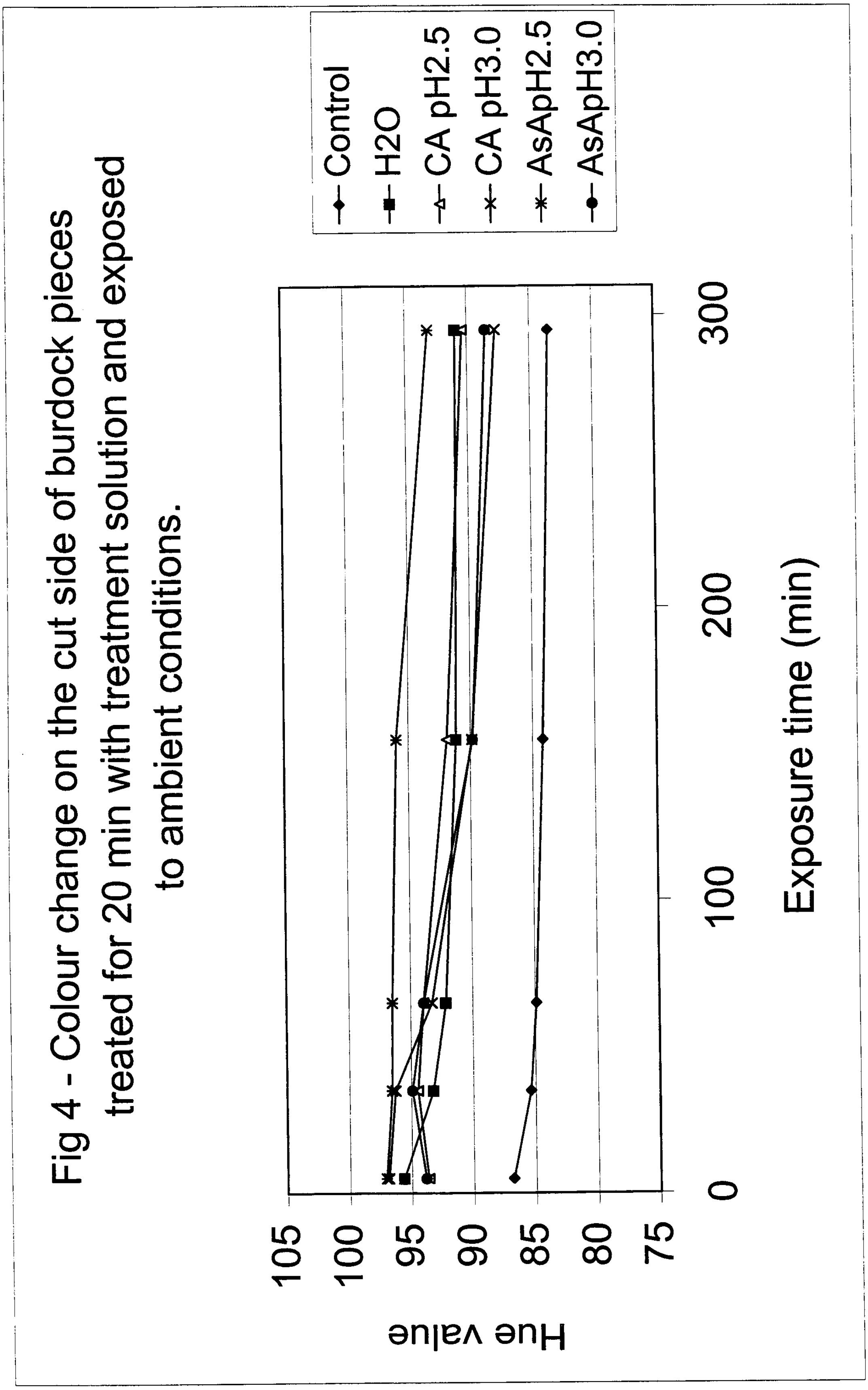


Fig 4 - Colour change on the cut side of burdock pieces treated for 20 min with treatment solution and exposed to ambient conditions.

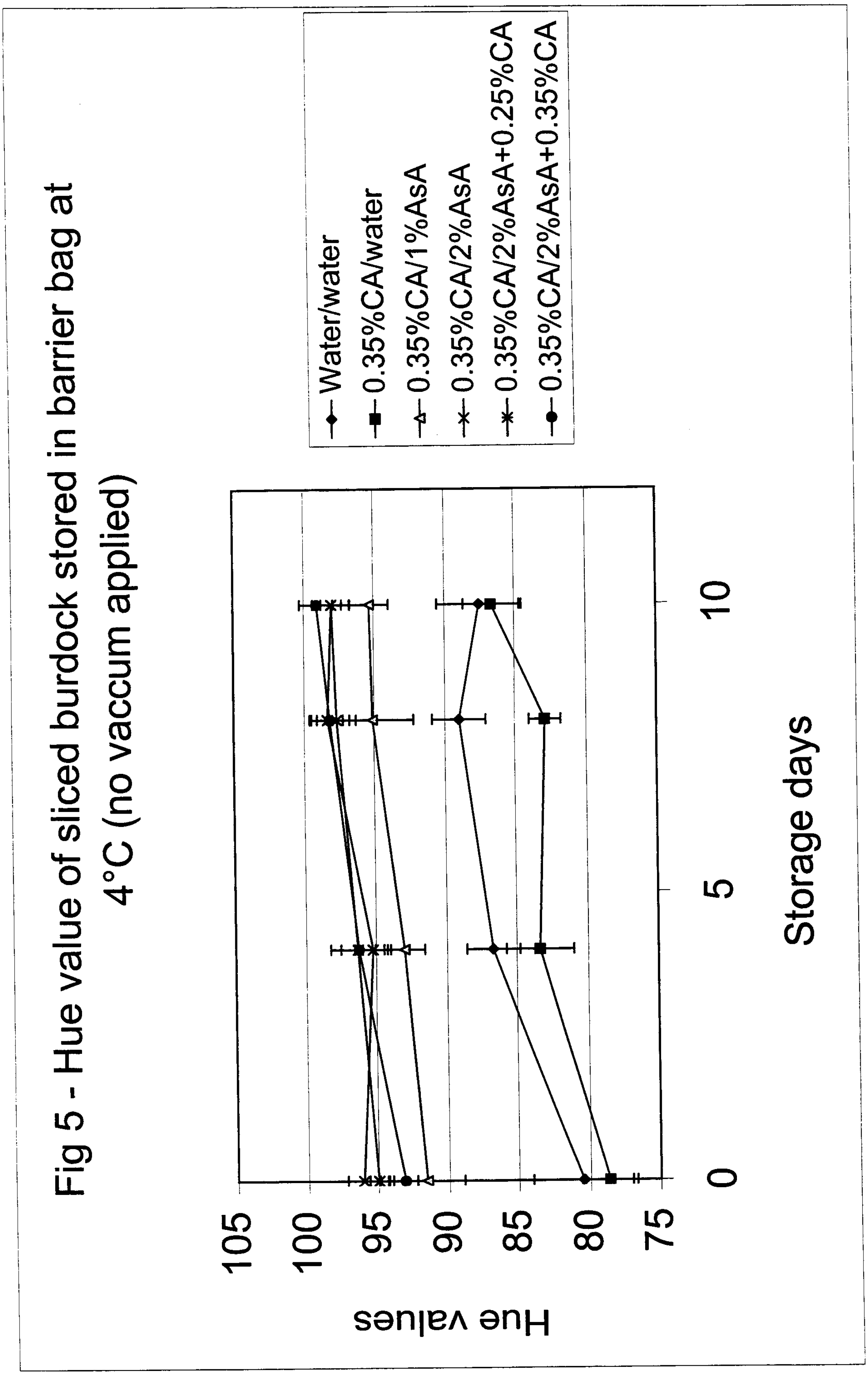


Fig 5 - Hue value of sliced burdock stored in barrier bag at 4°C (no vaccum applied)

