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Improving sweet potato agronomy to meet new market opportunities

Stephen Harper
QLD Department of Primary Industries and Fisheries

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VG01010

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Final report
HAL project VG01010 November 2005

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HAL

Queensland Government
Department of Primary Industries and Fisheries

HAL project No. VG01010

Improving sweetpotato agronomy to meet new market opportunities.

This report outlines the findings of project VG01010 that evaluated improved agronomic practices in sweetpotato production

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Contents

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Media Summary

The project was initiated to evaluate agronomic practices that improve marketable yield of sweetpotato.

An 80% yield improvement for cv. Beauregard was achieved using pathogen tested (PT) planting material. Beauregard selections made from grower lines did not give greater yield nor infer improved disease resistance compared with the DPI&F Beauregard.

An initial plant density trial (2001/02) showed no significant effect of varying within row plant spacings (20, 25 and 30 cm) over 9 varieties. A further plant spacing trial (at 20, 25, 30, 35 and 40 cm) on cvv. Beauregard and Northern Star showed no significant effect. The ideal within row spacing is between 25-30 cm. A maturity trial showed the lines Northern Star and L87-59 (Darby) exhibited particularly early maturity (17 weeks after planting).

In 2003 a series of experiments evaluated the effects of varying nitrogen (N) and potassium (K) rates on yield of cvv. Beauregard and Northern Star at three sites. The effect of N was variable suggesting factors other than simply N limited yield. Highest yields of Beauregard were obtained at 50-100 kg N ha^{-1} at Rockhampton and at 150 kg N ha^{-1} at Bundaberg. At Mareeba yield was reduced at 140 and 210 kg N ha^{-1} despite the soil having the lowest N concentration. There was no significant effect of K on root yield at any of the 3 sites. Incidence of cracking in Northern Star increased with increasing N rate at Bundaberg but not at Rockhampton.

In 2004 two trials evaluated effects of N (0-250 kg ha^{-1}) and K (0-300 kg ha^{-1}) on yield of Beauregard. Maximum yields were obtained at an N rate of 100 kg ha^{-1} and at a K rate of 120 kg ha^{-1}. At high N rates yield decreased. The N and K requirements of sweetpotato are not high and application can be reduced.

To test the effectiveness of project research recommendations, technology transfer trials utilising DPI&F best management options were conducted on commercial properties. The results showed that the DPI&F best management options, in particular, utilising foundation seed planting material and controlling nitrogen and potassium usage gave higher marketable yields. Dr. Mike Canon from Louisiana State University made presentations in the three major sweetpotato production areas in Australia outlining current research and production issues in the USA.

Grower surveys were carried out at the beginning and at projects end to evaluate the project impact. All growers surveyed were aware of the project and the greatest impact of the project was in changing their fertiliser usage and the adoption of pathogen tested planting material.

Technical Summary

A series of experiments demonstrated that using pathogen tested (PT) planting material gave an 80% improvement in marketable yield for Beauregard demonstrating that growers need to regularly introduce PT plant material in their production cycle. The research showed no significant disease tolerance in Beauregard selected from grower fields in Australia.

In the 2001/02 3 plant density treatments were imposed using within row plant spacings of 20, 25 and 30 cm over 9 varieties. The total and marketable yields for Northern Star and Beauregard appeared to increase when the plant spacing was reduced from 30 cm to 25 cm, but the effect was not significant ($p=0.05$). Across these plant spacings the marketable yield difference for Beauregard was about 10 tonne ha^{-1} whilst for Northern Star it was about 6 tonne ha^{-1}. A further plant spacing trial was conducted at Cudgen in 2003 on cvv. Beauregard and Northern Star. Five plant spacings were imposed (20, 25, 30, 35 and 40cm). There was no significant effect of manipulating plant spacing on the yield of either Beauregard or Northern Star. The ideal within row spacing would appear to be between 25-30 cm, which is consistent with standard industry practice.

A trial was conducted in 2001/02 to evaluate the different maturities of potential new sweetpotato varieties. Three harvests were conducted at 17, 21 and 23 weeks after planting. The lines Northern Star and L87-59 (Darby) exhibited particularly early maturity. High yields in both these lines were obtained at only 17 weeks and marketable yields were about 40 tonne ha^{-1}. The early maturity of this variety contrasts with the industry standard cropping duration of about 20 weeks. Growers of Northern Star need to closely monitor yield potential at about 15-16 weeks as harvesting may be possible at around this time.

In 2003 a series of experiments evaluated the effects of varying nitrogen (N) and potassium (K) rates (50-210 kg ha^{-1}) on yield and quality components of Beauregard and Northern Star at three sites. Total and marketable yields of Beauregard were not significantly affected by N application rate at Bundaberg and Rockhampton, but highest yields were obtained at 50-100 kg ha^{-1} at Rockhampton and at 150 kg ha^{-1} at Bundaberg. At Mareeba both total and marketable yields were significantly reduced at the 140 and 210 kg ha^{-1} despite the Mareeba soil having the lowest N concentration. There was no significant effect of K on root yield at any of the three sites. For Northern Star, N application had no effect on total yield at either Bundaberg or Rockhampton but incidence of cracking increased with increasing N at Bundaberg but not at Rockhampton. There was no significant effect of K on root yield at any of the 3 sites. All tissue test data for N were within or above the reported adequate range regardless of the N treatment. Beauregard had significantly higher concentrations of N ($P=0.001$) compared with Northern Star, the average difference being 0.54% suggesting a higher N requirement for Beauregard.

In 2004 two trials evaluated effects of N (0-250 kg ha^{-1}) and K (0-300 kg ha^{-1}) on yield of Beauregard. Maximum yields were obtained at an N rate of 100 kg ha^{-1} and at a K rate of 120 kg ha^{-1}. At high N rates marketable and total root yield was decreased. The trials showed that both N and K requirements of sweetpotato are not high and application can be reduced. Two trials at Mareeba in 2004 evaluated liming and trace element (B, Zn and Mo) effects on sweetpotato but no significant effects were observed.

To test the effectiveness of project recommendations technology transfer trials utilising DPI&F best management options were carried out on growers properties in Mareeba, Rockhampton, Bundaberg and Cudgen. The results showed the efficacy of the DPI&F best management options derived from the research trials. In particular, utilising foundation seed planting material and controlling nitrogen and potassium usage gave higher marketable yields.

A suite of technology transfer methods including on farm evaluations, media news releases, farmnotes, newsletters and information sessions were utilised during the course of the project. A survey of growers has shown adoption of projects outcomes to be very high. Dr. Mike Canon from Louisiana State University made presentations in the three major sweetpotato production areas in Australia outlining current research and production issues in the USA.

Grower surveys were carried out at the beginning and at projects end. The industry's production is growing rapidly with the gold fleshed 'Beauregard' variety being dominant. All growers surveyed were aware of the project and its findings. Growers found the greatest impact of the project was in changing their fertiliser usage and their adoption of pathogen tested planting material.

1. Introduction

Sweetpotato is one of the only growing categories in retail vegetable sales and growth has only been restricted by a lack of consistency and supply of product. The Queensland DPI&F in conjunction with HAL developed and released a suite of new sweetpotato varieties (HAL project VG97023). The project highlighted considerable geographic and seasonal variability in existing and new varieties suggesting each appeared to have specific cultural requirements in order to produce more roots of marketable size.

Growers have had more difficulty in achieving market specifications with some of the new varieties and there was a need to refine agronomic practices to improve marketable yield. These problems included high percentages of over or under sized roots, cracking skin, skin and flesh colour, shape and number of roots set. The variability in expression of these defects is likely to be at least partly related to specific agronomic requirements.

Factors including presence of feathery mottle virus, timing and rate of fertiliser application, genetic drift in propagative material, varietal maturation and plant spacing all potentially impact on yield and quality traits. In Australia, little is known about these agronomic issues particularly in relation to relatively new varieties including Beauregard and Northern Star.

This project evaluated and promoted the benefits of growers using virus free planting material as opposed to keeping their own material. Also improved agronomic practices in new and existing sweetpotato varieties was investigated with the aim of enabling growers to produce more roots of marketable size and quality.

2. Evaluation of Pathogen Tested Plant Material

2.1 Introduction

Yield decline for the sweetpotato cultivar Beauregard has been measured in the United States as a progressive change in physical shape of storage roots as virus and virus like disease build up in planting material (La Bonte et *al*. 2004). Field evaluations of pathogen tested (PT) planting material have demonstrated large improvements in storage root quality. Pathogen testing of grower maintained planting material of the cultivar Beauregard and its field evaluation before and after pathogen testing has been used as a method to quantify the effect of sweetpotato disease complexes on yield and quality. Although genetic variability is thought to also be a contributing factor to yield decline this study has only shown limited genetic decline in the cultivar Beauregard.

At the beginning of the present project in field quality of cultivar Beauregard was assessed using a survey of agronomic practices, farm inspections and a market evaluation. A number of grower selections were taken that exhibited similar foliage, and, in some cases dissimilar storage root characteristics, to that of the DPI&F PT Beauregard. Selections were compared with the DPI&F PT selection both before and after the pathogen indexing of the grower selections.

2.2 Methodology

Evaluation

A grower survey of agronomic practices was conducted at the beginning of the project to measure the awareness and usage of PT material (Chapter 6). A market survey was conducted to measure the quality of the product at the consumer interface (Appendix 1). Grower visits were used to assess the quality and virus status of the genetic stocks being used by growers in the industry.

Collection of grower field selections

Seven selections were made of gold fleshed bronze skinned sweetpotatoes at the beginning of the project. One selection was made at Rockhampton, four at Cudgen and two from Bundaberg. Although Cudgen was not the biggest production area there was anecdotal evidence from growers that distinct Beauregard lines may have been maintained from germplasm introductions that had taken place in isolation to the DPI&F Beauregard introduction. The collection of this material was conducted to ensure a reasonable sized sample of the potential genetic pool was taken from commercial grower lines.

Pathogen testing

To assess the efficacy of using PT material, experiments were conducted to evaluate the selections before and after heat treatment to remove virus. The procedure for removing virus and producing PT material is presented in appendix 2.1. Five experiments compared the DPI&F PT Beauregard to non-PT grower selections and two experiments were used to compare the DPI&F PT Beauregard to the grower selections after they had been put through the pathogen removal process; full details of the experiments are presented in appendix 2.2.

Field evaluations

Field evaluations of PT material were conducted on seven separate occasions. The aim of the assessments was to compare the DPI&F PT germplasm of Beauregard against grower selections used in commercial production. The initial assessments were conducted as part of larger cultivar evaluations (data not presented) where only one or two grower selections, that were not pathogen tested, were compared with the DPI&F PT material. Later in the project the DPI&F PT material was compared to a greater number of grower selections, initially with a large virus titre and subsequently after the pathogen testing procedure was conducted.

There were two distinct groups of experiments conducted. The first was a series of three experiments where a weight based grading system was used (Mareeba A, Mareeba B, Bundaberg varieties 2002). These experiments were conducted in 2002. The second was a series of 4 experiments where a size and shape based quality grading system was used based on current commercial requirements. These experiments included Cudgen evaluation 2003 (a comparison of PT and non-PT material), Bundaberg evaluation 2004 (a comparison of PT and non-PT material), Bundaberg evaluation 2005 (a comparison of all PT selections), Cudgen evaluation 2005 (a comparison of all PT selections).

Weight based grading system

The weight based grading system used was based on the following parameters

- Undersize(less than 151g)
- Small(151-250g)
- Medium (251-600g)
- Large (601-1000g)
- Oversize(greater than 1000g)

Size and shape based grading system

The size and shape based grading system is based on a commercial grade required for the Australian retail market. This system has primary requirements for size and the project team has developed secondary criteria to improve the objectivity of the system when size determinations are difficult to measure. This system was used for all experiments conducted after the Bundaberg 2002 variety experiment.

Primary shape specification

- Undersize (less than 130mm long and/or diameter less than 50mm)
- Small (length 130-180mm and/or diameter 50-60mm)
- Medium (length 180-250mm and/or diameter 60-75mm)
- Large (greater than 250mm long and/or diameter greater than 75mm

Secondary weight specification

- Undersize (63-170g)
- Small (171-310g)
- Medium (311-620g)
- Large (621-860g)

Defects

- Shape (included long thin, ribbed, bulby, bent)
- Mechanical damage (breaks, cuts, and skinning)
- Insect damage
- Old/Aged
- General (skin blemishes such as nematodes and scurf)

2.3 Results

Weight based evaluation

The three 2002 experiments i.e. Mareeba A, Mareeba B and Bundaberg Varieties 2002 were all evaluated using a weight based grading system. The grower Beauregard selections and the DPI&F PT Beauregard material showed no difference in marketable yield for any of these experiments (Appendix 2.3). An observation made at the Bundaberg Varieties 2002 experiment (data not presented) revealed a large difference in shape between the DPI&F PT Beauregard and the grower selection (figure 2.1) with a higher proportion of bent and twisted storage roots produced by the grower selection than the DPI&F PT material. However, this difference was not distinguishable using a weight based grading system.

Cudgen pathogen tested material evaluation 2003

The Cudgen 2003 experiment was the first evaluation using a size and shape based grading system. The PT veg tip Beau and PT sprout Beau appeared to have a higher yield for the small, medium, marketable and total yield compared with the non PT grower selections. However, the only significant differences were medium yield for PT veg tip beau compared with Cudgen gold and total yield for PT sprout Beau compared with Cudgen Gold (table 2.1).

Figure 2.1. The left of the frame shows sweetpotato was taken from a pathogen tested treatment and on the right from grower material at Bundaberg in 2002.

Bundaberg pathogen tested material evaluation 2004

The Bundaberg 2004 experiment compared a wider range of grower selections with the DPI&F gene bank Beauregard material. There were significant differences between the DPI&F PT material and all the non-PT grower selections with the biggest differences in the high value medium category (table 2.2). This difference between treatments in the medium category also translated to a significant difference for the total yield.

Table 2.1. Comparison of grower and pathogen tested DPI&F Beauregard at Cudgen 2003.

Variety	Yield (t ha^{-1})						
	Undersize	Small	Medium	Large	Seconds	Marketable (S+M+L)	Total
[1]PT Beau (veg tip)	6.67	15.22	26.88	5.28	1.85	47.18	55.71
PT Beau (sprout)	5.19	15.07	25.30	9.76	5.03	50.13	60.35
[2]Abernathy	5.52	13.66	24.88	6.93	4.64	45.46	55.62
[3]Cudgen Gold	4.44	13.37	19.9	6.92	1.38	40.19	46.01
F value	NS	NS	*	NS	NS	NS	*
LSD(P=0.05)	2.88	4.36	6.07	7.67	6.58	9.99	11.11

NS denotes Not significant at P=0.05, * denotes Significant at P=0.05, ** denotes Significant at P=0.01, *** denotes Significant at P=0.001

[1] PT Veg tip Beau was a treatment of pathogen tested Beauregard terminal vine cut from a whole plant as opposed to the PT sprout Beau that was also a pathogen tested Beauregard terminal vine but was produced from a seedbed i.e. a sprouted sweetpotato root planted in the ground.

[2] Abernathy treatment is a grower Beauregard selection collected from the Cudgen district

[3] Cudgen Gold treatment is a grower Beauregard selection collected from the Cudgen district

Table 2.2. Comparison of grower and pathogen tested DPI&F Beauregard at Bundaberg 2004 (White Maltese and JRW are not Beauregard cultivars).

Variety	Yield (t ha^{-1})							
	Undersize	Small	Medium	Large	Seconds	Rejects	Marketable (S+M+L)	Total
Abernathy	0.97	2.19	4.44	2.23	9.81	7.67	8.86	27.3
[1]Peterson	1.99	3.27	4.93	2.17	6.91	4.87	10.37	24.14
[2]Bundy gold	1.04	2.14	3.18	1.35	5.03	4.38	6.67	17.11
[3]Sam's	1.19	1.70	3.76	3.22	7.54	5.89	8.68	23.30
[4]Cudgen Gold	1.48	1.61	3.09	1.30	7.26	5.15	6.00	19.89
White maltese (PT)	1.77	4.18	6.53	1.20	7.38	21.26	11.91	42.33
[5]JRW (PT)	2.91	2.95	11.72	9.51	14.32	7.18	24.18	48.50
[6]DPI 2003 (PT)	1.60	2.73	10.24	3.18	11.48	7.31	16.15	35.54
F value	P=0.068	*	**	***	**	***	***	***
LSD (P=0.05)	1.26	1.52	3.79	2.72	3.82	4.27	4.14	7.29

NS denotes Not significant at P=0.05, * denotes Significant at P=0.05, ** denotes Significant at P=0.01, *** denotes Significant at P=0.001

[1] Peterson is a grower Beauregard selection collected from South Kolan in the Bundaberg district

[2] Bundy Gold is a Beauregard selection collected form Moore Park in the Bundaberg district

[3] Sam's is a Beauregard selection collected from the Cudgen district

[4] White Maltese(PT) is a white skinned white flesh selection not relevant to Beauregard comparison but included for completeness of data.

[5] JRW(PT) red skinned white flesh selection not relevant to Beauregard comparison but included for completeness of data.

[6] DPI 2003 (PT) is DPI&F Beauregard material from the 2003 virus free seed bed crop and considered to be pathogen free.

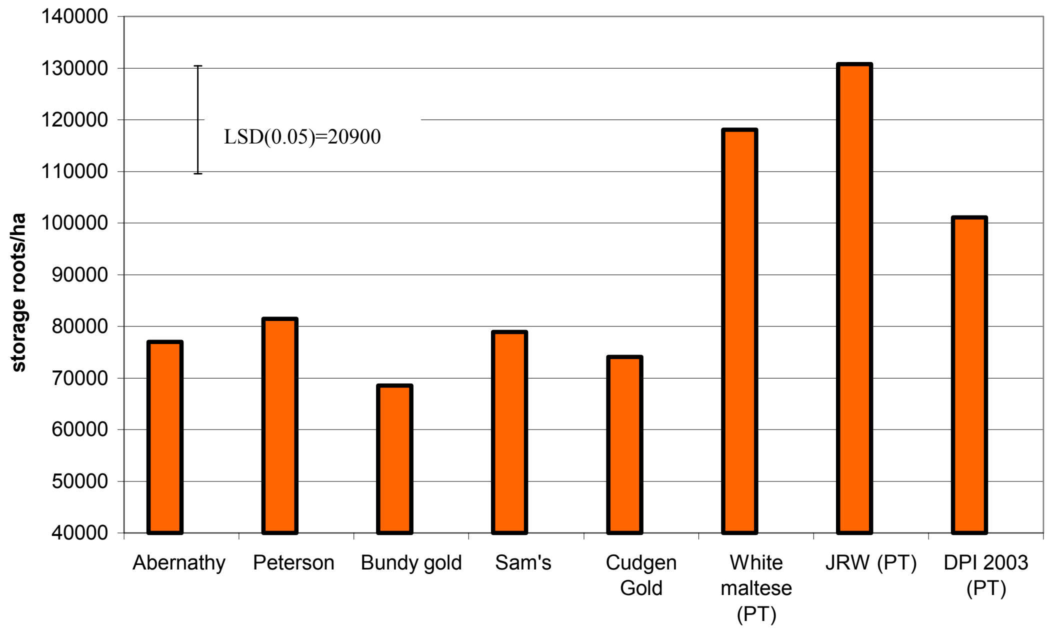


Figure 2.2. Comparison of total storage root numbers/hectare for grower and pathogen tested DPI&F Beauregard at Bundaberg 2004 (White Maltese and JRW are not Beauregard cultivars) LSD(0.05)=20900

Bundaberg pathogen tested material evaluation 2005

Minimal differences between the PT growers' selections and the DPI&F selection were evident for yield with the exception of the Peterson selection which had significantly less mediums and a higher number of seconds (table 2.3). This selection also had significantly more roots than any other selection (figure 2.3).

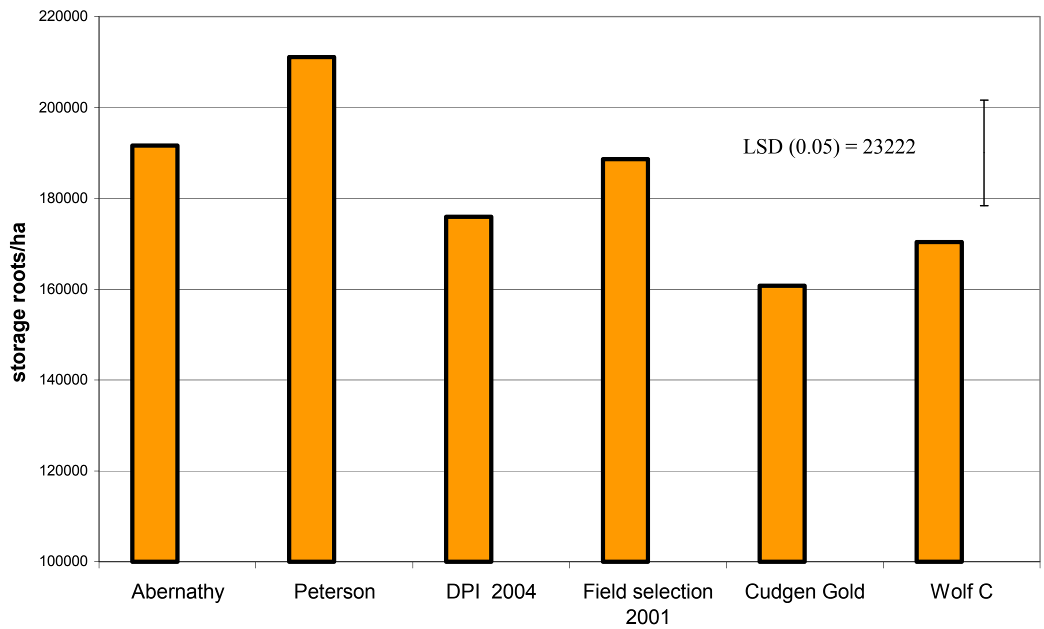


Figure 2.3. Comparison of total storage root numbers/hectare for pathogen tested grower selections and DPI&F Beauregard at Bundaberg 2005.

Table 2.3. Comparison of pathogen tested grower and DPI&F Beauregard at Bundaberg 2005.

Variety	Yield (t ha^{-1})							
	Undersize	Small	Medium	Large	Seconds	Rejects	Marketable (S+M+L)	Total
Abernathy	6.09	8.43	18.7	5.52	8.33	3.70	32.59	50.78
Peterson	3.48	4.85	7.12	4.58	24.1	15.35	16.54	59.48
[1]DPI 2004	3.89	5.32	13.98	7.78	12.67	5.32	27.04	48.94
[2]Field sel 2001	5.60	5.77	16.81	6.65	13.22	3.63	29.26	51.69
Cudgen Gold	4.25	7.48	19.22	12.07	6.41	2.94	38.77	52.37
[3]Wolf C	3.72	5.16	17.63	12.02	14.56	3.99	34.81	57.07
F value	P=0.071	*	**	*	***	***	**	*
LSD (P=0.05)	2.02	2.55	5.56	5.45	5.16	4.78	9.89	6.09

NS denotes Not significant at P=0.05, * denotes Significant at P=0.05, ** denotes Significant at P=0.01, *** denotes Significant at P=0.001

[1] DPI 2004 is DPI&F Beauregard material cut from the 2004 virus free seed bed crop and is considered to be pathogen free

[2] Field selection 2001 is DPI&F Beauregard material selected from the 2001 virus free seed bed crop due to high yielding potential and has been pathogen tested

[3] Wolf c is a Beauregard selection from the Rockhampton district

Cudgen pathogen tested material evaluation 2005

The Cudgen 2005 experiment showed few differences between selections (table 2.4) with only the Cudgen Gold selection having significantly more mediums then several of the other selections. The Peterson selection had significantly more rejects than Abernathy, Field selection 2002, Cudgen Gold and Wolf C while its root numbers per hectare were significantly higher than all other selections with the exception of DPI 2004 (figure 2.4).

Table 2.4. Raw fresh yield data for Cudgen grower reselections all PT 2005.

Variety	Yield (t ha^{-1})							
	Under-size	Small	Medium	Large	Seconds	Rejects	Marketable (S+M+L)	Total
Abernathy	3.44	4.97	16.94	14	19.76	6.16	35.88	65.27
Peterson	5.58	4.80	11.56	13.6	21.09	13.88	29.93	70.47
DPI 2004	4.86	7.52	18.33	8.91	16.22	8.78	34.76	64.62
Field sel 2001	4.29	5.14	18.03	18.9	8.71	4.63	42.11	59.69
Cudgen Gold	4.12	5.51	24.56	29.2	6.56	4.63	59.22	74.52
Wolf C	4.69	8.06	15.61	16.4	14.01	4.66	40.07	63.43
F value	NS	NS	NS	*	*	*	*	NS
LSD (P=0.05)				12	10.07	5.51	15.44	

NS denotes Not significant at P=0.05, * denotes Significant at P=0.05, ** denotes Significant at P=0.01, *** denotes Significant at P=0.001

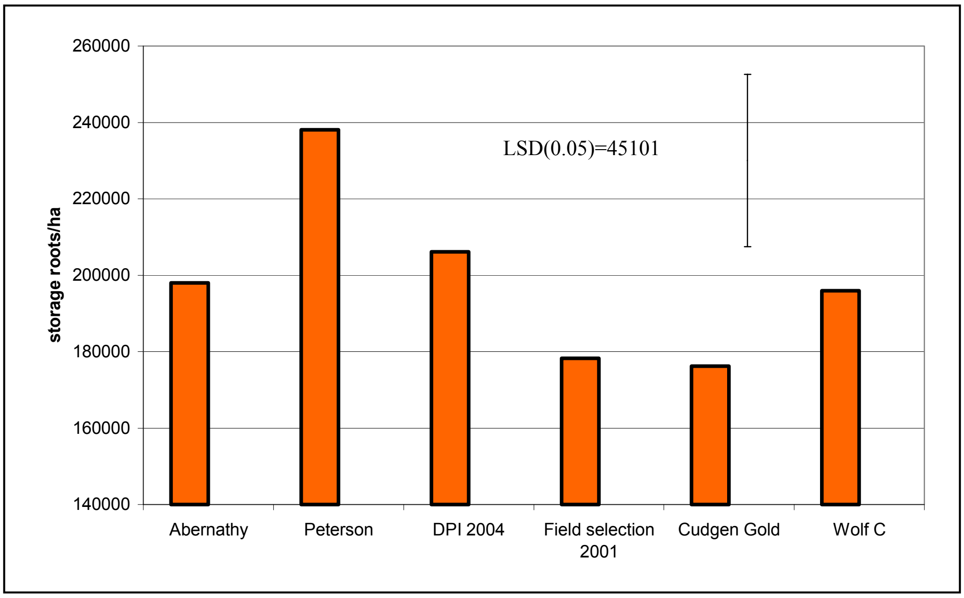


Figure 2.4. Comparison of total storage root numbers/hectare for pathogen tested grower selections and DPI&F Beauregard at Cudgen 2005. LSD(0.05)=45101

2.4 Discussion

Prior to the Bundaberg 2002 experiment, variety evaluation was based on a weight grading system. This system graded the sweetpotato roots into 5 grades: less than 150g; 150-250g; 250-600g; 600-1000g; and greater than 1000g giving no quality determinations based on shape (length, width, bends and ribbing). Our market evaluation conducted at the beginning of the project suggested that shape was the major quality criteria that needed to be addressed (appendix 1). Previous evaluations of cultivars from the HAL funded project VG97023 recommended a number of varieties as having significant market potential based on the yield of roots but not shape particularly in the 250-600g range, however there was limited uptake of these cultivars at the time project VG01010 commenced. The market evaluation conducted in 2002 ascertained the market preference for shape, skin and flesh colour and a grading specification based on shape for cv. Beauregard was developed to address this need. This grading specification was later refined by using a secondary weight category that could be used when length and diameter specifications were too close to evaluate by physical measurement. The adoption of a market based evaluation system was a major step towards developing evaluation criteria that enabled the project team to objectively evaluate sweetpotatoes to meet new market opportunities.

Grower reselections and potential genetic variation

The assumption at the beginning of the project was that all the grower selections would have originated from three separate introductions of Beauregard to Australia since the early 1980's. Furthermore, there was the potential with natural somatic variation for these cultivars to be quite different from the original parent Beauregard material and there was the potential for some disease tolerance to have developed over this time. In order to test this assumption our experiments compared gene-bank Beauregard material in a pathogen tested state with grower selections both before and after pathogen testing. The Peterson line collected from a grower in Bundaberg has, over a number of experiments, displayed a tendency to produce significantly more storage roots than other grower selections both before and after pathogen testing. This capacity to produce greater numbers of storage roots also appeared to reduce the marketable yield of this cultivar compared with several other selections. This is most probably occurs due to overcrowding causing the roots to deform, and, also the lack of sufficient assimilate to fill the storage roots adequately to achieve the quality specification for root diameter. This series of experiments suggests that the Peterson selection has genetic variation but there is no evidence of disease tolerance.

Impact of Disease on storage root quality

The Mareeba A, Mareeba B and Bundaberg Varieties 2002 were all graded using a weight grading system and failed to show any significant difference between the grower selections and the DPI&F gene bank material. In the Cudgen evaluation 2003 a comparison of PT and non-PT material was inconclusive and showed no significant differences between the DPI&F material and the 2 grower selections. This site was a non-irrigated site and was grown over an extended dry period, which may have checked growth. In the Bundaberg evaluation 2004 a PT planting material gave greater yield in all grade categories than the non-PT materials. This large difference was exhibited particularly in root quality, which has been demonstrated (La Bonte *et al.* 2004).

The later experiments that compared DPI&F PT material to the PT grower selections have not shown the large differences experienced in the Bundaberg 2004 experiment and the observed differences from Bundaberg in 2002. This clearly demonstrates the effectiveness of disease removal as a means of improving root shape and quality.

3. Sweetpotato plant spacing and maturity

3.1 Introduction

Under project VG97023 several new potential cultivars were developed which appeared to exhibit differing rates of maturation. This was based on high yields of over-size roots being achieved at the industry standard crop duration of 20 weeks. In particular, Northern Star appeared to exhibit very early maturity. The optimisation of plant spacing and maturity could assist in addressing the severe cracking that often occurs in this cultivar. In the USA, the main Gold cultivar is Beauregard and research there (Schultheis *et al.* 1999) has shown that smaller within-row plant spacings, as low as 15 cm, increase yield relative to spacings of 38 cm and 31 cm (the Australian industry standard). Similarly, research in Australia, conducted on cultivars other than Beauregard and Northern Star (Harper 1984), showed that highest marketable yields were obtained at a spacing of 26.6 cm compared with that at 40 cm. The variety LO-323 exhibited still higher marketable yield at a spacing of only 20 cm indicating an interaction between plant spacing and cultivar. The literature indicates that the yield of sweetpotato roots across a range of cultivars is decreased at spacings greater than about 40 cm (Harper 1984; Schultheis *et al.* 1999; Yassen and Thompson 1988).

The present series of experiments was initiated to evaluate the effects of density and maturity across cultivars to determine whether altered plant spacings could improve yield and quality traits.

3.2 Plant spacing

3.2.1 Materials and Methods

Redlands plant spacing trial 2001/02

Selected lines developed under project VG97023 were grown in a replicated trial at Queensland government DPI&F Redlands Research Station aimed at evaluating the effects of plant spacing treatments (20, 25 and 30 cm) on yield parameters. This gave plant densities of about 38 500, 30 800 and 25 600 plants ha^{-1} respectively. The trial was planted on 13 December 2001 and the design was a randomised complete block with four replicates. Pathogen tested tip cuttings were planted in 1.3 m wide beds. At the end of each 3 m plot a cutting of cultivar Hung Loc was planted as a marker and to eliminate plot end plant effects. This trial was harvested at 21 weeks after planting. All plots were dug mechanically and all roots from each plot collected into labelled bins then washed. All replicates were graded according to root weight (0-150g, 150-250g, 250-600g, 600g-1kg and >1kg). Marketable yield consisted of roots in the 250g-1000g range. Counts of root numbers in each grade range were made. Data was analysed using analysis of variance.

Cudgen plant spacing trial

The 2001/02 spacing experiment failed to give greatly meaningful results as considerable cockatoo damage was recorded on the roots. A further experiment was conducted to evaluate the effects of 5 plant spacings (20, 25, 30, 35 and 40 cm) on yield of sweetpotato (cvv.

Beauregard and Northern Star). This gave plant densities of about 37 700, 29 700, 24 700, 21 200 and 18 500 plants ha^{-1} respectively.

The trial was planted on 23 January 2003 at Cudgen (on a krasnozem soil) and conducted as a randomised complete block design with four replicates. Pathogen tested tip cuttings were planted in 1.35 m wide beds. Plots consisted of 4 rows and of varying length depending on the plant spacing treatment, but ranging from 3.2 m to 3.6 m. The 2 middle rows in each plot were the datum rows and planting of each pair was randomly allocated to the cultivars Beauregard and Northern Star.

Each pair was planted using cutting material from the Queensland government DPI&F Gatton Research Station Pathogen tested material. The 2 guard rows of each plot were planted using the commercial growers' planting material cv. Beauregard. At the end of each plot a cutting of a white skinned cultivar was planted as a marker and to eliminate plot end plant effects. A gap of 2 m was allowed between each plot.

The experiment was dug mechanically on 3/09/03 (a growth period of 223 days) and all roots from each plot collected into labelled bins and graded according to a generic retail market specification (Table 3.1). Yield was expressed on a per hectare basis and root number data was expressed on a per metre of row basis to account for the variation in plot length and plant number in each treatment. Data was analysed using standard analysis of variance.

Table 3.1 Generic retail grading specification for spacing trial at Cudgen.

Grade	Length (mm)		Diameter (mm)
Undersize	>130	and/or	>50
Small	130-180	and/or	50-60
Medium	180-250	and/or	60-75
Large	>250	and/or	>75

Other defects	Defect	Description
	Shape	Long thin, ribbed, bulbed bent
	Mechanical damage	Breaks cuts skinned
	Insect damage	
	Cracking	
	Other blemishes	Old/aged, skin blemishes, nematodes scurf

3.2.2 Results and discussion

For the Redlands plant spacing trial, in the interim time between removal of tops and harvest (about 2 weeks), severe damage was recorded due to cockatoo feeding. This caused high variability in data requiring corrections to be made in the data by making value judgements on the percentage damage, which was most pronounced in large roots. The data though showing some interesting trends is not definitive. **For this reason all results for this trial should be viewed cautiously**.

Redlands 2001/02

The total yield and marketable yield for Northern Star and Beauregard appeared to increase when the plant spacing was reduced from 30 cm to 25 cm, though the effect was not significant (p=0.05) (Table 3.2). At these spacings, the marketable yield difference for Beauregard was about 10 tonne ha^{-1} whilst for Northern Star the marketable yield difference was about 6 tonne ha^{-1}. At a still smaller plant spacing (20 cm plant spacing) the marketable yield for Northern Star declined compared with the 25 cm spacing but was still equivalent to that in the 30 cm spacing. Similarly, for Beauregard the highest marketable yield was recorded at a 25 cm spacing but marketable yield at the 20 cm spacing still appeared to be greater than at the 30 cm spacing.

For Northern Star the yield of roots over 1kg was about 20 tonne ha^{-1} at plant spacings of 30 and 25 cm and declined at a spacing of 20 cm (yield of roots greater than 1 kg = 13.2 tonne ha^{-1}). In contrast, the yield of Beauregard roots, greater than 1 kg, was unaffected by plant spacing and between 5 and 7 tonne ha^{-1} across the three densities.

The marketable root number per plant for Beauregard and Northern Star were the same at spacings of 30 and 25 cm and appeared only to decline at a spacing of 20 cm, though the effect was not significantly different (p=0.05) (Table 3.3). Though not significant, for Northern Star there was an apparent lower number of roots over 1 kg at the 20 cm spacing compared with the 25 and 30 cm spacings. The L87-59 was extremely sensitive to increasing plant density. At a spacing of 30 cm marketable roots per plant were 4.9 and at the spacings 25 and 20 cm this dropped to 3.3-3.6 roots per plant. Across all varieties (the mean of the 9 varieties) there was a significant difference in marketable root numbers per plant. Highest marketable root numbers were obtained at 30 cm spacing and there was a progressive decline in marketable root number with reduced plant spacing (higher density).

Cudgen 2003

In this trial there was no significant effect of manipulating plant spacing on any of the yield parameters for either Beauregard or Northern Star (Tables 3.4 and 3.5). Maximal yields of Beauregard were obtained at a spacing of about 25-30 cm.

Marketable root number per metre of row was similarly greatest at a spacing of 25-30 cm for Beauregard but the total root number for Beauregard appeared greatest at a spacing of 20-25 cm. This reflected the higher collective root number at the higher plant density due to there being more plants per metre of row. This highlighted that though total root number increased at the closer spacing interplant competition appeared to also increase reflected in the lower marketable root numbers at closer spacing.

For Northern Star the marketable root number per m of row was variable, but greatest at a spacing of 20–35 cm. Similarly, total root number per metre appeared the same at a spacing of 20-35 cm, but was significantly higher than that recorded at 40 cm. At the lower density the fewer number of plants resulted in a lower total root count.

Table 3.2 Comparison of total yield, marketable yield and yield of oversize roots for sweetpotato density trial, at three within row plant spacings (30, 25 and 20 cm), at Redlands Research Station 2001-2002.

	Total Yield (tonnes/ha)				Marketable yield (tonnes/ha)				Yield roots >1Kg (tonnes/ha)			
Variety	30 cm	25 cm	20 cm	Mean	30 cm	25 cm	20 cm	Mean	30 cm	25 cm	20 cm	Mean
L93-9-16	66.2	73.4	68.6	69.4	28.2	45.6	48.3	40.7	1.3	4.4	1.5	2.4
L93-93 Line	64.4	---	61.6	63.0	38.8	---	35.2	37.0	8.5	---	2.9	5.7
Q95-3	47.1	49.6	51.6	49.4	2.9	17.2	3.7	7.9	1.5	2.1	0.7	1.4
WSPF	16.1	31.7	16.2	21.3	1.5	8.4	6.0	5.3	0.0	0.0	0.0	0.0
L87-59	85.8	75.4	88.9	83.4	52.8	44.6	59.2	52.2	19.8	21.9	16.4	19.4
L86-33-5	57.6	61.3	61.3	60.1	35.1	32.5	29.3	32.3	0.0	0.0	0.0	0.0
Hernandez	50.5	53.0	54.1	52.5	33.6	35.2	34.7	34.5	1.0	0.7	0.0	0.6
Beauregard	59.2	65.8	68.3	64.4	40.6	50.5	45.6	45.6	6.4	5.1	6.9	6.1
Northern Star	73.5	82.0	76.3	77.3	44.7	51.1	44.8	46.9	21.8	20.7	13.2	18.6
Mean	57.8	61.5	60.8		30.9	35.6	34.1		6.7	6.9	4.6	
Significance												
Variety	** lsd = 10.61				** lsd = 8.90				** lsd = 6.05			
Density	NS				NS				NS			
Variety*Density	NS				NS				NS			

NS denotes Not significant at P=0.05, * denotes Significant at P=0.05 and ** denotes significant at P=0.01

Table 3.3 Comparison of total, marketable and oversize root number per plant for sweetpotato density trial, at three within row plant spacings (30, 25 and 20 cm), at Redlands Research Station 2001-2002.