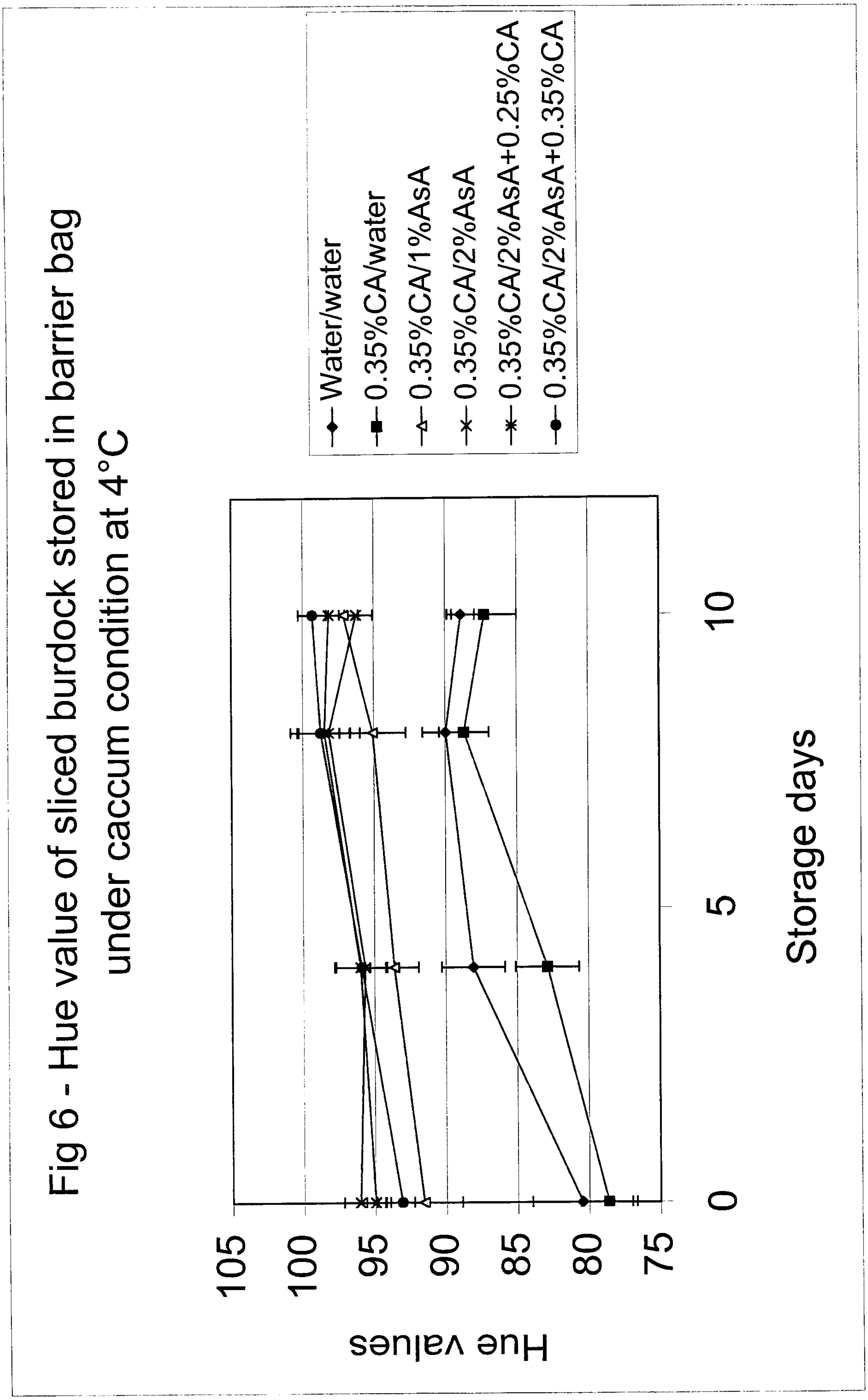


Fig 6 - Hue value of sliced burdock stored in barrier bag under caccum condition at 4°C


Control 1
at 4°C
Control 2
at 4°C


T2025
Barrier bag, 4°C
T2025
PE bag, 4°C


T2035
Barrier bag, 4°C
T2035
PE bag, 4°C

An economic analysis of supplying Western Australian semi-processed burdock to Japan

June 2002

Alexander Rahmig

Contents

Page

1.0. Executive Summary

Recent developments in China appear to have made Australia non-competitive in the fresh burdock market in Japan. China is the biggest supplier of imported burdock for the Japanese market. In 2001, China exported approximately 69,000 tonnes of fresh burdock to Japan. China delivered this fresh burdock for an average price of ¥59 per kg, which is A$0.94 per kg calculated with the annual average exchange rate for the year 2001 (A$1 = ¥62.81).

Japan is the biggest market for burdock worldwide and has a value of around 40 billion yen or A$573 million at Japan's wholesale markets (A$1 = ¥69.78 as at May 10th, 2002). The Department of Agriculture, Western Australia, conducted this market analysis to evaluate the export opportunities for Australian semi-processed burdock for the Japanese market.

This analysis shows the landed price of semi-processed burdock for a small-scale production in WA is approximately A$8.69 per kg. However, this price would not prove profitable if the achievable price at the Tokyo wholesale markets were in the reported range from A$4.00 – A$6.50 per kg. The major costs to produce and export an Australian value added product for the Japanese market are processing and packaging costs. These costs make up approximately 63% or A$5.52 of the total estimated landed price per kg. The reason for these high costs is the labour intensity of the processing procedure.

Mechanization and economies of scale could be a possibility to reduce the processing costs significantly. A cost reduction of 50% in the processing cost would result in an estimated landed price per kg of A$5.43. However, even at A$5.43 per kg this would not make the activity viable. Other cost factors like the exporter/processor and importer margins which are not included in the calculation will move the landed price of the product either close to the top end or out of the focused price range of A$4.00 – A$6.50 per kg.

On the basis of this analysis, Western Australian processors could not profitably supply the Japanese semi-processed burdock market.

2.0. Introduction

As a result of research conducted by the Department of Agriculture, Western Australia, Asian vegetables grown and/or processed in Australia have been identified as strategic opportunities for the Asian export markets. Based on these findings there is a need to evaluate the commercial benefits and the viability of the Asian export vegetable opportunities.

In general, there are many potential export vegetables for the Asian markets. These include Japanese taro, lotus root, Japanese pumpkin, daikon and burdock.