	Total roots/plant				Marketable roots/plant				Roots >1Kg/plant			
Variety	30 cm	25 cm	20 cm	Mean	30 cm	25 cm	20 cm	Mean	30 cm	25 cm	20 cm	Mean
L93-9-16	9.9	10.0	7.5	9.15	2.6	3.6	3.4	3.21	0.1	0.1	0.0	0.07
L93-93 Line	11.6	8.1	8.5	9.37	5.2	1.6	2.6	3.09	0.4	0.3	0.1	0.25
Q95-3	7.3	7.5	7.8	7.52	0.3	1.6	0.3	0.72	0.1	0.0	0.0	0.04
WSPF	1.4	3.2	1.0	1.87	0.1	0.6	0.3	0.34	0.0	0.0	0.0	0.00
L87-59	10.0	6.2	6.1	7.43	4.9	3.3	3.6	3.92	0.8	0.6	0.4	0.57
L86-33-5	11.9	12.0	10.7	11.54	3.9	3.1	2.3	3.10	0.0	0.0	0.0	0.00
Hernandez	7.8	7.3	6.4	7.17	2.9	3.1	2.3	2.78	0.0	0.0	0.0	0.02
Beauregard	6.3	6.1	5.7	6.01	3.4	3.5	2.7	3.18	0.2	0.2	0.2	0.18
Northern Star	6.6	7.1	5.8	6.50	3.7	3.5	2.5	3.22	0.5	0.7	0.3	0.49
Mean	8.08	7.50	6.61		3.01	2.63	2.22		0.22	0.21	0.11	
Significance												
Variety	** lsd = 1.569				** lsd = 0.868				** lsd = 0.19			
Density	** lsd = 0.906				** lsd = 0.50				NS			
Variety*Density	NS				** lsd = 1.504				NS			

NS denotes Not significant at P=0.05, * denotes Significant at P=0.05 and ** denotes significant at P=0.01

As with the previous density experiment the results exhibited high variability making it difficult to obtain meaningful and significant results.

Table 3.4. Effect of in row plant spacing on marketable (Mkt), Total, Large and Medium sized root yield and root number per plant for sweetpotato cv. Beauregard in a field trial at Cudgen 2003.

Plant Spacing (cm)	Yield (tonne ha^{-1})				Root Number per m of row			
	Mkt	Total	Large	Med.	Mkt	Total	Large	Med.
20	11.5	33.7	3.9	4.4	4.92	26.8	0.78	1.48
25	14.3	31.6	1.0	6.6	5.62	23.5	0.23	1.85
30	15.1	33.3	7.0	6.7	5.53	17.3	1.29	1.74
35	10.1	26.9	4.4	3.1	4.00	19.1	0.71	0.86
40	12.8	26.3	4.1	7.1	4.72	17.5	0.76	1.87
	NS	NS	NS	NS	NS	NS	NS	NS

NS denotes not significant at p=0.05

Table 3.5 Effect of in row plant spacing on marketable (Mkt), Total, Large and Medium sized root yield and root number per plant for sweetpotato cv. Northern Star in a field trial at Cudgen 2003.

Plant Spacing (cm)	Yield (tonne ha^{-1})				Root Number per m of row			
	Mkt	Total	Large	Med.	Mkt	Total	Large	Med.
20	34.7	69.7	23.5	18.4	8.75	19.84	2.66	3.67
25	30.9	65.4	21.1	17.1	8.15	18.54	2.31	3.38
30	35.4	72.0	26.4	22.0	8.48	18.33	2.80	3.86
35	31.9	69.4	26.6	20.4	8.36	19.93	2.86	4.21
40	23.0	54.2	23.3	14.1	5.76	12.92	2.57	2.78
	NS	NS	NS	NS	NS	* lsd = 4.47	NS	NS

NS denotes not significant at p=0.05, * denotes significant at p = 0.05

3.2.3 General discussion

In light of the lack of significant findings in the present experiments no recommendations can be made to alter current plant spacing practices. Within the trials, the ideal within row spacing appeared to be between 25-30 cm, which is consistent with standard industry practice. Consistent with this other Australian research showed the yield of various cultivars was optimal at a spacing of about 26.6 cm (Harper 1984). Under Australian growing conditions, the findings in the USA of high yield responses to extremely close plant spacing of 15 cm (Schultheis *et al.* 1999) do not appear to hold. There was evidence that precision planting of material, to ensure even spacing, could give a greater percentage of even product and that yield of Beauregard might be increased at reduced plant spacing. However, gains in productivity due to altered plant spacing are unlikely to be great and other agronomic factors, including using PT planting material and appropriate cutting orientation, are likely to give far greater yield gains.

3.3 Varietal maturity trials 2001/02

3.3.1 Methodology

Nine sweetpotato accessions developed under project VG97023 were grown in a replicated trial at Queensland Government DPI&F Redlands Research Station aimed at determining optimal maturity over three harvests. The trial was planted on 13 December 2001 and the design was a randomised complete block with four replicates. Pathogen tested tip cuttings were planted at a spacing of 30 cm in 1.3 m wide beds and plot length of 3 m. At the end of each plot a cutting of cultivar Hung Loc was planted as a marker and to eliminate plot end plant effects.

Harvests were conducted on 11 April, 9 May and 23 May and corresponded to 17, 21 and 23 weeks after planting. For harvests 1 and 3 green tops were removed 3 days prior to harvest. For harvest 2 green tops were removed at 19 weeks after planting and heavy rain immediately prior to the anticipated 20 week harvest resulted in a delaying of harvest until 21 weeks after planting. All plots were dug mechanically and all roots from each plot collected into labelled bins then washed. All replicates were graded according to root weight (0-150g, 150-250g, 250-600g, 600g-1kg and >1kg). Marketable yield consisted of roots in the 250g-1000g range. Counts of root numbers in each grade range were made. Data was analysed using analysis of variance for data within each harvest. No valid statistical analysis could be conducted across harvests as the effects were confounded with time.

As for the 2001/02 plant spacing trial, in the interim time between removal of tops and harvest (about 2 weeks), severe damage was recorded in Harvest 2 due to cockatoo feeding. This caused high variability in data requiring corrections to be made in the data by making value judgements on the percentage damage, which was most pronounced in large roots. **For this reason results for this trial should be viewed cautiously**.

3.3.2 Results and Discussion

The lines Northern Star and L87-59 (Darby) exhibited particularly early maturity. High yields in both these lines were obtained at only 17 weeks and marketable yield were about 40 tonne ha^{-1} (Table 3.6 and Appendix 3.1), which contrasts with an industry standard cropping duration of about 20 weeks. It is likely that high marketable yields of Northern Star and L87-59 could be achieved even earlier than that determined in this study. The early maturing nature of these lines is likely to impact greatly on the optimal timing for agronomic practices, particularly nutrition, irrigation and plant density. Difficulties in achieving good marketable product from Northern Star is widely recorded in the industry, to the point where reductions in planting have occurred despite a high market price and demand.

Though high marketable yields were recorded at Harvests 1 and 2 for Northern Star and L87-59, still higher marketable and total yields were recorded at Harvest 3. However, at Harvest 2 and 3 both varieties produced a very high percentage (20-30%) of roots greater than 1 kg (Table 3.6). This is a serious consideration as this product is not readily disposed of and at best attracts a low return.

The L87-59 shows some merit as a variety as its skin colour is a deep rose to red colour and flesh colour a deep even orange. The shape can be a little less desirable as it has a tendency to be slightly bulbous rather than elongate and this may relate to the early maturing nature of the line. The L87-59 though it looks similar to Beauregard has negative quality traits in shape making it unlikely to fill a role as an early maturing line.

Beauregard also showed early to mid-maturity compared with other lines and at 17 weeks its marketable yield was about 37 tonne ha^{-1} and slightly below that of L87-59 and Northern Star.

Line L86-33-Q5 was a Beauregard type and demonstrated a high capacity for root setting (Table 3.7). The total number of storage roots initiated per plant ranged between 10 and 12. This line has previously shown high yield potential. It appears to be a late maturing variety producing few roots over 1 kg even at 23 weeks after planting. The line warrants further investigation and agronomic research as the skin and flesh colour is attractive though skin russeting appears common. In some districts where late maturing or over wintering varieties are required this line may have potential.

The line L93-9-Q16 showed dramatic yield increase in both total and marketable yield from 21 to 23 weeks highlighting its mid-late maturity (Table 3.6 and Appendices 3.1-3.3). This variety yields attractive smooth skinned roots of generally good shape. However, roots were of a custard skin colour and despite the fact its flesh colour was an even deep orange and it had good flavour it is unlikely to find a marketplace.

The L93-93 line had medium to late maturity and though marketable and total yield were good at Harvests 2 and 3 (Table 3.6), other characteristics of this line, elongate and twisted roots, preclude it being accepted in the marketplace.

Yield of the WSPF (white skin purple flesh) was inconsistent and this may have been a nutritional issue. Similarly, L95-3 was inconsistent in yield and in Harvest 2 the majority of yield, greater than 90%, was cracked and broken. Marketable yield for both these lines was poor.

Table 3.6. Comparison of total yield, marketable yield and yield of oversize roots for sweetpotato maturity trial across three harvest dates (H1, H2, H3) at Redlands Research Station 2001-2002.

	Total Yield (tonnes/ha)			Marketable yield (tonnes/ha)			Yield roots >1Kg (tonnes/ha)		
Variety	H 1[a]	H 2[b]	H 3[c]	H 1[a]	H 2[b]	H 3[c]	H 1[a]	H 2[b]	H 3[c]
L93-9-16	44.8	66.2	84.1	28.7	28.2	55.1	3.5	1.3	11.4
L93-93 Line	53.7	64.4	75.6	32.0	38.8	51.4	0.0	8.5	0.7
Q95-3	52.9	47.1	65.9	33.2	2.9	43.3	5.2	1.5	3.0
WSPF	33.1	16.1	50.3	19.9	1.5	36.4	1.4	0.0	3.8
L87-59	58.6	85.8	95.3	41.7	52.8	56.5	3.4	19.8	31.1
L86-33-5	45.5	57.6	62.4	23.0	35.1	38.7	0.0	0.0	0.7
Hernandez	40.8	50.5	66.2	27.0	33.6	43.8	1.6	1.0	3.4
Beauregard	62.2	59.2	78.3	37.2	40.6	52.3	1.4	6.4	22.3
Northern Star	71.0	73.5	84.2	43.2	44.7	53.2	6.9	21.8	20.7
Significance	**	**	**	*	**	*	NS	**	**
lsd(P=0.05)	17.83	17.2	14.93	15.06	15.5	12.68	(F=0.07)	12.22	9.9

NS denotes Not significant at P=0.05, * denotes Significant at P=0.05 and ** denotes significant at P=0.01
[abc] Comparisons of least significant difference can only be made within columns having the same letter.

Table 3.7. Comparison of total, marketable and oversize root number per plant for sweetpotato maturity trial across three harvest dates (H1, H2, H3) at Redlands Research Station 2001-2002.

	Total roots/plant			Marketable roots/plant			Roots >1Kg/plant		
Variety	H 1[a]	H 2[b]	H 3[c]	H 1[a]	H 2[b]	H 3[c]	H 1[a]	H 2[b]	H 3[c]
L93-9-16	7.5	9.9	11.4	2.6	2.6	2.1	0.1	0.1	0.4
L93-93 Line	10.4	11.6	12.6	3.2	5.2	3.0	0.0	0.4	0.0
Q95-3	7.8	7.3	11.0	2.8	0.3	2.2	0.2	0.1	0.1
WSPF	6.0	1.4	6.8	2.3	0.1	1.2	0.1	0.0	0.2
L87-59	7.4	10.0	9.1	3.7	4.9	1.0	0.1	0.8	1.1
L86-33-5	10.4	11.9	12.3	2.7	3.9	3.0	0.0	0.0	0.0
Hernandez	6.7	7.8	10.6	2.5	2.9	2.2	0.1	0.0	0.2
Beauregard	9.8	6.3	6.2	4.8	3.4	0.1	0.1	0.2	0.8
Northern Star	7.5	6.6	7.9	4.0	3.7	0.9	0.2	0.5	0.7
Significance	**	**	**	**	**	NS	NS	**	**
lsd (P=0.05)	2.16	3.16	2.94	1.18	2.08	(F=0.46)	(F=0.07)	0.43	0.36

NS denotes Not significant at P=0.05, * denotes Significant at P=0.05 and ** denotes significant at P=0.01

[abc] Comparisons of least significant difference can only be made within columns having the same letter.

4. Nutritional responses in sweetpotato

4.1 Introduction

Knowledge of nutritional requirements for sweetpotato under Australian growing conditions and soils is limited. However, worldwide it is generally identified that excessive N rates reduce marketable root yield of sweetpotato (Hartemink *et al.* 2000; Villagarcia *et al.* 1998). US research shows that the standard recommendation for N application of 84 kg ha^{-1} on Beauregard in Virginia is excessive and could be reduced to 28-56 kg ha^{-1} whilst increasing yield (Phillips *et al.* 2005). In contrast, other USA research indicates maximum yield is obtained at about 90 kg ha^{-1} (Ankumah *et al.* 2003). Standard N use in sweetpotato production in Australia is in the order of about 150-170 kg ha^{-1} and there is potential to reduce its application.

In addition, monitoring of residual soil N levels by growers is not widely adopted and the potential for overuse of N is a real issue in intensive horticultural systems where there is a heavy reliance on N application.

The data for crop removal of K, in the order of 250 kg ha^{-1} for a 50 tonne ha^{-1} crop (O'Sullivan *et al.* 1997), would suggest that current K application rates are below that required for maximal root yield.

A series of experiments was conducted on various sites to evaluate effects of varying N and K rates and other fertility factors on the yield of Beauregard and Northern Star.

4.2 Nitrogen and potassium factorial experiments 2003

4.2.1 Experimental Aim

These experiments evaluated various rates of N and K on root yield and quality of sweetpotato (cvv. Beauregard and Northern Star) in three regions; Bundaberg, Rockhampton and Mareeba.

4.2.2 Methodology

Experimental plots for each trial site consisted of 4 rows of length 3 m. The 2 middle rows in each plot were the datum rows and planting of each pair was randomly allocated to the varieties Beauregard and Northern Star. Each pair was planted using cutting material from the DPI&F Gatton Research Station PT material. At the Mareeba site the Northern Star plots were planted 10–14 days after the Beauregard, given Northern Star has an earlier maturity. The 2 guard rows of each plot were planted using the commercial growers' planting material of cv. Beauregard. A marker plant was planted at each end of each datum plot and a gap of 2 m was allowed between plots. Soil samples from each rep were taken prior to planting and held for analysis as necessary. All agronomic practices, with the exception of N and K fertiliser application, were as per the growers' conventional practice. Key aspects of the trial, including planting and harvest dates and days of growth, are presented in Table 4.1.

Table 4.1. Agronomic data for nutrition trials conducted at Mareeba, Rockhampton and Bundaberg 2003.

	Mareeba	Rockhampton	Bundaberg
Planting Date			
Beauregard	22/04/03	9/04/03	6/03/03
Northern Star	15/05/03	9/04/03	6/03/03
Harvest Date	30/09/03	11/11/03	24/09/03
Growth Period (Days)			
Beauregard	160	217	203
Northern Star	139	217	203
Soil Type	Sandy Loam		
Row Spacing	1.2 m	1 m	1.5
Plant Spacing (cm)	30	30	30
Irrigation Type	Solid set	Lateral roll	trickle
Fertiliser Application			
P	70	76	30
S	115	96	65
Ca	83	173	68
Mg	11.5	0	21
Zn		0	0
B	2 applications Solubor at 1%	0	0

The Bundaberg trial was planted in a block of dimensions (122 m x 18 m) and the Rockhampton trial in a block of dimensions (182 m x 8 m). Two factors were evaluated and included four N rates (50, 100, 150 and 200 kg ha^{-1}) and four K rates (50, 100, 150 and 200 kg ha^{-1}). At Mareeba, the effects of rates of N (70, 140 and 210 kg ha^{-1}) and K (80, 140 and 210 kg ha^{-1}) on sweetpotato were evaluated in factorial combination. Total N and K application rates and fertilizer forms are presented in appendices 4.1 and 4.2. The timing of treatment application and proportions applied for each site is presented in Table 4.2. The experiments were conducted as randomised complete block factorials replicated four times with varieties being sub-plots of each rep.

At all sites the basal treatment nutrient application was made in solid form prior to planting and soil incorporated. At Rockhampton, the subsequent treatment nutrient applications were made as a solid form side dressing which was immediately irrigated in using hand shift irrigation spray lines.

At Bundaberg the non-basal N and K treatments were added using a fertigation technique. Four lengths of polypropylene T-Tape™ pipe, with evenly spaced water emitters, were cut to the plot length (3m). The four pieces were then joined in a grid pattern using T joiners and 1.5 m lengths of 18 mm polypropylene tubing such that the grid exactly aligned with plot rows and length. Four grids were prepared and a grid laid across each of the four replicates of the same treatment. The grids were connected to a common main and fresh water pumped through the system. Once the system was full relevant treatment nutrient solutions were applied in a dissolved form then flushed with fresh water. The polypropylene pipe grids were moved from one set of treatment replicate plots to the next and subsequent relevant treatment nutrient solutions applied again.

Table 4.2. Timing of treatment application (Time) for nutrition trials showing proportion applied (PA%), date, days after planting (DAP).

Time	Mareeba			Rockhampton			Bundaberg		
	PA%	Date	DAP	PA%	Date	DAP	PA%	Date	DAP
1 st (basal)	50	22/04 (Beau) – 15/05 (N Star)		50	8 Apr	0	20	5 Mar	0
2 nd	25	15/05		50	14 May	35	40	3 Apr	28
3 rd	25	03/06		--	--	--	40	9 Jul	146

Plots were harvested mechanically by digging the middle datum rows. Roots were graded according to a retail market specification; size range included undersize, small, medium, large, seconds and cracked (Table 4.3). A sample of roots from the medium size grade was kept for post harvest evaluation including dry matter, colour and root nutrient concentration, as required.

Table 4.3. Grading specifications for nutrition trials at Mareeba Bundaberg and Rockhampton.