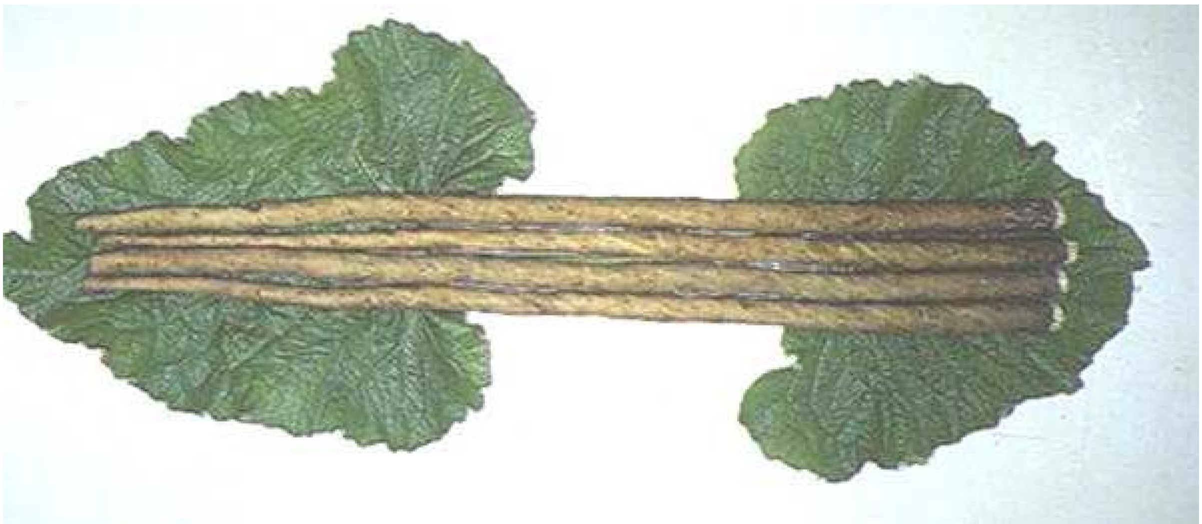
The aim of this market analysis is to examine the opportunity for the Western Australian vegetable industry to export semi-processed burdock to the Japanese market. This report discusses the risks and benefits of growing, processing and exporting burdock to Japan.

3.0. Product Analysis

3.1 General botanic information (Source: 2)

Burdock (*Arctium lappa* L.) belongs to the Chrysanthemum family (Compositae) which is a native of Asia. Burdock is a biennial plant that is grown and harvested as an annual. It can be found growing wild in Europe and North America where it is used as a folk medicine. Seeds are not produced until the second year. The plant carries its leaves on long stems (approximately 60 cm) originating from the crown. Leaves are large, almost heart-shaped, have a rough texture and are covered with short white hairs, dark green on the top and a paler green underneath with pinkish veins.

The root can reach lengths of up to 120 cm and a diameter of 1.5 - 3.0 cm. Burdock is high in carbohydrate inulin (can account for 45% of the plant dry weight), fibre, potassium, calcium, silicon, sulphur, volatile oil and resin as well as containing several antibiotics.



3.2. Uses for burdock (Sources: 1, 7)

Burdock is a popular root vegetable in Japan and is generally used in cooked food like soups and stews. A famous preparation of this vegetable in Japan is *kimpira*, a dish of sliced burdock, sugar, soy sauce, sesame and hot chilli. Burdock can be pickled, boiled and deep-fried. It is used to relieve constipation, as a diuretic, a blood purifier and against skin disorders. It is considered as one of the best vegetables for diabetics and also enjoys reputation as an aphrodisiac .

Lately, uses in salads and Japanese style hamburgers are increasing, which is due to the changes of the traditional eastern lifestyle, especially among young people.
Many people who eat burdock compare it to celery and artichoke, and consider the taste to be earthy and mildly sweet.

Nutrition Chart

Burdock: 1 cup cooked	
Calories	110
Total fat (g)	0.2
Saturated fat (g)	0
Monounsaturated fat (g)	0
Polyunsaturated fat (g)	0.1
Dietary fiber (g)	2.3
Protein (g)	3
Carbohydrate (g)	27
Cholesterol (mg)	0
Sodium (mg)	5
Vitamin B6 (mg)	0.4

Source:
www.wholesalefoodsmarket.com

3.3. Burdock production in Australia and WA

(Sources: 2, 3, 4, 7)

Burdock is a new crop to Western Australia and has potential to be grown during the late spring and early autumn. It prefers deep, friable and well-drained soils. Therefore the main production area for this root vegetable would be the Swan Coastal Plain from Busselton to Guilderton. The current areas where Burdock already has been grown in WA are Guilderton, Medina and Kununurra. Burdock also has been grown at Myalup, but the limestone layer at about 70 cm depth causes some difficulties.

Burdock was first grown in Western Australia in the early 1990s. In 2000/01, about 387 tonnes of burdock was exported from Western Australia, mainly to Japan (Australian Quarantine and Inspection Service). There is one known grower/exporter of burdock in WA. The domestic demand for Asian vegetables in Australia is limited, but the current trend shows an increasing popularity with non-Asian consumers.

There is a small market for burdock for domestic Asian restaurants, suburban supermarkets and greengrocers in the Eastern States of Australia. The New South Wales growers are concentrated in small holdings on Sydney's outskirts. They sell directly to restaurants or the Sydney markets in Haymarket, Cabramatta, Marrickville and Bankstown. Growers in Australia earned A$25 - 30 million annually (1992) from domestic sales of Asian vegetables to these markets (source: 2). These sales reached a figure of approximately A$60 million in 1998.

However, it does not open an opportunity for WA, because growers in Victoria, New South Wales and Southern Queensland can satisfy the demand of Asian vegetables. The market for Asian vegetables and burdock for the local Asian restaurants and greengrocers in Perth is limited.

3.4. Pest and diseases (Sources: 2, 4)

Nematodes (burrowing) are a major pest and soils should be assessed for nematode populations before sowing. A nematode-repelling crop, such as oats may be sown as a cover crop during winter and incorporated into the soil before sowing burdock.

Powdery mildew may become a problem in wet, humid conditions but in most cases the crop will tolerate the disease without loss of production.

Black root is a fungal disease caused by *Aphanamyces sp.*, which may also cause crop losses. Warm to hot weather and water-logged soil favours its development. The disease is minimized by correct irrigation scheduling, good drainage and crop rotation.

4.0. The Japanese market

4.1 General country details Japan

Capital: Tokyo

Languages: Japanese

Currency: yen (JPY)

Location: Eastern Asia, island chain between the North Pacific Ocean and the Sea of Japan, east of the Korean Peninsula

Area: total: 377,835 sq km

land: 374,744 sq km

water: 3,091 sq km

Climate: varies from tropical in south to cool temperate in north

Terrain: mostly rugged and mountainous

Land use:

arable land: 11%

permanent crops: 1%

permanent pastures: 2%

forest and woodland: 67%

other: 19% (1993 est.)

Irrigated land: 27,820 sq km (1993 est.)

Natural hazards: many dormant and some active volcanoes; about 1,500 seismic occurrences (mostly tremors) every year; tsunamis; typhoons

Population:
Japan: 127.096 million in 2000 (estimated 128.200 in the year 2010)
Tokyo metropolis: 11.781 million

Population growth rate: 0.17% (2001 est.)

Government type: constitutional monarchy with a parliamentary government

Administrative divisions: 47 prefectures; Aichi, Akita, Aomori, Chiba, Ehime, Fukui, Fukuoka, Fukushima, Gifu, Gumma, Hiroshima, Hokkaido, Hyogo, Ibaraki, Ishikawa, Iwate, Kagawa, Kagoshima, Kanagawa, Kochi, Kumamoto, Kyoto, Mie, Miyagi, Miyazaki, Nagano, Nagasaki, Nara, Niigata, Oita, Okayama, Okinawa, Osaka, Saga, Saitama, Shiga, Shimane, Shizuoka, Tochigi, Tokushima, Tokyo, Tottori, Toyama, Wakayama, Yamagata, Yamaguchi, Yamanashi

Source: http://www.cia.gov/cia/publications/factbook/geos/ja.html

4.2. The overall market for burdock in Japan (Sources: 1, 5, 9)

The total value of the burdock market in Japan is around 40 billion yen or A$573 million at Japan's wholesale markets (A$1 = ¥69.78 as at May 10th, 2002). Japan has a consumption of approximately 230,000 – 300,000 tonnes of burdock each year and represents the largest market for this root vegetable worldwide.

The Japanese consumer on average eats approximately 58 kg of fresh vegetables per annum. This includes 2 kg of burdock each year. Other small markets like Hong Kong and Taiwan are insignificant. Taiwan's demand can completely be satisfied by local production. In Australia, the use of burdock is largely unknown and the potential for expansion is limited. Further information about the domestic market is listed above in section *3.3 The Burdock production in Australia and WA*.

4.2.1. Consumption trends in Japan

There have been three significant trends affecting Japanese food consumption patterns in recent years. The first is the growing consumption of processed food. Second, is the westernisation of the Japanese diet. Finally, in response to the effects of the first two trends, Japan is also experiencing a health food boom.

In recent years Japanese consumers have come to rely more and more on processed foods. Between 1993 and 1997 production of "retort foods" (food processed through a high temperature sterilization method) increased almost 19 percent while sales of frozen prepared foods increased 17 percent. The popularity of these foods is explained by changes in the Japanese lifestyle. These changes include more people living alone, more working women in the population and busier schedules for working people.

The number of one-person households rose 21 percent between 1990 and 1996 and the number persons over 65 living alone increased by 46 percent. The number of female employees in the Japanese workforce has risen more than 16 percent in the last ten years. With more singles living in Japan with less time to prepare meals, consumers are looking for faster and more convenient ways to eat. This has resulted in higher sales of processed foods such as microwave dinners and "retort" packages. These products are especially popular among the rising numbers of elderly people living alone in Japan who are looking for ways to ease their daily burden.

The popularity of processed foods has been fostered by the rise in convenience stores in Japan, which sell various ready to heat and ready to eat meals. The number of convenience stores increased by 67 percent between 1987 and 1997. Sales of take-away foods at convenience stores reached 947 billion yen in 1997, which is an annual increase of 5.3 percent since 1987. Supermarkets are also stocking more ready-to-eat meals, as well as packaged combination foods known as "meal solutions".

These trends would support the export of semi-processed burdock to the Japanese market and would meet customers needs, because the use of this product helps the customer to reduce the preparation time and the waste problem.

Westernisation could be a threat to the use of burdock in the classic Japanese diet, but burdock recently entered the fast food industry (used in Japanese style hamburgers). This trend only compensates for part of the decreasing consumption of this root vegetable in traditional Japanese diets. The general consumption of burdock in Japan is slightly declining.

(Source: Foreign Agricultural Service/USDA, web page: www.fas.usda.gov)

4.3. Japan's burdock imports

In 2001 Japan imported approximately 88,283 tonnes of burdock. This does not include the burdock packed and imported with other vegetables like carrots, etc. China is the biggest burdock supplier for the Japanese market with a share of 76,565 tonnes or 86% of the total imported quantity in 2001. The other 13% of the imports are sourced from Taiwan and only 1% comes from countries such as Vietnam, Korea, Indonesia, France, USA and Australia.

From the 88,283 tonnes of burdock imported to Japan a share of 7,600 tonnes or 8.6% was imported in a processed form in 2001. This is an increase of 12%

compared to the year 2000 in which approximately 6,768 tonnes of processed burdock were imported to Japan. (Source: Japan Tariff Association)

China recorded a rapid market share growth over the last three years from 78% or roughly 60,389 tonnes in 1999 to a market share of 86% in 2001 (See details in *Appendix 5*). Due to competitive prices and increasing quality of Chinese burdock this trend is likely to continued. The production of burdock for export to Japan is concentrated in the Laiyang, Laixi, Cangshan, Jinan, Taian, Pizhou, Fengxian and Xuzhou regions of China.

Imported vegetables to the Japanese market can be broadly divided into four categories:

a) vegetables that compete with domestic products,
b) vegetables imported when there is a poor harvest in Japan,
c) vegetables imported during the off-season in Japan,
d) vegetables that are difficult to produce in Japan.

The target for Australian burdock production would be the off-season. Burdock is in short supply during the period March to May and prices are typically high.

The overseas competitors for Australian burdock producers are:

1. China,
2. Taiwan,
3. Others (Vietnam, Korea, Indonesia, USA and France).

But WA must also compete against the Japanese domestic burdock production.

The main reasons for the rising imports into Japan are the improving quality of Chinese products and the following circumstances in Japan:

- Increasing land prices due to the expansion of Japan's cities
- The rapid aging of the agricultural population
- The rural youth don't want to take over the farms
- Pressure on domestic prices due to cheaper imports
- Food service sector and processors tend to invest in offshore joint ventures for the production and processing of burdock. **(Source: 9)**

These facts have led to a decrease of the domestic Japanese production by 30% over the last 30 years and by 10% in the last five years.

4.4. Varieties and forms of semi processed burdock

4.4.1. Varieties

The varieties of burdock grown in Japan differ in colour, length and shape of the root, stem colour and maturity. There are four groups of burdock sold in Japan: Takinogawa, Oura, Aki and Etsuzenshirokei. The most popular group is Takinogawa. The long and thin roots are ideal for the fresh Japanese market **(Source: 2)**.

Forms

There are many different forms of semi-processed burdock as shown below:

(Source: 9)

1. Kimpira cut (julienne shape typically 2.5 x 2.5 x 45 mm or 3 x 3 x 35 mm)
2. Sasagaki cut (thin scallop shape)
3. Angle sliced
4. IQF (Individually Quick Frozen)
5. Pickled
6. Extended shelf life by using a water or brine solution in the packaging

The most common cuts with the highest demand in Japan are the kimpira and sasagaki cut. The fresh burdock is either imported or purchased locally and then sent to a processing plant in Japan to cut it into kimpira or sasagaki cut style. Another trend is to import processed burdock from China. In 2001 Japan imported 7,600 tonnes of processed burdock from China. This is an increase of 12% against the year 2000.

4.5 Pricing (Sources: 5, 6)

The figures and graphs attached in Appendix 2 and 3 give an indication of the prices and the handling volume of Burdock at the Tokyo wholesale market. In Appendix 4 the prices of Burdock by origin (from Japan and China) are displayed.

It is crucial that the following prices and figures should only be used as a general indicator of the market trend. It does not show if there are premium prices paid or what the price of the processed produce is.

Appendix 2 shows the monthly prices of burdock at the Tokyo wholesale market for the years 1996 to 2000. The graph generally shows higher prices during the months March to May, when burdock is in short supply from Asian producers. This can cause a price increase up to 60% compared to the average annual prices of burdock traded at the Tokyo wholesale market.

An overall view of the availability of burdock in Japan is displayed in the table below. This data does not show whether there are wide price and supply fluctuations within a trading day or month, but indications from wholesalers are that dramatic price fluctuations within a market day or between market days are unusual. **(Source:6)**

Availability of burdock from Japan, China and Taiwan **(source: 5)**:

Country / Prefecture	**Jan**	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Japan (Kagoshima)				H	H	H	H	H	H			
Japan (Chiba)	H	H	H								H	H
Japan (Aomori)											H	H
Japan (Hokkaido)								H	H	H	H	H
China	S	S				S	S	S	S	S	S	S
Taiwan		S	S	S	S							

Harvest = H
Supply = S

(Source: 9):
Recent developments in Chinese produced burdock have rendered Australia noncompetitive in the supply of fresh burdock into Japan. A Japanese wholesaler can purchase high quality fresh imported burdock from China nearly all year round at A$0.80 – A$1.15 per kg. In the same market, semi-processed burdock (fresh-cut into bulk bags) will typically sell for A$4.00 – 6.50 per kg, depending on the target market and the distribution system used.

The data provides a guide for the typical price movements within a year and shows the rough market trend. It would be useful to compare this data with other wholesale markets in Japan or prices from direct importers, but this would be beyond the scope of this market analysis.

Appendix 3 shows the handling volume and the unit price of burdock at the Tokyo central wholesale market. The average annual wholesale prices (per kg) from 1996 to 2000 ranged from a low of ¥204 in 1997 to a high of ¥322 in 1998. The majority of the burdock traded at the Japanese wholesale markets is fresh burdock, but an estimated 70% of all burdock purchased at the retail level is in processed or
semi-processed form **(Source: 9)**. The Tokyo wholesale market represents approximately 10% of Japan's burdock sales. The average annual volume traded at this market is approximately 15,300 tonnes (1996-2000).