Grade	Length (mm)		Diameter (mm)
Undersize	>130	and/or	>50
Small	130-180	and/or	50-60
Medium	180-250	and/or	60-75
Large	>250	and/or	>75

Other defects	defect	Description
	Shape	Long thin, ribbed, bulbed bent
	Mechanical damage	Breaks cuts skinned
	Insect damage	
	Cracking	
	Other blemishes	Old/aged, skin blemishes, nematodes scurf

Soil and tissue sampling

Prior to planting a bulked soil sample (to 10 cm) was taken at each experimental site and a full nutrient analysis conducted (Table 4.4) using the methods of Incitec (1998). At each site leaf samples were collected from each treatment replicate at 42 DAP. Samples were immediately field stored on ice in an esky and on completion of sampling immediately dehydrated and held for analysis as necessary. As required a complete soil nutrient analysis (N, P, K, S, Ca, Mg, Zn, B, Mn, Fe and Cu) was conducted. At Bundaberg extra samples were taken and a sap analysis for N and K conducted by CropTech®.

Table 4.4. Soil test results for Mareeba, Rockhampton and Bundaberg for nutrition trials 2003.

Soil test parameter	Mareeba[a]	Rockhampton	Bundaberg
pH (1:5 H_2O)	4.8	5.9	5.2
EC (0.01 mS/cm)	0.05	0.06	0.06
OC (%)	0.67	2.5	1.4
N (as NO_3-N mg/kg)	11	16	15.2
P (mg/kg)	120	45	88
SO_4-S (mg/kg)	3.8	9.8	10
Ca (meq/100g)	0.68	6.8	1.72
Mg (meq/100g)	0.2	1.5	0.45
Na(meq/100g)	0.06	0.1	0.05
K(meq/100g)	0.18	0.47	0.23
Cl (mg/kg)	<6	<6	5
Cu (mg/kg)	0.1	3.5	0.2
Zn (mg/kg)	0.69	6.8	1.4
Mn (mg/kg)	16	78	12
Fe (mg/kg)	43	50	232
B(mg/kg)	0.2	1.4	1.0

Data was analysed using 2 way ANOVA for N x K. The variance for Northern Star was twice that of Beauregard and hence the data for N x K for each variety was analysed separately.

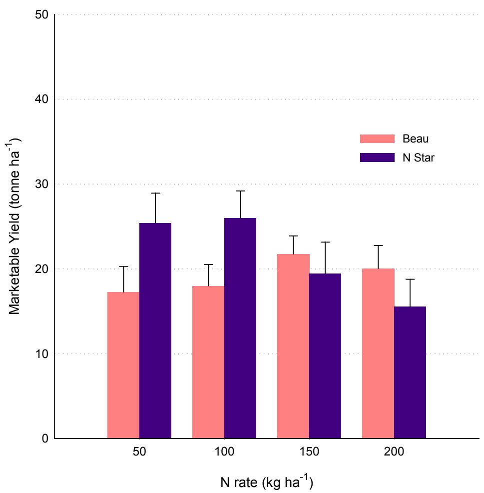
4.2.3 Results

Beauregard response to nitrogen

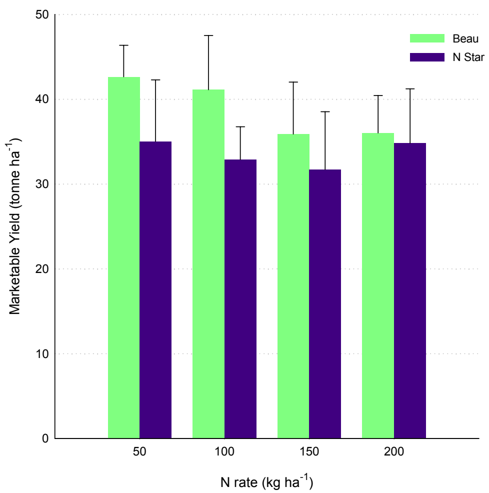
Application of N at rates of 50, 100, 150 and 200 kg ha^{-1} did not significantly affect either total or marketable yield in both the Bundaberg and Rockhampton trials (figures 4.1 and 4.2). However, in the Rockhampton trial, marketable and total yields were largest for the 100 kg N ha^{-1} treatment and lowest in the highest N treatment, 200 kg ha^{-1}, but, in the Bundaberg trial both total and marketable yield appeared marginally largest at 150-200 kg N ha^{-1} compared with the 50 and 100 kg N ha^{-1} treatments.

In the Mareeba experiment the higher rates of N (140 and 210 kg ha^{-1}) resulted in significantly lower marketable and total yield ($p=0.001$) compared with the lowest N rate (70 kg ha^{-1}) (figures 4.1 and 4.2). The total and marketable yield reductions at the higher N rates were in the order of about 9 and 3 tonne ha^{-1} respectively.

1a)



1b)



1c)

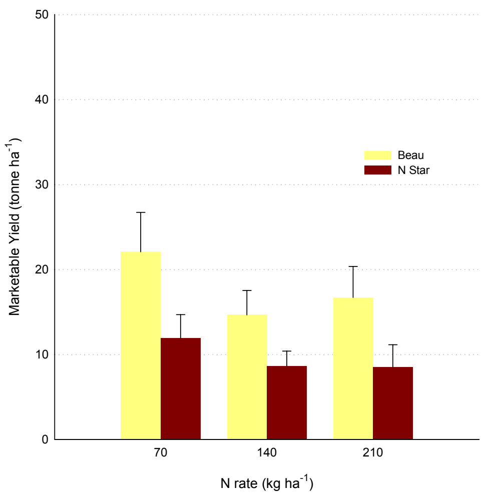
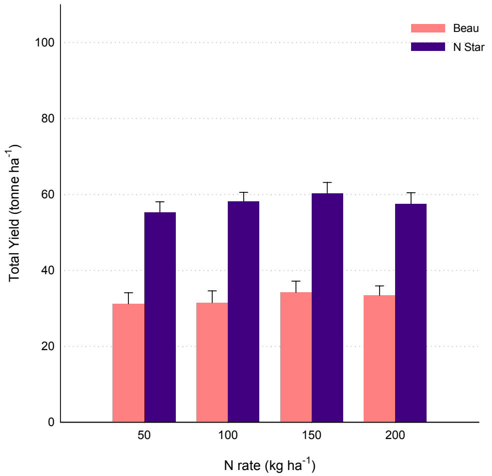
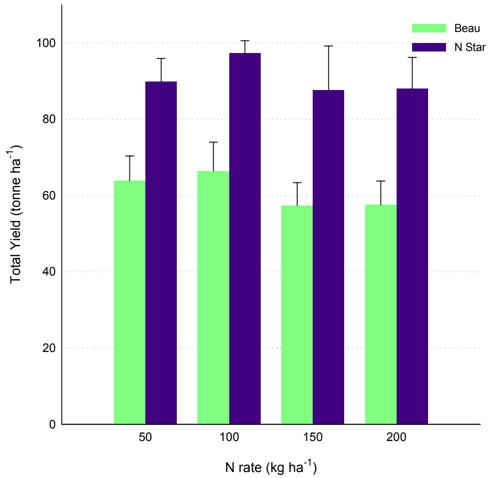


Figure 4.1. Marketable yields (tonne ha^{-1}) for Beauregard (Beau) and Northern Star (N Star) at varying N rates for field trials grown at a)Bundaberg, b) Rockhampton and c) Mareeba 2003.

2a)



2b)



2c)

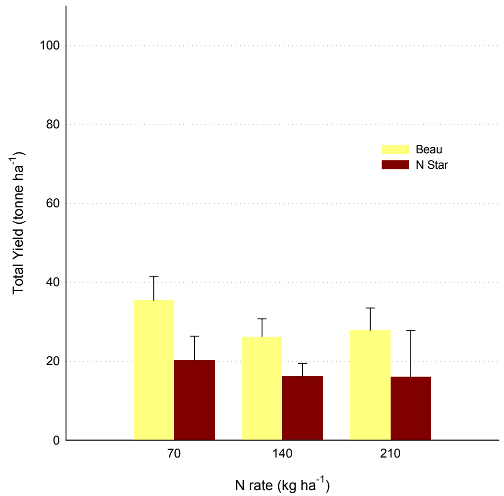
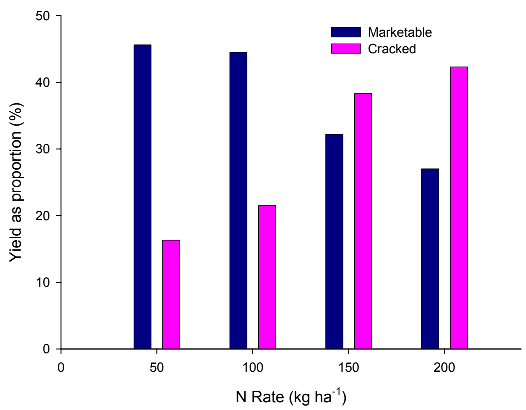


Figure 4.2. Total yields (tonne ha^{-1}) for Beauregard (Beau) and Northern Star (N Star) at varying N rates for field trials grown at a)Bundaberg, b) Rockhampton and c) Mareeba 2003.

Northern Star response to nitrogen

In both the Bundaberg and Rockhampton experiments, increasing the N rate did not significantly affect the total yield of Northern Star (figures 4.1 and 4.2). However, at the Bundaberg site, progressive increases in N rate resulted in decreased marketable root yield whilst simultaneously the yield of cracked roots increased. At the 50 kg N ha^{-1} the yield of cracked roots was only 8.8 tonne ha^{-1} whilst at 200 kg N ha^{-1} the yield of cracked roots was 24.3 tonne ha^{-1}. Importantly, when the cracked root yield is expressed as a proportion of total yield cracking increased from 16.3% at 50 kg N ha^{-1} to 42.3% at 200 kg N ha^{-1} (figure 4.3a). At the Rockhampton site there was no effect of N on either marketable or cracked root yield (figure 4.3b). The proportion of cracked roots at Rockhampton was nonetheless high ranging from 22-27% of total yield.

a)



b)

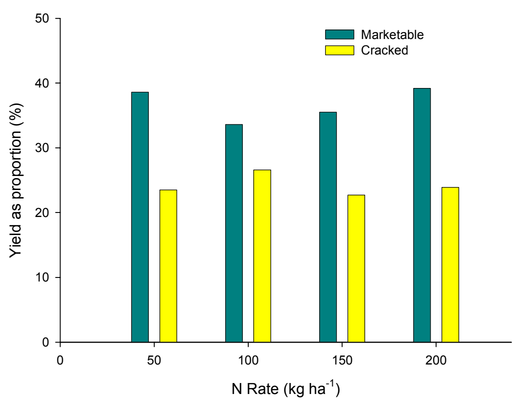


Figure 4.3. Effect of nitrogen rate on the marketable and cracked root yields of Northern Star expressed as a percentage of the total yield at sites a) Bundaberg and b) Rockhampton.

At Mareeba the effects of N application were very different to that recorded at the other sites. Highest total and marketable yields were recorded at 70 kg N ha^{-1} whilst at 140 and 210 kg N ha^{-1} significant reductions were recorded in both these yield components.

Across sites the application of N had a similar effect on root number as that on root yield (Table 4.5). The greatest number of roots was recorded at both sites at 100 kg ha^{-1}. As with the yield data the number of cracked roots per plant increased with N application in the Bundaberg trial but not in the Rockhampton trial.

Table 4.5. Effect of N rate on the total, marketable (Mkt) and cracked root numbers (roots per plant) and proportion cracked and marketable root numbers for Northern Star for field trials grown at Bundaberg and Rockhampton 2003. The marketable and cracked root proportions are expressed as a percentage of the total root number per plant.

N rate (kg ha^{-1})	Total root no.	Mkt root no.	Cracked Root no.	Proportion no. cracked (%)	Proportion no. Mkt (%)
Bundaberg					
50	7.84	2.43	0.77	10.3	31.6
100	8.15	2.48	1.08	13.5	30.6
150	7.66	1.87	1.96	25.5	24.5
200	7.60	1.54	1.96	26.3	20.2
	NS	*** lsd (p=0.05) = 0.364	*** lsd (p=0.05) = 0.361	*** lsd (p=0.05) = 5.05	*** lsd (p=0.05) = 5.14
Rockhampton					
50	4.81	1.71	0.75	23.5	35.5
100	5.21	1.80	0.93	26.7	34.3
150	4.59	1.62	0.74	22.7	34.7
200	4.82	1.79	0.74	23.9	36.8
	NS	NS	NS	NS	NS

NS denotes not significant
*** significant at p =0.001, ** significant at p =0.01 and * significant at p =0.05

Potassium response

The application of K at rates of 50-210 kg ha^{-1} had no significant effect on the marketable or total yield of either Beauregard or Northern star at any of the 3 trial sites (Table 4.6). Indeed, there was not even an apparent trend for K to affect either of these yield components. Similarly, and specifically for Northern Star, application of K from 50-200 kg ha^{-1} did not affect the yield of cracked roots or the yield of cracked roots when expressed as a proportion of the total yield.

Tissue test indices

The correlations between N and K dry tissue test and sap results with yield were not significant (data not presented). This is to be expected given that there was largely no response to N or K application.

For K the tissue concentrations of all samples of Beauregard from Bundaberg and Rockhampton were within the adequate range. In contrast, all samples (9 samples taken) from Mareeba were below the critical K value irrespective of K application rate. This would further suggest that nutritional problems other than K and N had a bearing on results at Mareeba.

Table 4.6. Total, marketable (Mkt) and Cracked root yields (tonne ha^{-1}) for Beauregard (Beau) and Northern Star (NStar) at varying potassium (K) rates for field trials grown at Bundaberg, Rockhampton and Mareeba 2003.

Nitrogen rate (kg ha^{-1})	Total (tonne ha^{-1})		Mkt (tonne ha^{-1})		Cracked (tonne ha^{-1})	
	Beau	NStar	Beau	NStar	Beau	NStar
Bundaberg						
50	34.2	56.5	19.7	20.5	0.0	15.2
100	32.9	58.7	20.4	21.2	0.0	18.2
150	32.4	57.0	18.2	22.2	0.0	15.9
200	30.7	59.0	18.7	22.4	0.0	19.3
	NS	NS	NS	NS	NS	NS
Rockhampton						
50	63.5	91.5	40.4	32.6	0.0	22.6
100	56.5	91.9	36.1	33.4	0.0	22.1
150	62.8	91.9	40.1	36.8	0.0	19.5
200	62.3	87.4	39.0	31.6	0.0	23.6
	NS	NS	NS	NS	NS	NS
Mareeba						
80	30.8	17.4	18.5	9.0	--	--
140	29.0	18.4	16.5	10.9	--	--
210	29.8	16.8	18.4	9.2	--	--
	NS	NS	NS	NS		

NS denotes not significant
*** significant at p =0.001, ** significant at p =0.01 and * significant at p =0.05

4.2.4 Discussion

Nitrogen effects on Beauregard

Negative effects of high N application on marketable and total yields were observed at Mareeba with application of 140 and 210 kg N ha^{-1}. This contrasted with the result for Bundaberg where there was no significant effect of N on marketable or total yield at N rates from 50-200 kg ha^{-1}, though the highest yield at Bundaberg was recorded at 150 kg N ha^{-1}. In the Rockhampton trial, the N effect was also not significant; the highest marketable and total yields were obtained at 100 kg N ha^{-1}.

Overall the highest yields were obtained in the Rockhampton trial. This was likely to be due to a combination of factors, but particularly the longer growing season and more favourable conditions late in bulking. Additionally, the soil test data for the Rockhampton site indicated higher nutrient status and general fertility than that for the other test sites (Table 4.4). In particular, the pH, organic carbon, zinc, boron and calcium concentrations in the Rockhampton soil were at levels more optimal for plant growth. Despite all these soil parameters being in order there was still no significant or obvious response to N even though the basal soil N concentration was only 15.2 mg/kg. This tends to suggest that N requirements of sweetpotato are not high, a result consistent with the literature on sweetpotato nutrition (Hammett *et al.* 1984; Harper and Walker 1985). The data suggested that growers may be able to reduce N application rates whilst maintaining yield. Given the often high residual soil N levels in horticultural soils the use of soil testing particularly for N will be a useful tool in determining N application rates.

The marketable and total yields of Beauregard at Mareeba and Bundaberg were largely similar, though the responses to N were different. At Bundaberg there was a trend for increased yield at higher N. This contrasted with that at Mareeba where a substantial and significant reduction in marketable and total yield was observed when N was applied at 140 and 210 kg N ha^{-1} compared with that at 70 kg ha^{-1}. This occurred despite the fact that the base N concentration in the Mareeba soil was somewhat lower than that in the Bundaberg soil (11.0 and 15.2 mg/kg NO_3-N respectively).

The Mareeba soil had the lowest N concentration yet sweetpotato was negatively affected by N application, suggesting other factors may have been limiting growth. The base soil data for the Mareeba site indicated fertility problems other than N and K may have limited crop growth. The soil had low pH (4.8 in 1:5 H_2O), low organic carbon (0.67%) and low status of Zn, B and Ca. This suggests potential issues with acidic soil infertility and under such conditions application of N at high rates may have reduced yield despite the low initial soil N levels.

Table 4.7 Averaged tissue nutrient concentrations for samples of Beauregard collected from the 3 experimental sites.

Nutrient	Mareeba	Rockhampton	Bundaberg
N	4.9	5.3	4.7
P	0.35	0.33	0.41
K	2.7	4.3	3.8
Ca	1.06	1.46	0.68
Mg	0.47	0.54	0.46
S	0.44	0.44	0.42
Na	0.02	0.11	0.03
Cu	79	12	10
Zn	34	34	24
Mn	1082	97	190
Fe	143	603	301
Al	276	890	407
B	35	42	44

Averaged tissue concentrations for the sites are presented in Table 4.7. Overall the tissue test data for all sites showed the nutrient status for the Rockhampton trial was higher than that at the other sites and this is also consistent with the soil test data for Rockhampton. A major issue with the tissue test data from Mareeba was the high leaf concentrations of manganese (Mn) and copper (Cu), which were in the toxic range. No mancozeb or copper fungicides were used on this trial. It is possible though unlikely that the laboratory results were inaccurate. There is a need for a further more detailed assessment of the soil fertility issues at Mareeba.

Further experimental work is required to evaluate whether sweetpotato production is being affected by acidic soil infertility since there is some evidence to suggest this might be the case, particularly on the light textured granitic soils in Mareeba, but also at Bundaberg where low soil pH was observed.

Nitrogen effects on Northern Star

At Bundaberg increasing the N rate on Northern Star decreased marketable yield though total yield remained unaffected (figure 4.3a). This reduction in marketable yield at higher N rates was due to an increase in cracked root yield. The proportion of cracked roots, expressed as a percentage of total yield, also increased from 16.3% at 50 kg ha^{-1} N to 42.3% at 200 kg N ha^{-1} highlighting that the increase in cracked root yield was not simply an artefact of an overall increased yield at higher N rates, but, rather was directly associated with the application of more N.

In the Rockhampton trial the proportion of cracked roots, as a percentage of total yield (figure 4.3b), did not increase with increased N application, as was the case at Bundaberg. Similarly, in the Mareeba trial the application of N had no effect on either reject or second grade root yield indicating that cracked root yield was also unaffected by increasing N rate (data not presented). Interestingly, at the Rockhampton site, though N had no significant effect on cracking, the highest amount of cracking was recorded in the 100 kg N ha^{-1} treatment, which also had the highest total yield. This might at least suggest that a relationship exists between yield potential and incidence of cracking.

Though the Bundaberg experiment demonstrated a strong effect of N application on cracking in Northern Star the causes of this type of cracking appear more complex. Many factors are known to induce cracking including nematodes, boron deficiency and physiological cracking, which is less well understood. Cracking in other root and tuber species is generally associated with conditions favourable for rapid growth. A more thorough evaluation of causes of cracking in Northern Star is required.