Appendix 4 contains the handling volume and the unit price of burdock in Tokyo central wholesale markets by origin for the year 2000. The Japanese burdock supply is shown divided in prefectures like Aomori/Hokkaido in the north of Japan, Ibaraki/Chiba located around Tokyo and the Kagoshima prefecture in the south of Japan. The main local production in Japan is located in these prefectures. The table shows that the price for Chinese burdock is significantly lower than the price for the Japanese produce.

4.6. Distribution channels for burdock

There are two steps necessary to export burdock from Australia to the Japanese market **(Source: 6)**:

1. Transport of burdock to Japan (four possible ways):

Trading houses

Japan's trading houses, also called *sogo shoshas*, are the major importers of food into Japan. Most trading houses are affiliated with a large number of primary wholesalers and retail outlets through complex, cross-shareholding arrangements.

Specialty Importers

Specialty importers are becoming more important as they concentrate on particular food imports.

Primary wholesalers

Primary wholesalers operate from central wholesale markets. They can distribute imported vegetables as sole agents for either the food service sector or retailers,
or as speculating importers. The sole agent approach is more common with processed vegetables and the speculator role more common with fresh products. Distribution channels tend to be regional and local but there are some wholesalers who distribute nationally.

Retailers

The retail stores are becoming increasingly involved with the direct importation of food. Many of them have overseas operations. An advantage of this move for potential exporters is access to the retailer's precise specifications including delivery timing, product specification and shipping conditions.

2. Deliver the burdock to the customer

Consumers can buy the imported burdock at two different points of sale:

- retail stores
- food service sector

Retail stores

Following are the types of retail stores, which sell vegetables:

- cooperative
- department stores
- hypermarket stores
- supermarkets
- convenience stores
- general merchandise stores
- specialty stores
- variety stores

Expensive

Large			**Small**
	Department Stores	Specialty Stores	
	Supermarkets	Convenience Stores	

Cheap

Food Service Sector

Supply stability offered by importers is very attractive to the food service sector. Restaurants especially appreciate stability in their menu composition and cost structure.

Semi-processed vegetables are also an attraction to the food service sector as they represent a reduction in expensive Japanese labour.

Examples for food service companies or organisations are:

- General eating outs (restaurants, sushi shops, planes)
- Institutional eating (schools, work sites, hospitals)
- Eating in (home delivered meals and food home catering)

5.0 The landed price per unit (1kg semi-processed burdock – kimpira cut)

This model assumes a producer payment of A$1per kg of burdock delivered to the processor (see *Appendix 1*).
In the processing procedure, losses of 38.3% of the raw burdock material occur. Therefore 1.6207 kg of the raw material is needed to produce 1 kg of final product. The value of the raw burdock included in the final product is accordingly A$1.6207.
This model further calculates with a quantity of 20 t transported in a 20 foot refrigerated container from Fremantle to Tokyo.
No exporter/processor or importer margins are included in the calculation.

Cost/Price	Single prices/costs in AUD/kg for steps 1- 10	Calculation and Description	Accumulate prices and costs in AUD/kg
1. Producer Payment	**1.6207**	Maximum price paid by the processor/exporter to the grower is 1 AUD per kg (including freight to the processor). It has to be considered that 1.6207 kg of raw Burdock is required to produce 1 kg of final processed product. See *Appendix 1* for gross margin details.	**1.6207**
2. Processing and Packaging Cost	**5.5170**	Direct processing costs including filling, weighing, vacuum packaging See *Appendix 6* for direct processing cost details.	**7.1377**
3. Cool storage	**0.02**	Cool storage after packaging 20 AUD/t = 0.02 AUD/kg	**7.1577**
4.Transport to Port	**0.02**	Transport from the processing plant to the Fremantle Port for 20 AUD/t = 0.02 AUD/kg	**7.1777**
5. AQIS	**0**	AQIS Certificate is not required. Product is processed (precooked).	**7.1777**
6. Sea freight from Fremantle to Tokyo	**0.2**	**Sea freight from Fremantle to Tokyo in a 20 foot reefer container.** AUD **Sea freight 3,049.21** **Port service charge 257.94** **Lift on Lift off 27.64** **Origin terminal handling 497.45** EBS (Emergency Bunker Surcharge) 92.12 Document fee 55.27 **Total 3,979.63** **Total per kg 0.20** (Freight quotation given from Maersk on May 7th, 2002)	**7.3777**
7. Insurance	**0.0148**	Insurance premium is 0.2% of the CIF value 1,002 * 7.3777 = 7.3925	**7.3925**
8. Import Tariff	**0.8871**	Import Tariff for processed Burdock with the HS Codes 0710 80 030 ***** 0711 90 093 ***** is 12% and has to be calculated on the price before Consumpt. Tax are added 7.3925 * 1.12 = 8.2796	**8.2796**
9. Consumption Tax	**0.4140**	Consumption Tax in Japan is 5%, which has to be calculated on the price after the Import Tariff was added. 8.2796 * 1.05 = 8.6936	**8.6936**

10. Landed Price per Unit	**8.6936**	xxx	**8.6936**

List of abbreviations:

AQIS = Australian Quarantine and Inspection Service
CIF = Cost, Insurance, Freight
HS Code = Harmonized System Code
kg = kilogram
t = metric tonnes (1000 kg)

HS Code* description for processed Burdock:

0710 80 030 Burdock (uncooked or cooked by steaming or boiling in water), frozen

0711 90 093 Vegetables provisionally preserved (for example, by sulphur dioxide gas, in brine, in sulphur water or in other preservative solutions), but unsuitable in that state for immediate consumption

Source:

APEC Tariff Database

Web page:

http://www.apectariff.org/tdb.cgi/ff3133323230/apeccgi.cgi?JP

Consumption Tax:

In addition to custom duties, a 5 percent consumption tax effective since April 1997 is levied on all imported goods. Goods valued at less than 10,000 yen, except for knitwear, leather goods and some other items, are exempt from the consumption tax. The amount of consumption tax is calculated according to the following formula:

(CIF + duty + indirect taxes other than consumption tax) * 5%.

5.1 Cost description

The calculation of the landed price per unit includes three major costs components listed below:

1. The growers cost structure

In general, the costs of burdock production will vary between seasons, time of production, growing location and business resources. In *Appendix 1* is a gross margin calculations for burdock production near Perth. The calculation is from May 2002 updated by Vynka McVeigh from the Department of Agriculture in Bunbury, WA. The calculation of the landed price per unit is based on a producer payment of A$1.00 per kg and includes the freight to the processor/exporter. Farm overheads are not included in this gross margin analysis. For details of the cost structure see *Appendix 1*.

2. Exporters/processors cost structure

For the purposes of this analysis the exporting/processing company are one company. Processing, packaging and transport are the major costs and risks of the exporter/processor. The responsibility of this participant in the supply chain is to process and deliver a high quality product to the Japanese importer. For details of the processing cost for a small scale production in WA see *Appendix 6.* For transport costs see the landed price per unit calculation above.

3. Importers cost structure

These costs are obviously market specific and including tariffs, port and customs costs and consumption tax. The costs of storing and distributing once landed in Tokyo are not included in the calculation and will be dependent on the distribution channel used and the market where there the product will be sold. For details see the landed price per unit calculation above.