Potassium effects

There was no significant effect of K on either marketable or total yield of Beauregard or Northern Star, nor was there any evidence of trend in response to K in any of the 3 experiments. This is perhaps not surprising for the Rockhampton trial where residual soil K concentrations were high (0.47 meq/100g). However, at the Mareeba and Bundaberg sites soil K levels were low (0.18 and 0.23 meq/100g respectively) and given the reported high K requirements for sweetpotato the lack of response was a little perplexing.

A trial on straight K at 50, 100, 150, 200, 250 and 300 kg ha^{-1} (data not presented) at Bundaberg showed no response to K was observed even at 300 kg ha^{-1}. Several tentative explanations for this lack of response are proposed. First, the trial was conducted under the suboptimal winter period and this had an overriding effect on crop growth. Second, a further underlying nutritional limitation may have prevented a response. Though the soil levels indicated adequate Zn and B, tissue test results for these nutrients could be considered marginal depending on the diagnostic criteria used. In this event the application of extra N and K would not have increased yield. Third, soil pH issues may have overridden a response to K. Fourth, sweetpotato does not have a high K requirement as reported in the literature.

At the Mareeba site no response was recorded to K and this may have related to a general poor soil fertility. The soil test data for this site indicated very low soil pH (4.8 in 1:5 H2O), low soil OC, and low status of most nutrients. It is likely in this trial that the underlying soil fertility limitation was not K and hence no response was recorded.

Tissue test indices

Sixty dry tissue samples of Beauregard were taken across the treatments at each site and 58 of these samples, irrespective of the treatment N rate, had N concentrations greater than 4%, which is considered above the critical value (Huett *et al.* 1997; O'Sullivan *et al.* 1997; Weir and Cresswell 1993).

Thirty of the 60 samples had tissue N concentrations greater than 5.0%, which is described as above normal (Weir and Cresswell 1993) and above the adequate range reported by O'Sullivan *et al.* (1997) and Huett *et al.* (1997) over various cultivars. A paired comparison of differences in N tissue concentrations for Beauregard and Northern Star was conducted for samples taken from the Bundaberg trial. Beauregard had significantly higher concentrations of N (P=0.001) (mean 4.97%) compared with Northern Star (mean 4.43%), with an average difference of 0.54%. Much of the research on tissue nutrient concentrations has been conducted on staple white-fleshed varieties. The above analysis would suggest that tissue concentrations for the orange-fleshed variety Beauregard might be 0.5 % units higher than for white-fleshed varieties. A more comprehensive study would be required to confirm optimal tissue nutrient status for Beauregard.

4.2.5 2003 general conclusion

This research has largely given inconsistent results from site to site and there is no evidence of N and K interactions. Despite inconsistencies the results of these trials suggest that N requirements of sweetpotato (cvv. Beauregard and Northern Star) were not high and there was a trend for yield to decrease as N application increased. Also, there was no significant effect of K on root yield at any of the three sites despite the literature indicating high K requirements for sweetpotato. There is a need to establish N and K fertilizer response curves that can form a basis for determining application rates that maximise yield.

At Mareeba, yield was significantly reduced at the two highest N rates compared with the lowest rate despite the fact that the soil N levels were the lowest of all three sites. The results suggested soil acidity or trace element limitations may be limiting sweetpotato yield.

4.3 Nitrogen and potassium response curves 2004

These 2004 trials evaluated the response of sweetpotato (cv. Beauregard) to applications of N (0-250 kg ha^{-1}) and K (0-300 kg ha^{-1}) at Bundaberg.

4.3.1 Methodology

Two experiments were conducted as field trials at Bundaberg on a commercial growers' property to evaluate effects of N and K rates on sweetpotato cv. Beauregard. The N experiment consisted of 6 N rates (0, 50, 100, 150, 200 and 250 kg ha^{-1}) replicated 4 times in a randomised complete block design. The K experiment consisted of six K rates (0, 60, 120, 180, 240, 300 kg ha^{-1}) replicated four times in a randomised complete block design.

In both experiments the N and K basal treatments were surface applied into a furrow along the top of the hill in the plot area and to 1m past each end of the plot. The furrow was immediately covered and the hills reformed to incorporate the basal nutrients. For the nitrogen experiment, 40% of the total N treatment and all the required K (180kg ha^{-1}) were applied at planting with the remaining 60% of the treatments being applied to plots through trickle irrigation as 2 even amounts at 28 and 56 DAP. For the potassium experiment, all K was applied as a basal application while the required N was applied in a split of 65 kg N ha^{-1} basal and 65 kg N ha^{-1} side-dressing at 35 DAP as ammonium nitrate.

Phosphorus was incorporated into the trial at hilling as triple super phosphate and magnesium, zinc and boron were applied at planting directly injected through the trickle irrigation. Liquid lime was applied through the trickle at a rate of 75 L ha^{-1} to increase soil pH. Nutrient rates and forms are presented in appendix 4.4.

Experimental plots for each trial site consisted of 2 datum rows planted using PT cuttings of cv. Beauregard and guard rows planted using the commercial growers' planting material cv. Beauregard. A marker plant of variety Northern Star was planted at either end of each datum plot and a gap of 2 m was allowed between plots. Soil samples from each plot were taken prior to planting and held for analysis as necessary. Samples were analysed as per the previous experiment. All agronomic practices, with the exception of N and K fertiliser application at Bundaberg, were as per the grower's conventional practice. The trial planting and harvest dates and days of growth are presented in Table 4.8.

Table 4.8. Agronomic data for nutrition trials conducted at Bundaberg 2004.

	N Experiment	K Experiment
Planting Date	23/12/03	23/12/03
Harvest Date	16/06/04	16/06/04
Growth Period (Days)	176	176
Soil Type		
Row Spacing	1.5 m	1.5 m
Plant Spacing (cm)	30	30
Irrigation Type	Trickle	Trickle
Nutrient application (kg ha^{-1})		
P	30	30
S	106	58
Ca	22	22
Mg	20	20
Zn	1	1
B	1	1

Plots were harvested mechanically by digging the middle datum row. Roots were graded according to a retail market specification; size range includes undersize, small, medium, large, seconds and cracked (Table 4.3).

Prior to planting a bulked soil sample was taken at each experimental site and a full nutrient analysis conducted (Table 4.9) as per the previous experiments. Individual plot soil samples were taken and held for analysis as required. At each site leaf samples were collected from each treatment replicate at 56 DAP. Samples were immediately field stored on ice in an esky and on completion of sampling immediately dehydrated and held for analysis as necessary. As required a complete nutrient analysis (N, P, K, S, Ca, Mg, Zn, B, Mn, Fe and Cu) was conducted by the DNR laboratory Indooroopilly. At Bundaberg extra samples were taken and a complete sap analysis (N, P,K, Ca, Mg, Zn, S, Cu, Mn, Fe, B and Si) was conducted by CropTech. At harvest soil samples were taken from each experimental plot, dried and held for analysis as required. Root samples were taken from the N trial and root dry matter and N content determined.

Table 4.9. Soil test results for Bundaberg and Mareeba nutrition trials 2004.

Soil test parameter	Bundaberg	Mareeba[a]
pH (1:5 H_2O)	4.9 (5.7*)	6.2
EC (0.01 mS/cm)	0.04	0.05
OC (%)	1.7	0.44
N (as NO_3-N mg/kg)	12	11
P (mg/kg)	148	110
SO_4-S (mg/kg)	6.3	1.5
Ca (mg/kg)	300	1.4
Mg (mg/kg)	45	0.41
Na (mg/kg)	<10	0.03
K (mg/kg)	49	0.43
Cl (mg/kg)	27	10
Cu (mg/kg)	0.4	0.4
Zn (mg/kg)	0.9	3.0
Mn (mg/kg)	45	22
Fe (mg/kg)	396	65
B (mg/kg)	0.6	0.22
* after liquid lime was applied		

For each experiment an ANOVA was conducted on data using Genstat 6.1.0.205. The variance of data was normally distributed requiring no transformation.

4.3.2 Results and discussion

Nitrogen experiment

The maximum total yield was recorded at an N application rate of between 50 and 100 kg N ha^{-1} (p=0.044) (figure 4.4). The effect of N treatment on marketable yield was not significant (p = 0.106) but the trend was similar to that recorded for total yield over N treatment, in so far as the highest marketable yield was recorded at 50-100 kg N ha^{-1} (figure 4.4). At N rates of 150-250 kg ha^{-1} the responses were somewhat different for total and marketable yield. This probably reflects the higher variability in determining marketable yield, which is a more subjective quality based assessment than is straight total yield. Total yield at 250 kg ha^{-1} was no different to that recorded in the 0 kg N ha^{-1} treatment highlighting the need for sweetpotato growers to carefully manage N application to maximise yield potential. The reduction in yield at high N rates is consistent with other research (Hammett *et al.* 1984; Hartemink *et al.* 2000; Villagarcia *et al.* 1998). However, maximum yield was obtained at 100 kg N ha^{-1} in comparison to other studies that indicate maximum yield is obtained at about only 56 kg N ha^{-1} (Phillips *et al.* 2005). Excessive N application rates reduced yield potential confirming the suggestions made in relation to the 2003 nutrition experiments.

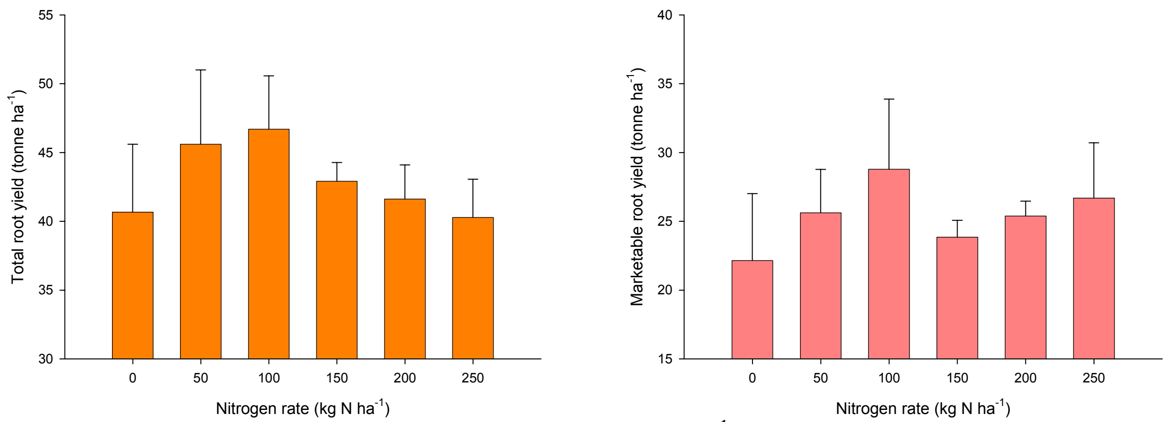


Figure 4.4. Total and Marketable fresh yields (tonne ha^{-1}) for sweetpotato cv. Beauregard at varying N rates in a field trial grown at Bundaberg 2004.

Both total root number per plot and marketable root no per plot were not significantly affected by N treatment (figure 4.5) (F probabilities 0.389 and 0.054, respectively). However, the trends in root number per plot over N rate differed to that for yield. Whereas yield tended to be reduced at the highest N rates the application of N at rates higher than 100 kg ha^{-1} did not reduce marketable root number. Two explanations are proposed. First, the effect of higher N rates may have been in reducing bulking of individual roots. Given that the N was applied in 3 applications many of the storage roots in the higher N treatments (150-300 kg ha^{-1}) may have achieved close to marketable size before the effects of the high N were expressed. Second, given that sweetpotato can switch between vegetative growth and storage roots, as the sink for metabolites, the high N may have increased vegetative growth at the expense of storage root bulking. Interestingly, the application of N 100 kg ha^{-1} at planting in the 250 kg ha^{-1} N treatment did not appear to have affected root initiation evidenced by the root number at harvest data (figure 4.5).

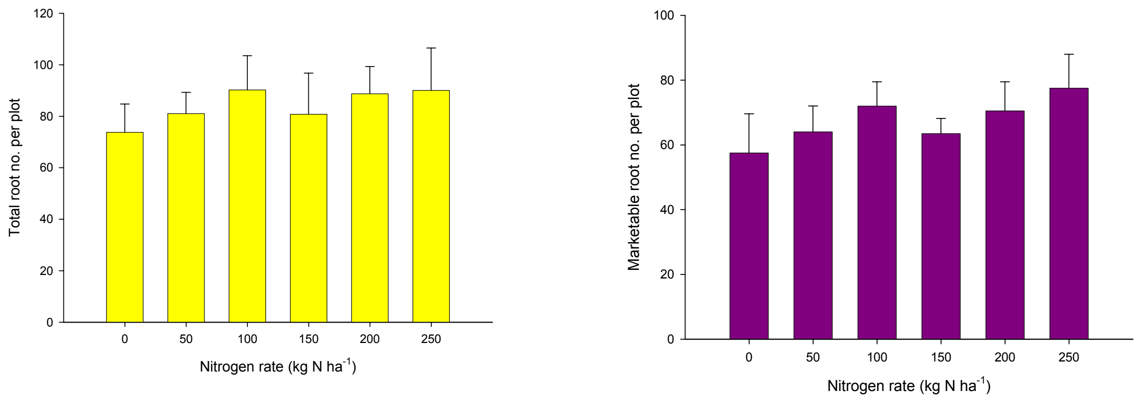


Figure 4.5. Total and Marketable root number per plot for sweetpotato cv. Beauregard at varying N rates in a field trial grown at Bundaberg 2004.

There was no significant effect of N treatment on root dry matter concentration (DM%) ($p=0.374$) (figure 4.6), nor was there any discernible trend in DM%; evidenced by the highly variable means across treatments. The total dry matter yield was determined by multiplying fresh yield by the DM% for each treatment replicate. The highest total dry matter yield was recorded at 100 kg N ha^{-1} ($p=0.051$) (figure 4.6). This was consistent with the response of total root yield data to N treatment.

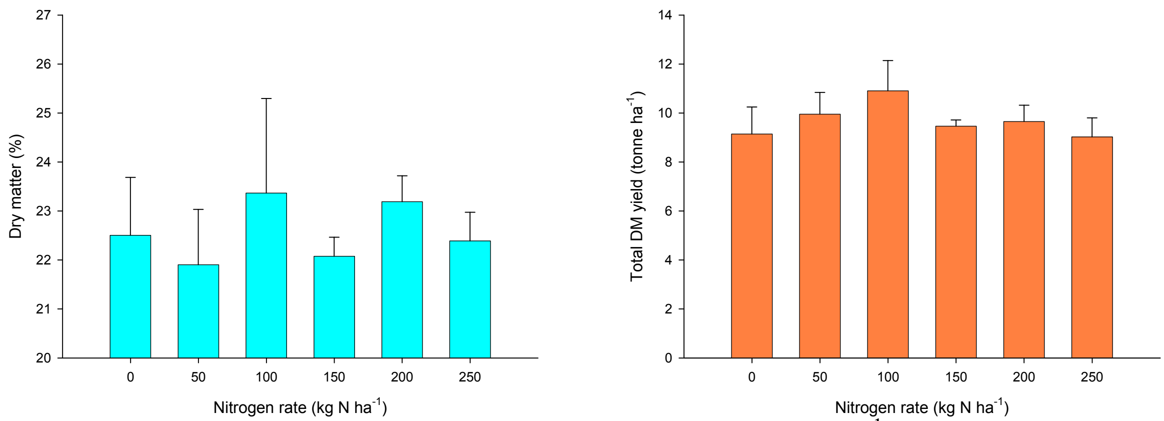


Figure 4.6 Root dry matter (%) and total dry matter yield (tonne ha^{-1}) for sweetpotato cv. Beauregard at varying N rates in a field trial grown at Bundaberg 2004.

The residual N levels and mineral N forms in the soil at harvest varied across treatments. In the 0 kg N ha^{-1} treatment higher levels of NH_4^+ were recorded than that in the highest N treatment at 250 kg N ha^{-1} ($p=0.008$) (figure 4.7). In contrast, the response profile for NO_3^- N was the opposite to that of NH_4^+. Highest residual soil NO_3^- levels at harvest were recorded in the 250 kg N ha^{-1} treatment (figure 4.7). This suggests that the dynamics of N mineralisation were affected by the application rate of N. The highest ammonia N concentration was recorded in the 0 kg ha^{-1} treatment suggesting that in this treatment mineralised N from labile N stored in organic forms was important in providing crop N requirements at low (nil) N application rates. There was a general trend for NH_4^+ to decline with increasing N application whilst in contrast NO_3^- increased with increasing N application rate. All side dressing N at 28 and 56 DAP was applied as ammonium nitrate yet, despite this, NH_4^+ levels declined with increasing N application rate, suggesting nitrification of ammonium forms had occurred.

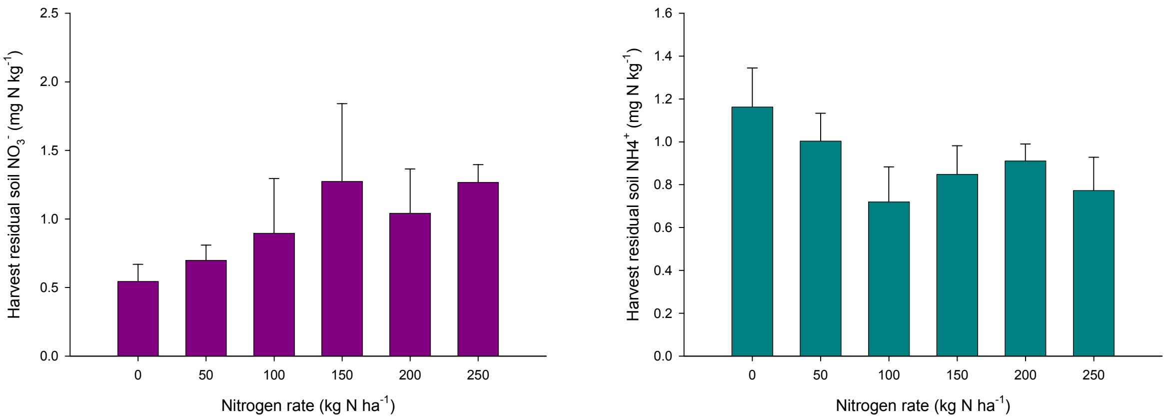


Figure 4.7. Residual soil nitrate and ammonium concentrations of samples collected at harvest from a field experiment evaluating the effects of varying N (0-250 kg ha^{-1}) rates on growth of sweetpotato cv. Beauregard at Bundaberg 2004.