5.2. Assessment

As this calculation shows, the landed price per kg semi-processed is approximately A$8.69. This price would not prove profitable if the achievable price at the Tokyo wholesale markets were in a range from A$4.00 – A$6.50 per kg. This price indication was taken from the New Export Vegetable Study Tour to Japan report completed in December 2001. However, the only way to get an indication or quotation for semi-processed burdock from Western Australia is to send a sample of the product to a Japanese importer/processor. The criteria for the quality assessment are texture, colour, flavour, etc. These criteria and the current supply and demand determine the achievable price for the product.

The landed price calculation shows that the major part of the cost structure is direct processing and packaging costs. This part makes up approximately 63% (A$5.52 per kg) of the total landed price. For Australian semi-processed burdock to become profitable and competitive the emphasis should focus on the processing and packaging costs. The best opportunities for reducing costs and making savings are in this stage of production. For example the costs of skinning and trimming are responsible for nearly half of the direct processing of burdock. In the end this makes up A$2.70 of the final saleable product.

Due to the labour-intensive production of processed burdock, mechanization may be a possibility to reduce the processing costs significantly (for example skinning and trimming). Another issue is economies of scale. Economies of scale in production means that production at a larger scale (more output) can be achieved at a lower cost per unit.

Other cost factors like import tariffs and consumption tax are fixed by the Japanese government and are not in the scope of influence of the producer, exporter or importer.

Prices for insurance premiums, sea freight, land freight and cool storage are negotiable, however, the possibilities for savings for these cost factors are limited.

6.0 Conclusion

The Japanese market for fresh burdock is very hard to penetrate for the Australian vegetable industry. China is well positioned with increasing quality and low prices.

The opportunities for a semi-processed product from Australia are also limited. The landed price per unit calculation shows a landed price per unit of A$8.69 per kg.
With a focused price range of A$4.00 - 6.50 at the Tokyo wholesale markets the enterprise would not be profitable.

Mechanization and economies of scale are possibilities to reduce the processing costs significantly. A cost reduction of 50% would result in a landed price per unit of A$5.43 per kg. Even then, the enterprise would still not prove profitable, given that the exporter/processor and importer margins are not included in this analysis.

Remark:

Jeff Hastings of Xylem International Pty Ltd. provided the following costs for two alternative methods of processing burdock. These costings are based on small scale commercial testing but do claim much lower processing costs than estimated in the current study.

The first alternative is to apply edible coatings to fresh cut burdock. The second option is to use the IQF-method (Individually Quick Frozen). The cost for these alternatives is suggested to be A$0.58 per kg and A$0.63 per kg respectively. This source further mentioned that the recovery of processed burdock is 74% compared with approximately 61.7% used in this analysis. The figures were based on labour input of 40 man days to produce 20 tonnes of IQF product. The market price for frozen burdock and the market acceptance of burdock with edible coatings need to be investigated before any detailed assessment of the feasibility of exporting these products is made.

7. Appendices

(Source: McVeigh, Vynka - Department of Agriculture, WA)

Appendix 1 Gross Margin per hectare for burdock production near Perth, WA

INCOME **5/1/02**

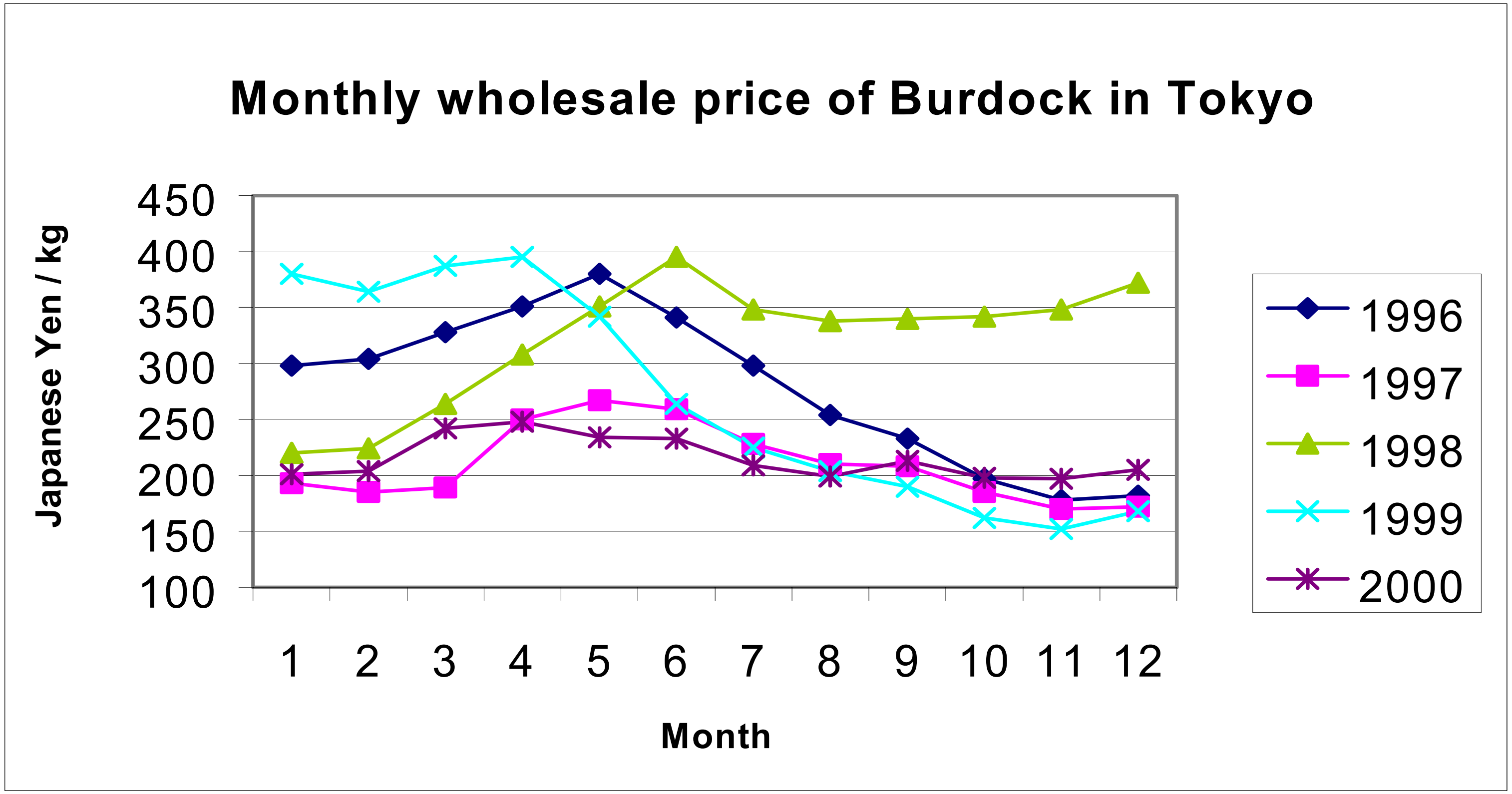
Paddock Yield	23,000 kg/ha	
	Processing for Export	
Marketable Yield	13,800 kg/ha	
Producer Payment	$1.00 /kg	
	A. TOTAL INCOME	**$13,800**

DIRECT COSTS	**Unit**	**Times**	**Amount/ha**	**$/unit**	**$/ha**	**Total $**
Seed	kg	1	3.00	270.00	810	810
Fertiliser						
Basal agran	t	1	0.10	350.00	35	35
Gypsum	t	1	0.25	16.20	4	4
Double super	t	1	0.90	397.00	357	357
Agran	kg	10	31.0	0.35	109	109
Potassium nitrate	kg	10	24.0	1.10	260	260
Trace elements	kg	1	150.0	1.53	230	230
Herbicide						
Glyphosate	L	1	3.0	9.75	29	29
Insecticide						
Malathon	L	1	0.2	9.70	2	2
Fungicide/Fumigant						
Bravo	L	1	2.0	14	28	28
Metham sodium	L	1	500.0	1.45	725	725
Nemacur	L	1	24.0	38.00	912	912
Irrigation Power						
water applied	mm	130	10			
total head	mm		100.00			
pump efficiency			0.6			
motor efficiency			0.8			
electricity	kWh		7367	0.17		
or fuel	L	0.36 L/kWh	7367	0.34	902	902
Machinery						
tractor hours	hr		48.75			
fuel - distillate (net)	L	Ave L/hr: 9.6	469.98	0.34	160	160
Repairs, parts, sundries - incl. Irrigation equip't					290	290
Labour						
Fertilising	hr	3	2	15.00	90	90
Cultivating (Deep rip and trenching)	hr	2	5	15.00	150	140
Seeding	hr	1	3	15.00	45	42
Boomspraying	hr	3	2	15.00	90	84
Irrigation, crop inspection	hr	20	1	15.00	300	280
Setting up, maintenance	hr	2	9	15.00	270	252
Vibrating ripper	hr	1	2	15.00	30	28
Harvesting and washing	hr	1	235	15.00	3525	3290
Grading	hr	1	40	15.00	600	980
Bin Hire	t	1	13.8	5	69	69
Freight to processing plant	t	1	13.8	10	138	138
			B. TOTAL DIRECT COSTS			**$10,246**
			GROSS MARGIN PER HA (A-B)			**$3,554**

Appendix 2

Monthly wholesale price of Burdock in Tokyo (in Japanese Yen/kg)

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1996	298	304	328	351	380	341	298	254	233	197	178	182
1997	193	185	189	250	267	259	228	210	208	185	170	172
1998	220	224	264	308	351	395	348	338	340	342	348	372
1999	380	364	387	395	342	264	225	204	190	162	152	168
2000	201	204	242	248	234	233	209	199	213	198	197	205



Appendix 3

Handling volume & unit price of Burdock in Tokyo Central Wholesale markets

(Unit: Quantity: MT, Price: Japanese yen/kg, Ratio:%)

	Whole year			**Jan**			**Feb**			**March**		
	Q'ty	**Price**	Ratio	Q'ty	**Price**	Ratio	Q'ty	**Price**	Ratio	Q'ty	**Price**	Ratio
1996	15543	**263**	100.0	930	**298**	6.0	1165	**304**	7.5	1164	**328**	7.5
1997	16142	**204**	100.0	1122	**193**	7.0	1283	**185**	7.9	1333	**189**	8.3
1998	14363	**322**	100.0	1158	**220**	8.1	1254	**224**	8.7	1154	**264**	8.0
1999	15465	**248**	100.0	929	**380**	6.0	1032	**364**	6.7	1016	**387**	6.6
2000	14860	**214**	100.0	1079	**201**	7.3	1345	**204**	9.1	1213	**242**	8.2

April			**May**			**June**			**July**			**Aug**		
Q'ty	**Price**	Ratio	Q'ty	**Price**	Ratio	Q'ty	**Price**	Ratio	Q'ty	**Price**	Ratio	Q'ty	**Price**	Ratio
1101	**351**	7.1	1039	**380**	6.7	1013	**341**	6.5	1062	**298**	6.8	963	**254**	6.2
1203	**250**	7.5	1156	**267**	7.2	1119	**259**	6.9	941	**228**	5.8	912	**210**	5.6
1085	**308**	7.6	967	**351**	6.7	998	**395**	6.9	834	**348**	5.8	756	**338**	5.3
1071	**395**	6.9	1091	**342**	7.1	1141	**264**	7.4	1045	**225**	6.8	874	**204**	5.6
1206	**248**	8.1	1107	**234**	7.4	1009	**233**	6.8	852	**209**	5.7	761	**199**	5.1

Sept			**Oct**			**Nov**			**Dec**		
Q'ty	**Price**	Ratio	Q'ty	**Price**	Ratio	Q'ty	**Price**	Ratio	Q'ty	**Price**	Ratio
1422	**233**	9.1	1608	**197**	10.3	1697	**178**	10.9	2380	**182**	15.3
1402	**208**	8.7	1682	**185**	10.4	1549	**170**	9.6	2441	**172**	15.1
1191	**340**	8.3	1452	**342**	10.1	1348	**348**	9.4	2163	**372**	15.1
1336	**190**	8.6	1823	**162**	11.8	1803	**152**	11.7	2305	**168**	14.9
1156	**213**	7.8	1495	**198**	10.1	1441	**197**	9.7	2196	**205**	14.8

Appendix 4 Handling volume & unit price of Burdock in Tokyo central wholesale markets by origin for the year 2000

	Whole year			Jan			Feb			March			April			May			June		
	Q'ty	Price	Ratio	Q'ty	Price	Ratio	Q'ty	Price	Ratio	Q'ty	Price	Ratio	Q'ty	Price	Ratio	Q'ty	Price	Ratio	Q'ty	Price	Ratio
2000																					
Saitama	2908	291	19.6	219	297	20.3	246	292	18.3	259	284	21.4	220	287	18.2	197	283	17.8	252	292	25.0
Aomori	2833	179	19.1	223	176	20.7	238	181	17.7	107	180	8.8	321	145	26.7	150	99	13.6	14	157	1.4
China	**1871**	**101**	**12.6**	**138**	**86**	**12.8**	**217**	**77**	**16.1**	**174**	**102**	**14.3**	**102**	**98**	**8.5**	**79**	**87**	**7.1**	**94**	**91**	**9.3**
Ibaragi	1451	166	9.8	149	142	13.9	202	123	15.0	170	156	14.0	81	150	6.7	27	163	2.5	24	238	2.3
Tokyo	1367	267	9.2	90	284	8.4	111	268	8.2	109	270	9.0	89	262	7.4	83	252	7.5	102	269	10.2
Chiba	1181	130	8.0	113	110	10.4	137	113	10.2	139	132	11.5	120	129	9.9	74	136	6.7	56	128	5.6
Gunma	1147	195	7.7	11	200	1.0	16	158	1.2	10	183	0.8	6	240	0.5	65	215	5.9	272	222	27.0
Kumamoto	584	418	3.9	0	1059	0.0	0	727	0.0	26	1033	2.1	161	565	13.3	309	327	28.0	80	294	8.0
Tochigi	439	184	3.0	43	184	4.0	84	157	6.2	83	185	6.8	28	192	2.3	5	79	0.5	1	124	0.1
Miyazaki	342	483	2.3	20	633	1.9	37	910	2.7	53	758	4.4	25	592	2.1	74	280	6.7	54	302	5.4
Others	737	228	5.0	72	257	6.7	57	414	4.3	82	303	6.8	53	293	4.4	42	236	3.8	59	175	5.9
Total	**14860**		**100**	**1078**			**1345**			**1212**			**1206**			**1105**			**1008**		

	July			Aug			Sept			Oct			Nov			Dec		
	Q'ty	Price	Ratio	Q'ty	Price	Ratio	Q'ty	Price	Ratio	Q'ty	Price	Ratio	Q'ty	Price	Ratio	Q'ty	Price	Ratio
2000																		
Saitama	240	287	28.2	215	276	28.2	273	289	23.6	257	297	17.2	244	298	16.9	287	302	13.1
Aomori	5	211	0.6	20	168	2.7	84	238	7.2	449	184	30.0	470	190	32.6	751	195	34.2
China	**103**	**94**	**12.1**	**97**	**95**	**12.8**	**190**	**108**	**16.4**	**223**	**109**	**14.9**	**187**	**112**	**13.0**	**267**	**125**	**12.2**
Ibaragi	49	198	5.7	66	177	8.6	104	217	9.0	89	191	6.0	143	174	10.0	346	176	15.8
Tokyo	98	273	11.4	91	260	12.0	139	270	12.1	139	267	9.3	135	257	9.4	179	270	8.1
Chiba	51	135	6.0	50	125	6.6	98	124	8.5	103	128	6.9	98	135	6.8	142	158	6.5
Gunma	244	175	28.7	179	164	23.5	185	203	16.0	88	221	5.9	32	165	2.2	38	200	1.7
Kumamoto	6	251	0.7	1	74	0.1	0	0	0.0	0	0	0.0	0	0	0.0	1	433	0.0
Tochigi	1	117	0.2	1	217	0.1	23	249	1.9	65	185	4.3	33	175	2.3	73	201	3.3
Miyazaki	24	243	2.8	19	269	2.5	13	296	1.1	6	355	0.4	2	320	0.1	15	632	0.7
Others	31	165	3.7	22	143	2.9	47	165	4.1	77	155	5.2	96	171	6.6	97	213	4.4
Total	**852**			**761**			**1156**			**1496**			**1440**			**2196**		