The leaf N concentration at 56 DAP showed a progressive increase in response to N rate (p=0.024) (figure. 4.8) In the 100 kg ha^{-1} treatment, for which maximum total yield was obtained, the leaf N concentration was 4.76%, at which time only 70% of the N treatments had been applied. The leaf N concentrations showed considerable variance making direct associations between leaf N status and N requirements difficult to judge. However, optimal leaf N concentrations at 56 DAP appeared to be in the range 4.5-4.9%. This is consistent with data in the literature. O'Sullivan *et al.* (1997) report a critical deficiency N concentration of 4.0% and an optimal range of 4.2-5.0%. at 28 DAP. In contrast, both Weir and Cresswell (1993) and Huett *et al.* (1997) present data showing much lower adequacy ranges than that of O'Sullivan *et al.* (1997). Weir and Cresswell (1993) note an N adequacy range of 3.5-4.5%. The data presented by Huett *et al.* (1997) from the literature indicates highly variable optimal concentrations for N at different growth stages. These optimal leaf N ranges included the ranges 4.3-4.5% at 28 DAP, 3.52-4.14 at 44 DAP 2.65-3.24 at 58 DAP and 3.2-4.2% at mid growth. In the present study the leaf N% in the 0 kg ha^{-1} N treatment at 56 DAP was about 4.5% and within or above the adequacy ranges presented by Huett *et al.* (1997) and Weir and Cresswell (1993) at a similar stage of growth. Despite this, yield increased with increased N application rate up to 100 kg N ha^{-1} and concomitant increases in leaf N concentrations were observed. The ranges for N adequacy concentrations reported by Huett *et al.* (1997) and Weir and Cresswell (1993) appear to be too low for Beauregard grown under Queensland conditions and the more reasonable figure for adequacy appears to be that presented by O'Sullivan *et al.* (1997) at 4.2-4.9%, albeit at 28 DAP and for a white fleshed cultivar. The variability in leaf N concentrations could relate to natural variability across cultivars. In support of this in 2003 nutrition experiments leaf N concentrations in Beaureguard were about 0.5% unit higher than in Northern Star and this could account for the variable leaf N concentrations established by other researchers. The results for Beauregard suggest that an adequacy concentration of 4.2% is too low and the figure should be closer to a minimum of 4.5%.

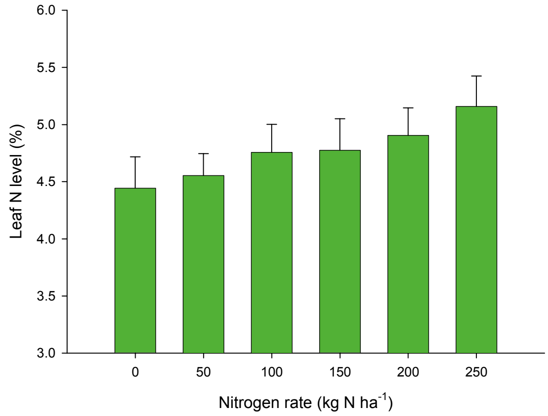


Figure 4.8. Total leaf N concentrations of sweetpotato cv. Beauregard samples collected at 56 DAP from a field experiment evaluating the effects of varying N (0-250 kg ha^{-1}) rates on sweetpotato growth at Bundaberg 2004.

With increasing N application rate both, the root N concentration, and, the total units of N removed in roots, progressively increased (p=0.001) (figure 4.9). The maximum total yield was obtained at 100 kg N ha^{-1} with a root N concentration of 0.96%, whilst under the reduced yield at 250 kg N ha^{-1} the root N concentration was substantially higher at 1.46%. A similar trend was observed for the units of N removed (kg N ha^{-1}) with increasing N application rate (figure 4.9). The N removal was calculated by multiplying the total dry matter yield (t ha^{-1}) by the root N concentration. In the 100 kg N ha^{-1} treatment the calculated N removal was 104.9 kg N ha^{-1} but in the 250 kg N ha^{-1} treatment 132.1 kg N ha^{-1} was removed despite the fact that yield had declined.

The management of N in sweetpotato requires further consideration since excessive N raises several concerns. Firstly, the application of N rates in excess of that required to maximise yield resulted in high N content in the product. Secondly, the calculated N removal in the 250 kg ha^{-1} treatment was about 132 kg ha^{-1} resulting in approximately 120 kg ha^{-1} of N unaccounted for. The residual soil NO_3^- levels at harvest were mostly lower than the initial soil NO_3^- levels (data not presented) indicating in the high N treatments the excess N had been converted to non-mineral forms or somehow lost from the system. This could include labile N or volatile forms lost to the atmosphere or leaching of mineral forms below the sampling zone. In contrast, application of N at 100 kg ha^{-1} resulted in highest yield, and crop N removal was equivalent to that applied allowing better accountability for N application. Growers should closely monitor N application to maximise yield and avoid excessive N application. Depending on residual soil N levels, growers may be able to reduce N application rates whilst maintaining yield, particularly given the often high residual soil N levels found in intensive horticultural systems. Soil testing for NO_3^--N should provide a useful tool in determining N application rates.

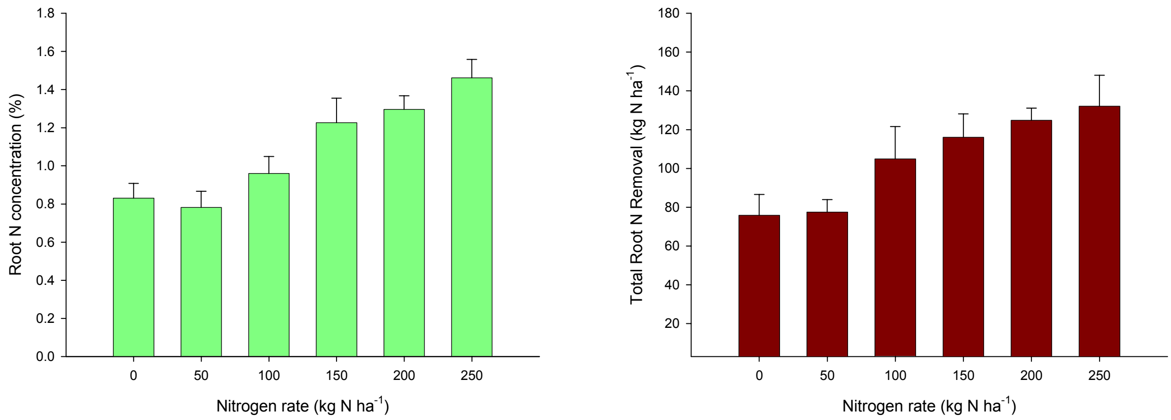


Figure 4.9. Sweetpotato root N concentrations, expressed on a dry weight basis, and root N removal (kg ha^{-1}) for a field experiment evaluating the effects of varying N (0-250 kg ha^{-1}) rates on sweetpotato cv. Beauregard growth at Bundaberg 2004.

Photographic images of foliage development across treatments were taken at 38 DAP, at which point only 70% of the treatment nutrient application had been made (figure 4.10). Foliage development appeared to occur most prolifically in the N treatments at 150 and 200 kg ha^{-1} representing actual N applications of 105 and 140 kg N ha^{-1} respectively. Furthermore, 30% of the treatment N had been applied only 11 days prior to filming and it is likely the full effect of this N dose had not been translated into a foliage growth response. The photographic evidence was consistent across all replicates and suggests that early and effective N application is critical in early canopy development and is likely to impact on time to maturation. In support of this a single application of N at 90 kg ha^{-1} at 20 DAP gave higher yield across 4 cultivars compared with 4 split applications at 22.5 kg ha^{-1} at 20 day intervals (Ankumah *et al.* 2003). Also, rapid early foliage development is likely to result in early root proliferation giving more effective fertilizer uptake as well as the prevention of weed competition.

Potassium Experiment

Increasing the K application rate up to 120 kg ha^{-1} significantly increased total root yield (p=0.006) (figure 5.11), but, thereafter root yield plateaued. There was a reduction in root yield at 240 kg ha^{-1}, which could not be explained, particularly since the standard error for this mean was low in comparison to all other treatments (figure 4.11). The effect of K on marketable yield was not significant (p=0.511) but the highest marketable yield was recorded at 120 kg K ha^{-1} (figure 4.11). These results suggest that the K requirements for sweetpotato (cv. Beauregard) are not as high as previously thought and maximum yields can be obtained at about 120 kg ha^{-1}.

Both total and marketable root number per plot were not significantly affected by K application rate (F probs. p=0.368 and p= 0.393 respectively), however there was a trend for both total and marketable root number per plot to be highest at a K application rate of 120 kg ha^{-1} (figure 4.12) This result was consistent with the trend recorded for total and marketable yield suggesting a role for optimising K nutrition to increase storage root initiation. At this point however, a rigorous interpretation is not possible given the highly variable data.

Figure 4.10. Foliage development in a trial evaluating rates of N at 0-250 kg ha^{-1} on sweetpotato cv Beauregard growth. Photos were taken at 39 DAP at which time 70% of the treatment N application had been made.

0 kg N

50 kg N

100 kg N

150 kg N

200 kg N

250 kg N

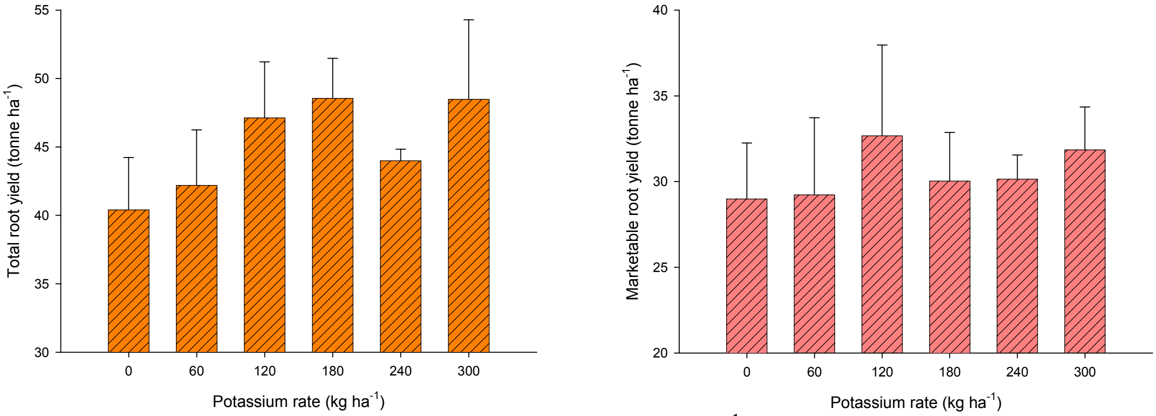


Figure 4.11. Total and Marketable fresh yields (tonne ha^{-1}) for sweetpotato cv. Beauregard at varying K rates in a field trial grown at Bundaberg 2004.

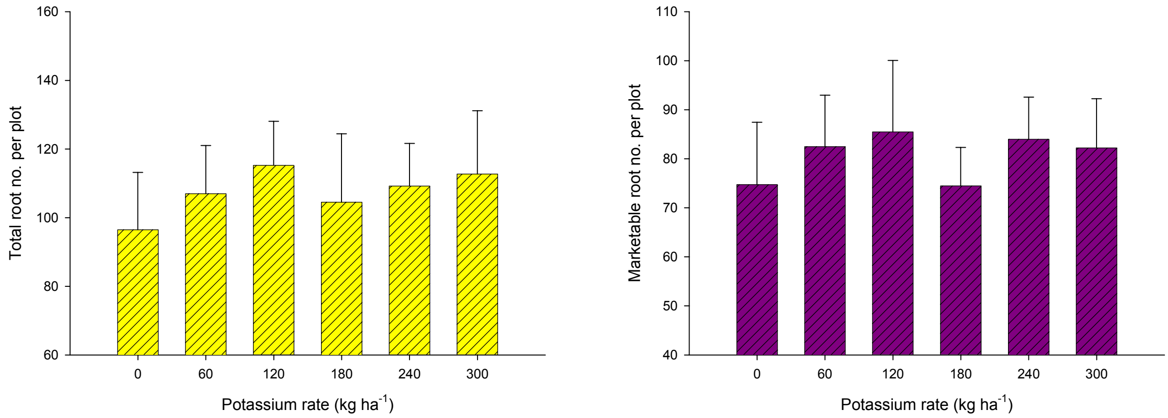


Figure 4.12. Total and Marketable root number per plot for sweetpotato cv. Beauregard at varying K rates in a field trial grown at Bundaberg 2004.

Leaf K levels at 56 DAP showed a logarithmic response to K application rate (figure 4.13). Relatively large increases in leaf K concentration were recorded up to 120 kg K ha^{-1} but thereafter the increase in leaf K concentration was less pronounced. This response was similar to that recorded for total yield over K treatments. This would suggest that a leaf K concentration of at least 3% at about 7-8 weeks is required in achieving maximum yield. This figure is consistent with an optimal range of 3-4% reported by Weir and Cresswell (1993) for sweetpotato (cultivar not specified) at mid crop growth. Also, O'Sullivan *et al.* (1997) report a critical deficiency K level of 2.6% and an optimal range of 2.8-6.0% in cv. Wanmun at 28 DAP. In contrast, data presented by Huett *et al.* (1997) present a range of optimal leaf K values determined by various researchers but cite a critical deficiency leaf K concentration of 4.0% over a range of maturities. This variance in optimal leaf K concentration within the literature is likely to be a function of the varieties examined and the conditions under which the crops were grown.

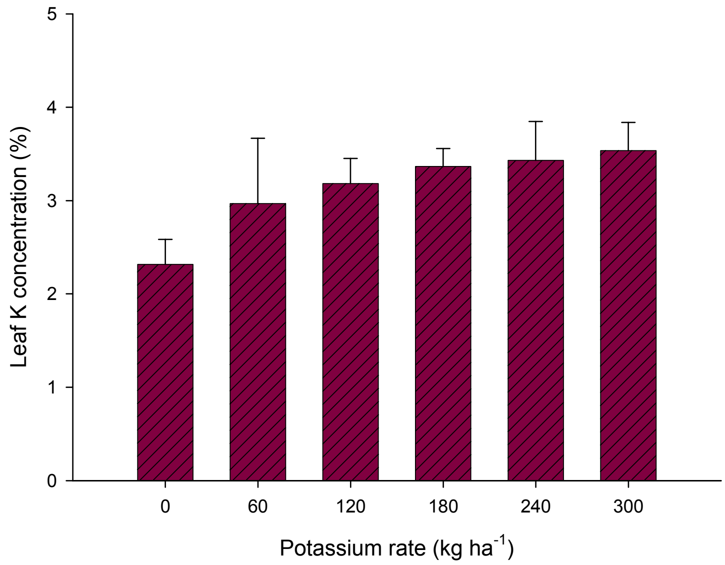


Figure 4.13. Leaf K concentrations of sweetpotato cv. Beauregard samples collected at 56DAP from a field experiment evaluating the effects of varying K (0-300 kg ha^{-1}) rates on sweetpotato growth at Bundaberg 2004.

The residual soil K levels at harvest increased progressively with increasing K application rate ($p<0.001$) (figure 4.14). The maximum yield was recorded at 120 kg K ha^{-1} and excessive K application provided no further increase in yield but substantially increased soil K levels. It is recommended that growers use soil testing to determine available K and apply K at a rate of about 120 kg K ha^{-1}.

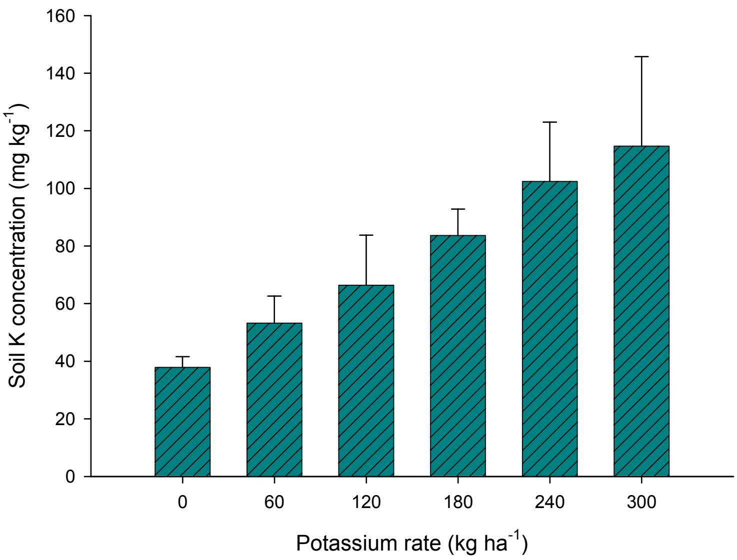


Figure 4.14. Residual soil K concentrations of samples collected at harvest from a field experiment evaluating the effects of varying K (0-300 kg ha^{-1}) rates on growth of sweetpotato cv. Beauregard at Bundaberg 2004.

4.4 Addressing soil fertility issues at Mareeba

4.4.1 Methodology

Two experiments were conducted as field trials at Mareeba on a commercial growers' property to evaluate effects of liming and trace element application.

The liming trial evaluated 4 lime rates (0, 1, 2 and 4 tonne ha^{-1}) and was conducted as a randomised complete block with 4 replicates. Lime treatments were applied by hand broadcast over the plot area 6m x 7m with 2m buffer between plots and incorporated in 4 weeks prior to planting. Data was collected from a 3m plot in the centre of the treated area. Lime applications and planting were timed to coincide with on farm operations.

The trace element experiment was conducted as a nutrient omission trial in a randomised complete block design replicated 4 times. The treatments included a Nil trace element treatment (basal nutrients only), All (basal nutrient plus Zn, B and Mo), - Zn, -B and –Mo. The Zn (1 kg ha^{-1}) was applied as Zn sulfate heptahydrate, B (1 kg ha^{-1}) as solubor and Mo (100 g ha^{-1}) as sodium molybdate.

Experimental plots for each trial site consisted of datum rows planted using PT cuttings of Beauregard and guard rows planted using the commercial growers' planting material cv. Beauregard. A marker plant of variety Northern Star was planted at either end of each datum plot and a gap of 2 m was allowed between plots. Soil samples from each plot were taken prior to planting and held for analysis as necessary. All agronomic practices, with the exception of the lime and trace element application, were as per the grower's conventional practice. The trial planting and harvest dates and days of growth and limited agronomic details are presented in Table 4.10.

Table 4.10. Agronomic data for sweetpotato nutrition trials conducted at Mareeba 2004.

	Liming Experiment	Trace element Experiment
Planting Date	10/05/2004	10/05/2004
Harvest Date	26/10/2004	26/10/2004
Growth Period (Days)	169 days	169 days
Soil Type	Sandy loam	Sandy loam
Row Spacing	1.2	1.2
Plant Spacing (cm)	30	30
Irrigation Type	Overhead	Overhead
Fertiliser Application		
N	97.8	97.8
S	6.1	6.1
K	160.1	160.1
Ca		
Mg	14.4	14.4
Zn		1
B		1
Mo		1

Plots were harvested mechanically by digging the middle datum row. Roots were graded according to a retail market specification; size range includes undersize, small, medium, large, seconds and cracked (Table 4.3).

Prior to planting a bulked soil sample was taken at each experimental site and a full nutrient analysis conducted (Table 4.9). Individual plot soil samples were taken and held for analysis as required. At each site leaf samples were collected from each treatment replicate at 56 DAP. Samples were immediately field stored on ice in an esky and on completion of sampling immediately dehydrated and held for analysis as necessary.

For each experiment an ANOVA was conducted on data using Genstat 6.1.0.205. The variance of data was normally distributed requiring no transformation.

4.4.2 Results and discussion Mareeba

Effect of Lime on sweetpotato growth

The effect of lime on total yield was statistically significant at 5%, however the result was not meaningful since the trend over increasing lime rate was not consistent (Table 4.11). Yield was highest in the Nil and 2 tonne ha^{-1} treatments and lowest in the 1 and 4 tonne ha^{-1} treatments. Similarly, the total dry matter yield was statistically significant but the response was also not meaningful. Lime application did not significantly affect total or marketable root number per plant, but there was a trend for higher storage root numbers at 2 tonne lime ha^{-1}. This trial did not provide sufficient evidence to indicate acidic soil infertility was limiting sweetpotato growth.