Exchange Rate in 2000: J63.88=AU$1

Appendix 5 Japans Burdock Imports from 1999-2001 (quantity in kg, value in 1,000 JPY)

70690010	Burdock, fresh or chilled									
HS Code	E	Country		Unit	199912		200012		200112	
	I	Abbreviation	No		Quantity	Value	Quantity	Value	Quantity	Value
70690010	**I**	**TOTAL**	**990**	**KG**	**71715272**	**5128777**	**81676205**	**4866316**	**80683244**	**5126559**
70690010	I	(NIES)	993	KG	17139805	2445704	12990590	1065691	11472510	999699
70690010	I	(APEC)	994	KG	71682702	5125964	81655565	4865213	80683244	5126559
70690010	*I*	*CHINA*	*105*	*KG*	*54538667*	*2679797*	*68500769*	*3780378*	*69025924*	*4104708*
70690010	I	TAIWAN	106	KG	17139805	2445704	12990590	1065691	11449550	997679
70690010	I	AUSTRAL	601	KG	-	-	154488	17071	184810	22152
70690010	I	R KOREA	103	KG	-	-	-	-	22960	2020
71080030	Burdock, uncooked or cooked by steaming or boileng in water, frozen									
HS Code	E	Country		Unit	199912		200012		200112	
	I	Abbreviation	No		Quantity	Value	Quantity	Value	Quantity	Value
71080030	**I**	**TOTAL**	**990**	**KG**	**4054499**	**468408**	**5466931**	**507517**	**6217802**	**642383**
71080030	I	(E . U)	991	KG	8640	1845	5040	934	6560	1361
71080030	I	(APEC)	994	KG	4045859	466563	5461891	506583	6211242	641022
71080030	*I*	*CHINA*	*105*	*KG*	*3990805*	*458558*	*5461891*	*506583*	*6211242*	*641022*
71080030	I	FRANCE	210	KG	8640	1845	5040	934	6560	1361
71190093	Burdock, provisionally preserved									
HS Code	E	Country		Unit	199912		200012		200112	
	I	Abbreviation	No		Quantity	Value	Quantity	Value	Quantity	Value
71190093	**I**	**TOTAL**	**990**	**KG**	**1859847**	**172924**	**1300568**	**92189**	**1382200**	**111484**
71190093	I	(ASEAN)	992	KG	-	-	14363	2254	54416	7794
71190093	I	(APEC)	994	KG	1859847	172924	1300568	92189	1382200	111484
71190093	*I*	*CHINA*	*105*	*KG*	*1859847*	*172924*	*1286205*	*89935*	*1327784*	*103690*
71190093	I	INDNSIA	118	KG	-	-	14363	2254	54416	7794
Total:					**77629618**		**88443704**		**88283246**	

Source: Japan Tariff Association

Appendix 6

Estimated direct costs to process 1000 kg or 1t of fresh burdock

(Source: McVeigh, Vynka - Department of Agriculture, WA)

Processing	**Unit**	**$/unit**	**Total $**
Skinning and trimming (4 people) 20% loss skinning and trimming - 800 kg	32 hrs x 4	$13/hr	1664
Burdock kimpira cutting (2 people + machine) less 10% loss - 720kg	100 kg/hr	8 hrs @$13/hr x 2	208
Blanche burdock (boiling water for 1.5 mins) (1 person) less 5% loss - 684 kg	5 kg/ 2 mins	5 hrs/720kg @$13/hr	65
Spin dried (machine + 1 person) less 5% loss - 650 kg	5 kg / 4 mins	9 hrs/684kg @$13/hr	117
Filling, weighing, vacuum packing (2 people + machine) less 5% loss - 617 kg	1 kg/ 3 mins	32 hrs/650 kg@$13/hr x 2	832
Packaging costs for 5 kg cartons holding 5 kg of semi-processed Burdock packed in 1 kg plastic vacuum pack bags	$518	cost of materials $518	518
Total			3404
Total cost per kg ($3404 / 617 kg)			**5.517**

Appendix 7

Tabular presentation of the **S**trengths, **W**eaknesses, **O**pportunities and **T**hreats of a Western Australian semi-processed Burdock production for the Japanese market:

(Source: 3)

Strengths: • good climatic and soil conditions of the Swan Coastal Plain for the production of Burdock for the Japanese market • the optimal timing of production in WA can meet time window, when local production in Asia is in short supply • existing general production and produce handling skills for Burdock in WA • **already established contacts and relationships to the Japanese market (wholesaler, retailer, importer, trading house)** • relatively low land prices in WA • possibility to use existing post harvest infrastructure • the “clean and green” image of Australians environment for the production of vegetables
Weaknesses: • high transportation and processing costs • low knowledge in processing Burdock in Australia • new investments in special machinery for cultivation, harvesting, processing • harvesting and processing of Burdock is labour intensive • small demand in Australia and other countries • low export experience in the Japanese Burdock market • good quality of Japanese products, customers tends to favour domestic vegetables • **soiled roots are associated with fresh products - no soil on processed Burdock** • **sea freight from Fremantle to Tokyo takes approx. 21 days – from China only one week** • distance to customers and the Japanese market in connection with changes in customers needs
Opportunities: • decrease of the domestic Japan production by 30% over the last 30 years and by 10% in the last five years • fluctuating prices, exchange rates and transport costs • very high waste removal prices in Japan • outsourcing trends of Japanese food processors due to waste problems, labour costs and large space requirements • diversify range of products and establish new markets for the WA production • build up new links for other Western Australian products • limited quality and supply from the Asian markets from March-May, where WA can meet this demand • as in WA there is no daylight saving period in the rest of the Asian region • the time difference between Perth and Tokyo is only one hour
Threats: • fluctuating exchange rates can influence the income of WA agribusinesses • poor choice of distributor • changing customer behavior can cause decreases in demand • other producers can be more competitive than WA and deliver the Burdock for lower prices • increasing quality of Chinese Burdock • processing costs are not known and difficult to calculate • the Japanese diet becomes more and more westernized • trend of establishing joint ventures between Japan and China to secure the supply of Burdock into the Japanese market

8.0. Recommendations for further research

1. Conduct further research on the processing costs based on the findings in this analysis and on the figures provided by Jeff Hastings to build up a Western Australian semi-processed burdock industry into Japan.

2. Gather information about the production practices in China. Find out if there are immanent disease or pest problems or unsustainable production practices which could lead to supply problems in the next years.

3. Further analysis of the general demand trend for burdock. Who will demand burdock in the future (international and domestic) and who will pay a premium for the product.

4. Investigate opportunities for Western Australian growers to establish joint-ventures with Japanese companies to grow burdock in WA and to export the product to the Japanese market.

5. Continue research on technologies to extend the shelf-life of semi-processed burdock to secure the distribution of produce to the Japanese market

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