Table 4.11. Effect of liming rate (tonne ha^{-1}) on the total and marketable (Mkt) yield (tonne ha^{-1}), dry matter percentage (DM%), Total dry matter yield (Total DM yield) (tonne ha^{-1}), and total and marketable storage root numbers per plant in sweetpotato cv. Beauregard at Mareeba in 2004.

Lime rate	Total yield	Mkt yield	DM%	Total DM yield	Tot root no.	Mkt root no.
0	54.1	33.8	19.6	10.6	3.28	2.73
1	48.1	29.6	20.1	9.6	3.55	2.25
2	54.1	36.9	19.6	10.6	4.03	3.00
4	46.7	27.4	20.0	9.3	3.48	2.43
	* lsd = 5.8	NS	NS	* lsd = 1.0	NS	NS

NS denotes not significant
*** significant at p =0.001, ** significant at p =0.01 and * significant at p =0.05

Effect of boron, zinc and molybdenum on sweetpotato growth

There was no significant effect of trace element application on total or marketable root yield, total or marketable root number per plant, DM%, or dry matter yield (Table 4.12). The effect of trace element treatments on total yield was however close to significance at p=0.065. The only consistent trend in the treatments with respect to total yield was that treatments receiving

B (All TE, -Mo and –Zn) appeared to have lower total yields compared with the 2 treatments to which B was not added (Nil, TE and –B). However, given that significant but meaningless results were recorded in the liming trial it is difficult to draw any strong conclusion on this issue. Nonetheless, the application of B should be made with caution using soil and leaf tissue testing as a basis for application. There was no evidence of a response to Zn or Mo.

Table 4.12. Total and marketable (Mkt) yield (tonne ha^{-1}), dry matter percentage (DM%), Total dry matter yield (Total DM yield) (tonne ha^{-1}), and total and marketable storage root numbers per plant in a trace element (TE) omission trial evaluating effects of Boron (B) molybdenum (Mo) and Zinc (Zn) on sweetpotato cv. Beauregard growth at Mareeba in 2004.

Treatment	Total yield	Mkt yield	DM%	Total DM yield	Tot root no.	Mkt root no.
All TE	41.1	31.1	18.8	7.7	2.90	2.35
Nil TE	47.7	31.8	19.2	9.2	2.90	2.35
-B	47.4	28.1	18.9	9.0	2.50	1.97
-Mo	41.6	29.6	19.3	8.0	3.05	2.32
-Zn	41.1	24.8	19.4	8.0	2.73	2.10
	NS F prob = 0.065	NS	NS	NS	NS	NS

NS denotes not significant
*** significant at p =0.001, ** significant at p =0.01 and * significant at p =0.05

5. Best Management Options Grower Trials

5.1 Introduction

Results of nutrition trials (Chapter 4) have shown for the variety Beauregard growers need to monitor nitrogen application very carefully. At grower information days the project team outlined research results with the recommendation that on low nitrogen soils growers should not use more than 100 kg ha^{-1} N when split across three applications. On high nitrogen soils less nitrogen should be added. Excess nitrogen could lead to yield decreases and potential losses of nitrogen into the environment.

For potassium depending on soil analysis a maximum 180 kg ha^{-1} elemental potassium was recommended.

To test the effectiveness of the nutrition recommendations under commercial growing conditions unreplicated technology transfer trials were carried out on grower properties in Rockhampton, Bundaberg and Cudgen. Results from variety trials (reported elsewhere) had shown the superiority of PT planting material supplied by DPI&F. Use of PT material was included in the nutrition trials in Rockhampton, Bundaberg and Cudgen whereas in Mareeba PT planting material only was compared.

5.2 Methodology

In Rockhampton, Bundaberg and Cudgen after grower site selection the following activities were carried out:

1. Soil analysis taken prior to planting and 8 weeks after (fertiliser recommendation made on basis of soil analysis)
2. Recommended fertiliser added by grower using commercial machinery
3. Cuttings for planting taken from PT foundation seed and grower field material.
4. All sites watered by trickle irritation
5. If required, fertiliser side dressings made through the trickle system
6. At maturity sixty plants were harvested for yield estimations

In Mareeba cuttings for planting were taken from PT foundation seed and grower field material. Plants were then grown on the cooperating growers' property using the growers' fertiliser program.

5.2.1 Nutrition and PT planting material Trials

5.2.1.1 Grower Site 1: Rockhampton

Soil Analysis

Category	Planting	56 DAP
pH (1:5 water)	6.70	7.2
Nitrate Nitrogen mg/kg (N)	140.0	3.2
Phosphorus mg/kg (P)	81.00	64
Potassium meq/100g (K)	0.98	0.39
Zinc mg/kg (Zn)	5.20	8.8
Boron mg/kg (B)	1.40	2

Fertiliser

Basal: Due to the high soil nutrient levels (particularly nitrogen) only 1kg ha^{-1} Boron added.
Side dressing: At 77 DAT (kg ha^{-1}): 30 N, 21 K
At 98 DAT (kg ha^{-1}):3.25 N, 8.5 K
Total fertiliser (kg ha^{-1}): 33.25 N, 29.5 K, 1 B

Planting

The trial was planted on October 6, 2004 using PT foundation seed cuttings at three plant spacings: 30, 45 and 60 cm in double rows on a bed width of 1.95 m centres. This resulted in plant densities of 34 186, 22 791 and 17 093 plants ha^{-1} respectively. No grower planting material comparison was conducted.

Harvesting

At 97 DAP plants were harvested at the 30, 45 and 60 cm spacings.
At 118 DAP plants were harvested for commercial yield estimation.

5.2.1.2 Grower Site 2: Bundaberg

Soil Analysis

Element or Category	Planting	8 weeks after planting
pH (1:5 water)	5.1	5.8
Nitrate Nitrogen mg/kg (N)	12	26
Phosphorus mg/kg (P)	81	150
Potassium meq/100g (K)	0.52	1.0
Zinc mg/kg (Zn)	8.1	9.3
Boron mg/kg (B)	1.1	2.5

DPI&F Trial Fertiliser

4 tonnes ha^{-1} lime added two months prior to adding basal fertiliser
Basal (kg ha^{-1}): 40 N, 22 P, 44 K, 57 Sulphur (S), 1.64 Zn and 0.7 B.
Side dressing (kg ha^{-1}): At 36 DAP 30 N, 16 P, 66 K, 0.05 Zn, 0.12 B
At 70 DAP (kg ha^{-1}): 30 N, 39.8 K
Total fertiliser (kg ha^{-1}): 100 N, 38 P, 150 K, 57 S, 1.7 Zn, 0.82 B

Grower Fertiliser

Basal (kg ha^{-1}): 47 N, 53 P, 44 K, 24 S
Side dressing (kg ha^{-1}): 70 N, 145 K, 22 S, 67 Calcium (Ca)
Total fertiliser (kg ha^{-1}): 117 N, 53 P, 189 K, 46 S, 67 Ca

Planting

The trial was planted on November 16, 2004, using PT foundation seed cuttings and grower field cuttings, at 30 cm spacing on a bed width of 1.5 m centres. This spacing resulted in a plant density of 22 222 plants ha^{-1}. PT seed cuttings were fertilised using DPI&F fertiliser. Grower field cuttings were fertilised using the Trial and grower fertiliser.

Harvesting

At 140 DAP plants were harvested from each of three treatment sites. Treatment 1 Trial fertiliser and foundation seed cuttings. Treatment 2 Trial fertiliser and grower field cuttings. Treatment 3 Grower fertiliser and grower field cuttings.

5.2.1.3 Grower Site 3: Cudgen (NSW)

Soil Analysis

Element or Category	Planting	8 weeks after planting
pH (1:5 water)	5.1	5.2
Nitrate Nitrogen mg/kg (N)	6	72
Phosphorus mg/kg (P)	26	177
Potassium meq/100g (K)	0.47	0.64
Zinc mg/kg (Zn)	1	1.9
Boron mg/kg (B)	0.6	1.4

DPI&F Trial Fertiliser
Basal (kg ha^{-1}): 84.6 N, 46.6 P, 92.5 K, 121 S, 3.5 Zn, 1.5 B
Side dressing): No side dressing
Total fertiliser: As for basal

Grower Fertiliser
Basal (kg ha^{-1}): 92 N, 37 P, 109 K, 59 S, 0.15 Zn, 0.11 B
Side dressing (kg ha^{-1}): 8 N, 24 K
Total fertiliser (kg ha^{-1}): 100 N, 37 P, 133 K, 59 S, 0.15 Zn, 0.1 B

Planting
Same as for grower site 2 except for planting which was carried out on June 20, 2005.

Harvesting
At 194 DAP plants were harvested from each of three treatment sites. Treatments were the same as for grower site 2.

5.2.1.4 PT planting material only trial

Mareeba

Grower Fertiliser
Basal (kg ha^{-1}): 117 N, 130 P, 88 K, 47 S
Side dressing (kg ha^{-1}): 49 N, 149 K, 45 S, 10 Calcium (Ca)
Total fertiliser (kg ha^{-1}): 166 N, 130 P, 237 K, 92 S, 10 Ca

Planting
The trial was planted on April 8, 2005 using PT foundation seed cuttings and grower field cuttings at a 38 cm spacing on a bed width of 0.91m centres. This spacing resulted in a plant density of 28 900 plants ha^{-1}. PT seed cuttings and grower field cuttings were fertilised using grower fertiliser.

Harvesting
At 172 DAP plants were harvested for commercial yield evaluation.

5.3 Results

Grower Site 1: Rockhampton

Yields (tonnes ha^{-1}) at 97 DAP for three plant spacings (30, 45 and 60 cm) are shown in figure 5.1. Results indicate that maturity of Beauregard may be influenced by plant spacing with a wide spacing (60 cm) maturing much earlier.

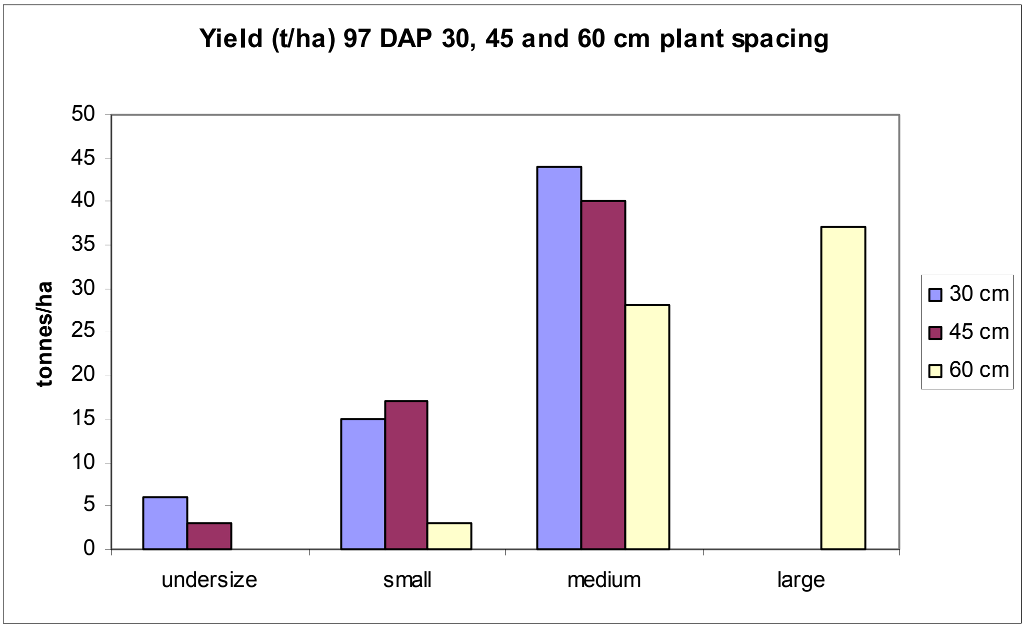


Figure 5.1 Yield results at 97 DAP for best management option trial on plant spacing at Rockhampton.

Yield (tonnes ha^{-1}) at 118DAP for the 30 and 45 cm plant spacings are shown in figure 5.2. Results again show that the wider the spacing the earlier the maturity (45 cm has more large than 30 cm). Premium prices are paid for the small and medium size range suggesting 30 cm would be the preferred spacing.

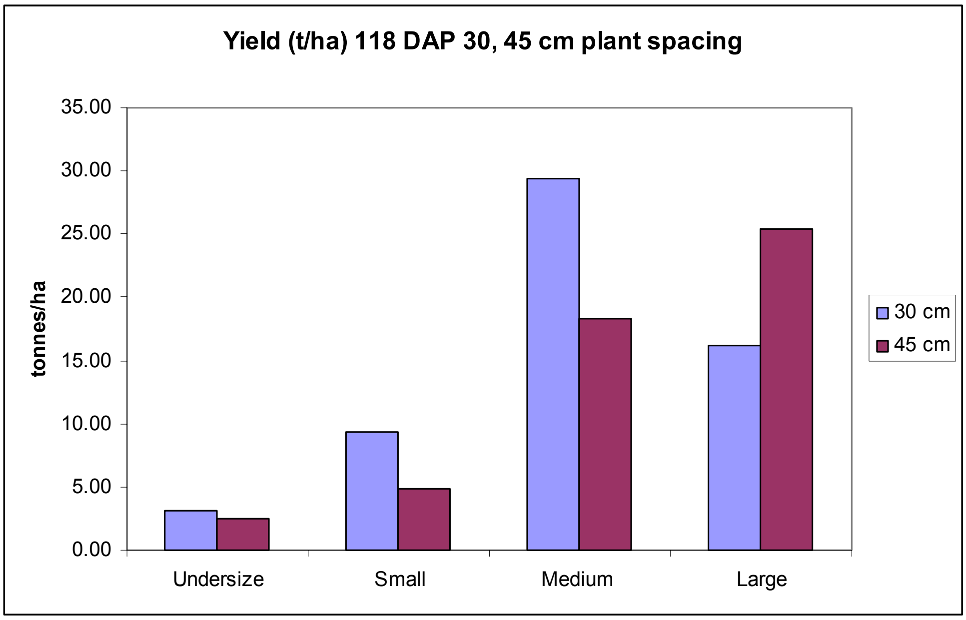


Figure 5.2 Yield results at 118 DAP for best management option trial on plant spacing at Rockhampton.

Grower Site 2: Bundaberg

Yield (tonnes ha^{-1}) at 140 DAP for treatments 1, 2 and 3 are shown in figure 5.3. Results show the superiority of PT foundation seed planting material (treatment 1) particularly in the premium price small and medium size range. There was no apparent difference between treatments 2 and 3.

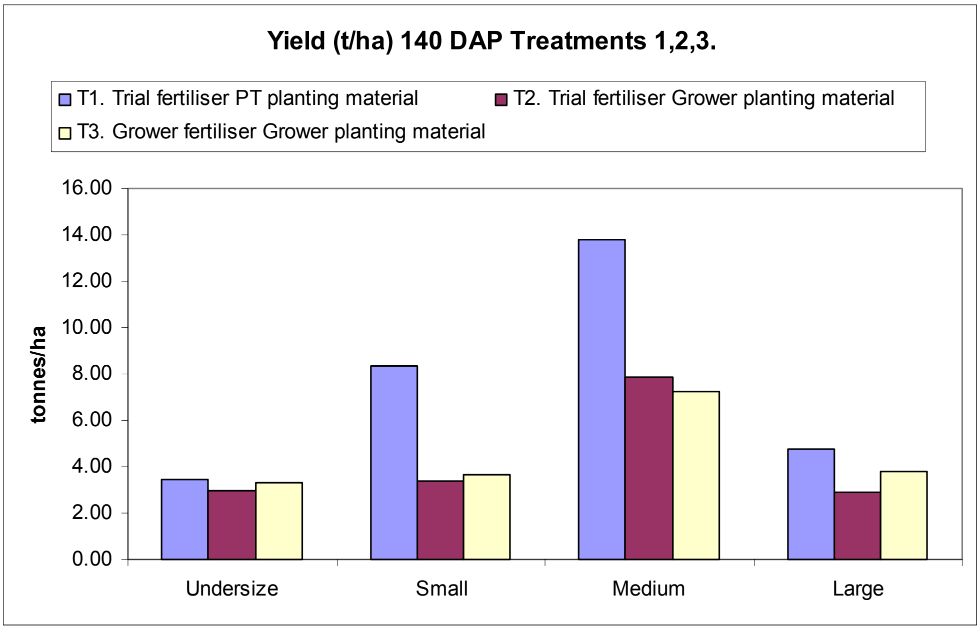


Figure 5.3 Yield results at 140 DAP for best management option trial at Bundaberg.

Grower Site 3: Cudgen

Yields (tonnes ha^{-1}) at 194 DAP for treatments 1, 2 and 3 are shown in figure 5.4. Results are similar for Grower site 2 with the superiority of PT foundation seed material (treatment 1) again expressed and no observable difference between treatments 2 and 3.

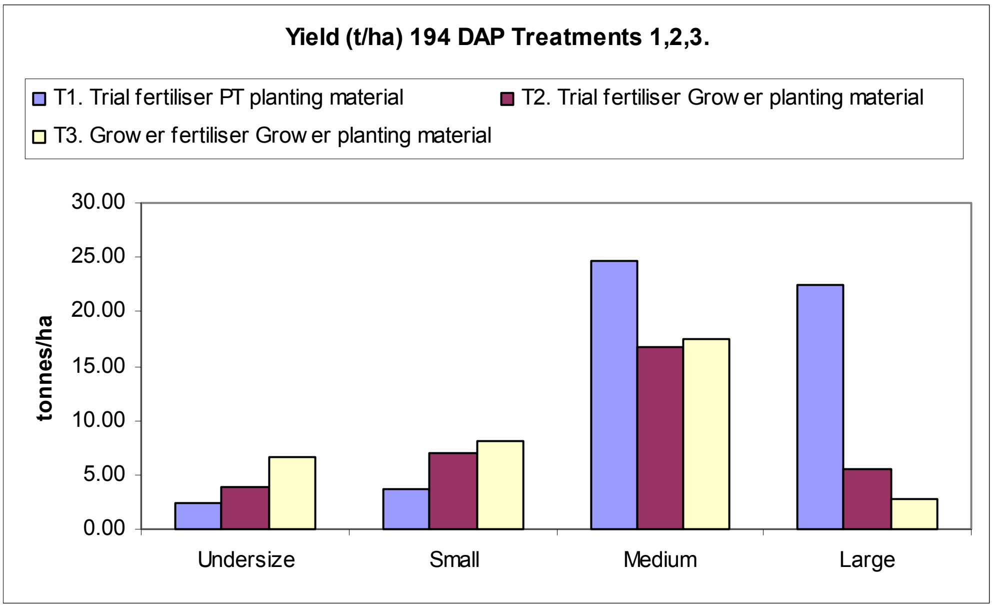


Figure 5.4 Yield results at 194 DAP for best management option trial at Cudgen.

Mareeba site

Yields (tonnes ha^{-1}) at 172 DAP for treatment 1 (PT foundation seed cuttings) and treatment 2 (grower field cuttings) are shown in figure 5.5. Results again show the superiority of PT foundation seed material.

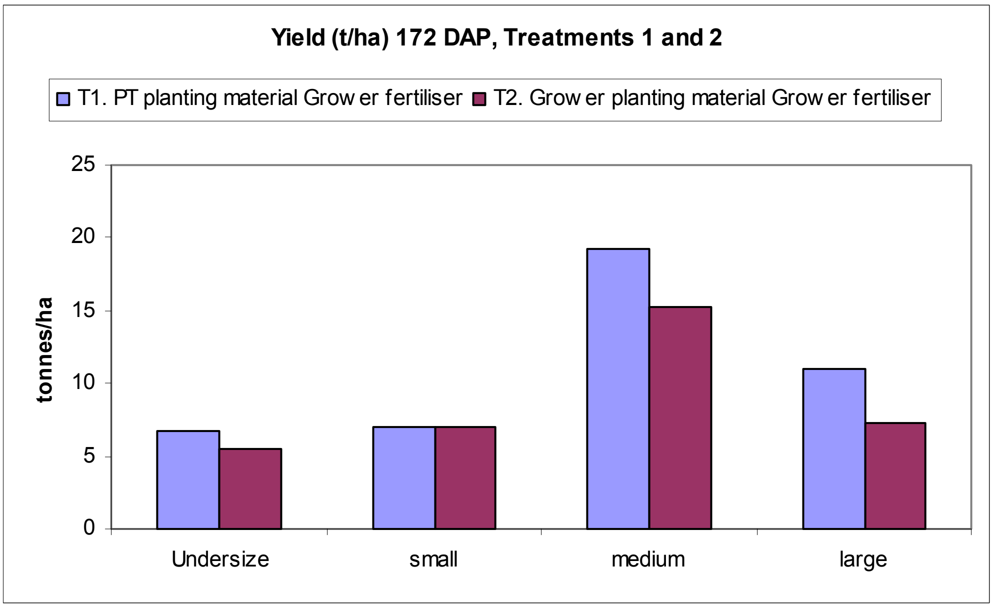


Figure 5.5 Yield results at 172 DAP for best management option trial at Mareeba.

5.4 Discussion

Due to the small trial area available the Rockhampton site did not have any grower planting material included as part of the trial. However, the trial showed the potential for manipulating the maturity of Beauregard using plant spacing. More importantly, the results showed the reliability of the DPI&F best management options, derived from the research trials ie utilising foundation seed planting material and controlling nitrogen usage. The marketable yield of small + medium + large was equivalent to 3051 cartons (18kg) per hectare. These yields are considered very high by industry standards (as reported in the grower survey Chapter 6). Yields were obtained using only 33 kg ha^{-1} N and 29.5 kg ha^{-1} K (much less than industry standard) with the nitrogen all added post planting based on soil analysis.

In Bundaberg, the superiority of PT foundation seed planting material was clearly evident, highlighting the significant negative impact virus has on commercial sweetpotato production. Virus infection is endemic in all commercial sweetpotato crops. In terms of fertiliser application there was no apparent difference between DPI& F trial application and the growers' application. Results suggest that growers can reduce N, P, K, S and Ca applications without any detrimental effects on yield.

In Cudgen, again the superiority of PT foundation seed planting material was shown. Once more there was no apparent difference between the DPI&F trial fertiliser application and the growers' fertiliser. This was not surprising as the grower was adding almost identical amounts of nutrients.

In Mareeba the superiority of PT foundation seed planting material was also shown, this time using growers' fertiliser. This trial also highlighted how quickly virus infection can influence yield as the growers' planting material used in the trial was only 2 generations from PT foundation seed.

Results of the best management options trials were presented to growers in Bundaberg, Cudgen and Mareeba where 40, 30 and 8 growers attended respectively.

Impact of adoption of the research and best management options tech transfer trial results have been captured in the survey results (Chapter 6). The adoption of PT foundation seed material, reduction in fertiliser usage (particularly N) and use of soil analysis by industry had been a very pleasing aspect of the project.

6. Grower Surveys

6.1 Introduction

To gain baseline information on growers' production practices a survey was undertaken at the beginning of the project during March/April 2002. To ascertain if there had been any changes in production practices during the duration of the project and what, if any changes could be attributed to the project a second survey was undertaken at the end of the project during May/June 2005.

6.2 Methodology

The 2002 survey and the 2005 survey were carried out in the key growing areas of Bundaberg and Mareeba in Queensland and Cudgen in New South Wales. Growers were interviewed by a project officer on a one is to one basis. Growers interviewed were selected to cover the grower segments small, medium and large based on number of cartons produced.

Questions in the 2002 survey (see Appendix 6.1) covered management practices (varieties, planting method, fertiliser, irrigation) and marketing. Marketing was included to complement a retail marketing survey carried out in 2002 (Appendix 1). Questions in the 2005 survey (see Appendix 6.2) were focused on management practices and what if any practice change could be attributed to the project. A total of 51 genuine growers across the major production areas of Bundaberg Mareeba and Cudgen was determined. In each survey 16 growers (30% of the industry) were surveyed.

6.3 Results

Results of the 2002 survey were re-evaluated in 2005 using evaluation methodology used in the 2005 survey. In essence the two surveys asked a number of similar questions; the re-evaluation consisted mainly of interpretation and recording the results in a spreadsheet format as done for the 2005 survey. If growers from the 2002 survey were still growing they were included in the 2005 survey. Results are reported under questions asked in the surveys.

Question: Area of sweetpotato grown per year, cartons produced, average production and varieties grown.

Results for this question are shown in table 6.1.

Table 6.1 Sweetpotato area grown, total and average production per ha and varieties grown in 2002 and 2005.

Production parameter	2002	2005
Area grown (ha)	331	435
Total production (cartons (18 kg))	583 730	833 400
Average production per ha (cartons)	1779	1916
Variety Beauregard %	98.1	89.9
Variety Northern Star %	1.8	9.1
Any other varieties %	0.1	0.9

Questions on area grown and total production were used primarily used as "ice breaker" questions. The increase in area grown and production for 2005 reflects both an increase in production by some growers from the 2002 survey and the fact there were many additional growers included in the 2005 survey since some of those surveyed in 2002 had left the industry. When comparing areas grown by the same growers in both surveys results showed that in Bundaberg 90% of growers had increased their areas of production (in some cases quite significantly - 40 to 85%). In Cudgen, growers had also increased production area albeit to a lesser extent than Bundaberg, whereas in Mareeba growers had not increased production area.

The total increase in average production per ha for 2005 cf 2002 was also reflected within regions with the average production per ha in the following order: Bundaberg > Cudgen > Mareeba.

Results for varieties grown show the overwhelming dominance of Beauregard compared with other varieties. The increase shown in 2005 for varieties other than Beauregard reflects growers trialling new varieties to satisfy niche markets and the inclusion of new growers in the 2005 survey.

Question: Grower awareness of the DPI&F project work

In 2005, all growers surveyed had heard of the DPI&F sweetpotato project with only one grower not aware of any results from the project. Over 90% of growers became aware of project information from technology transfer information and field days, 80% from farm visits dropping to 50% for the newsletter and 30% from other growers.

Question: Growing practice change in the last 3-4 years.

In 2005, when asked if they had changed any growing practices in the last 3 to 4 years all of the growers surveyed in Bundaberg and Cudgen indicated they had, whereas half of the growers surveyed in Mareeba indicated they had made no changes.

In Bundaberg, growers rated PT planting material (supplied by DPI&F), followed by planting method, fertiliser addition and adoption of trickle irrigation as the major changes. In Cudgen, the ranking was fertiliser followed by trickle irrigation and planting method followed by PT material. In Mareeba, the only change listed was fertiliser addition.

Question: What influence if any did the DPI agronomy work have on any of the changes?

In Bundaberg and Cudgen, growers indicated DPI&F's greatest influence had been on fertiliser changes and the adoption of PT material with a less significant influence on planting method changes. Mareeba growers considered DPI&F had no influence.

Question: Obtaining planting material

In 2002 and 2005, all growers surveyed selected planting material from their own commercial crops, however, over 50% of growers surveyed in 2005 also obtained material from other growers compared with less than 15% in 2002.

Question: DPI&F Pathogen Tested (PT) foundation seed scheme

In 2002, 20% of growers were using PT material every year, 25% had never used PT material with the remainder using PT material infrequently. By 2005 all of the growers surveyed in Bundaberg and Cudgen were using PT material every year whereas in Mareeba no grower consistently used PT material.

When asked if the project had any influence on their adoption of PT material all growers surveyed in Bundaberg and Cudgen indicated that it had a major influence. In Mareeba, two growers indicated that the project had stimulated them to consider using PT material.

Question: Plant spacing

In 2002, 50% of growers were using a plant spacing of 30 to 40 cm, 38% were using 25 to 30 cm and 12% were using 20 to 25 cm. By 2005 plant spacings had reduced with only 26% using 30 to 40 cm, 58% were now using 25 to 30 cm and 16% were using 20 to 25 cm.

When asked if they had changed their plant spacing in the last 4 years 80% of growers in Bundaberg and Cudgen indicated they had, whereas in Mareeba no grower surveyed had changed plant spacing. Some growers in Bundaberg also mentioned that they used different plant spacings depending on the time of planting.

Question: Irrigation Method

In 2002, all growers in all regions used overhead sprinkler irrigation at planting. During the growth of the crop growers in Cudgen and Mareeba continued with sprinkler irrigation. However, in Bundaberg the majority of growers changed to travelling winch during the growth of the crop. In terms of monitoring irrigation all growers in all regions used experience to monitor irrigation requirements. No growers were using soil water measuring devices eg. tensiometers.

In 2005, all growers in Cudgen and Mareeba still used sprinkler irrigation at planting whereas in Bundaberg this had dropped to 60% with the remainder planting into moisture using trickle irrigation. During crop growth all growers in Mareeba continued with sprinkler irrigation whereas in Cudgen this dropped to 40% with the remainder using trickle irrigation. In Bundaberg, all growers used trickle irrigation during crop growth with some using travelling winch to supplement their trickle irrigation. When asked about monitoring irrigation only one grower used tensiometers (and then only infrequently) with all others basing their irrigation decisions on experience.

Question: Planting method

In 2005, 60% of the Bundaberg growers surveyed were flat planting by hand into moisture with the remaining growers surveyed flat planting by machine. In Cudgen, 60% of surveyed growers used a V plant method (push plant into dry soil with a stick) and then irrigated with remaining growers flat planting by hand and then irrigating. In Mareeba, all growers surveyed used machine planting.

Question: Soil testing

In 2002, 80% of growers surveyed used soil testing with the remainder indicating they saw no need for it. Growers based their decision on when to soil sample on previous land use history.

In 2005, 90% of growers were using soil testing, some on every block before planting.

Question: Plant tissue testing

In 2002, only 25% of growers surveyed used plant tissue testing and then only as a trouble shooting guide. The remaining growers did not see plant tissue testing as a reliable tool for decision making.

In 2005, the number of growers using plant tissue testing had risen to 40% with some now using tissue testing for monitoring and not just trouble shooting. Although the majority of growers still did not see tissue testing as a reliable decision making tool.

Question: Fertiliser program

In 2002 and again in 2005 growers were asked to outline their current fertiliser program. The averages of the results for basal application for Nitrogen, Phosphorus, Potassium and Sulphur and the % change over the years is shown in table 2.

Table 6.2 Amount of basal nutrient applied (kg ha^{-1}) by sweetpotato growers in 3 regions in 2002 and 2005.

	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Sulphur (S)
Bundaberg 2002	99	106	136	35
Bundaberg 2005	57	45	98	60
% change	-42*	-57	-28	75
Cudgen 2002	100	69	219	70
Cudgen 2005	79	35	101	56
% change	-20	-50	-54	-19
Mareeba 2002	125	126	90	51
Mareeba 2005	121	87	110	89
% change	-3	-31	22	76

*: - indicates a decrease in amount applied

Results in table 6.2 show that in Bundaberg and Cudgen noteworthy decreases in N, P and K applied had occurred from 2002 to 2005 whereas in Mareeba only P showed a noteworthy decrease in application.

When asked what influence if any the DPI&F project had on their fertiliser additions 70% of growers in Bundaberg and all Cudgen growers indicated in the affirmative. All growers in Mareeba indicated the DPI&F project had no influence on their fertiliser additions.

Question: Customer demands

In 2002, 60% of growers surveyed indicated they were having difficulty meeting the increasingly stringent demands of the major wholesalers.

In 2005, 50% of all growers indicated they were having difficulty although when broken down on an area basis only 30% of Bundaberg growers surveyed indicated they were having difficulty compared with 60% for Cudgen and 100% for Mareeba.

Question: Critical issues

In the 2002 survey growers were asked to list the most critical issues in relation to growing sweetpotatoes. The following issues were listed by growers as critical: Effect of virus, Pests, Irrigation, Fertiliser, Varieties and Marketing. When ranked in terms of number of times mentioned the following ranking was found: Pests > Virus > Marketing > Fertiliser = Irrigation = Varieties.

In 2005 growers were asked to rank the six issues listed in 2002 from 1 to 6 (with 6 being the most critical and 1 least critical). The ranking was then summed across all grower responses to arrive at the ranking for that issue. The summed ranked results are shown in figure 6.1.

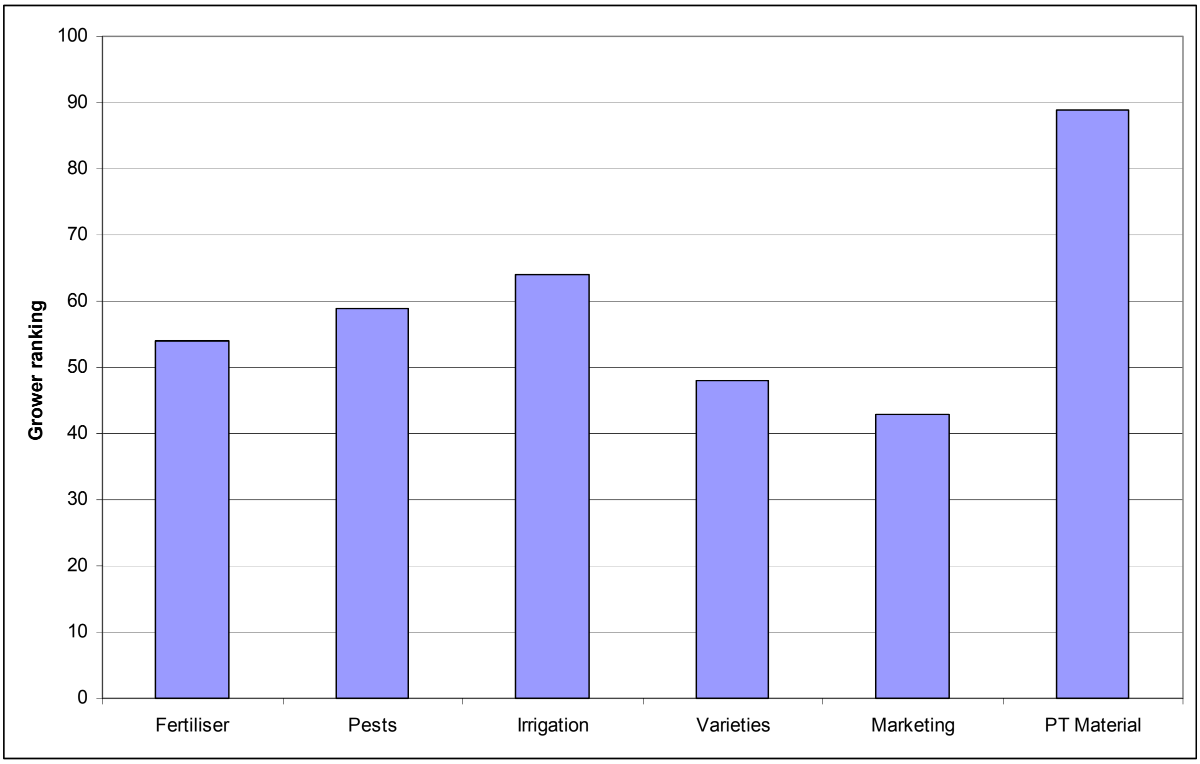


Figure 6.1 Survey results showing summed grower rankings for sweetpotato issues 2005.

Results between the two surveys indicate the continuing importance of virus and pests as major issues with the interesting result that irrigation was ranked much higher in 2005.

6.4 Discussion

The 43% increase in sweetpotato production from 2002 to 2005 reflects an industry in a rapid growth phase. The growth figures found in the survey are considered very representative of the industry when compared with DPI&F figures for Bundaberg collected from transport companies which show a 30% increase in road transport of sweetpotatoes (to Brisbane, Sydney and Melbourne markets) over the same period. History suggests that such increases are unsustainable unless the market continues to grow commensurately. The rapid market growth in the last 3 years has been achieved with little or no industry sponsored marketing or promotion.

The overwhelmingly dominance of the gold fleshed variety 'Beauregard' reflects both consumer demand for a gold fleshed low dry matter sweetpotato and the positive agronomic characteristics of the variety. An industry based predominantly on one variety does raise questions of genetic diversity for the industry. Growers are testing other varieties as shown by the increase in production of Northern Star and other varieties during the four years of the project.

It was pleasing to note that all growers (except one Mareeba grower) in 2005 indicated they were aware of the results of the project. Not unexpectedly growers became most aware of project results through direct project officer contact either in a group format (information days and field days) or farm visits compared with written information eg. newsletters. The greatest adoption of project results occurred in Bundaberg and Cudgen where the bulk of the project work, information days and grower visits occurred. Importantly, these are the two regions where the industry is concentrated. This has important implications for dissemination of research results showing that an over reliance on written reporting (final reports, farm notes, internet etc) severely limits adoption. The question of risk management in adoption of project results must also be considered. Sweetpotato is the primary income source for Bundaberg and Cudgen growers whereas it is a secondary income source for Mareeba growers and it is surmised this also influenced adoption rates between the areas.

When asked if they had made any growing practice change in the last 3 to 4 years the majority of changes had been made by Bundaberg and Cudgen growers in the project study areas of PT material, fertiliser and the non project study area of irrigation. Growers attributed DPI&F's greatest influence had been on fertiliser and PT adoption. Mareeba growers indicated they had only made some change in fertiliser additions as a side dressing and considered DPI&F had no influence. Again it suggests these results reflect the more active involvement of project officers in other regions and the fact that Mareeba growers consider sweetpotato a secondary crop (after fruit tree crops).

It was interesting to find that by 2005 over 50% of growers had started obtaining planting material from other growers rather than relying on their own commercial plantings (2002). It is surmised this was due to growers trying to obtain planting material from crops that were as close to PT material as possible. The influence of virus was also reflected in the uptake of PT material over the project. Only 20% of growers used PT material in all regions in 2002 whereas in 2005 all growers surveyed in Bundaberg and Cudgen used PT material. Again Mareeba was the exception (no grower was consistently using PT material).

The decrease in average plant spacing by Bundaberg and Cudgen growers over the project period is intriguing. Project work (inconclusive due to pest pressure) suggested that for

Beauregard there was no gain in decreasing plant spacing. From talking to growers it appears that growers are using plant spacing to manipulate the maturity of Beauregard. Certainly the Best Management Options work (Chapter 5) showed that by increasing plant spacing from 30 to 60 cm Beauregard matured much earlier, but with a potential yield loss due to the wider spacing. The opposite of this of course is to decrease plant spacing to so as to lengthen time to maturity; a practice some growers in Bundaberg have started to adopt.

Although irrigation was not part of the current project, irrigation questions were asked in both surveys to gain basic industry agronomic information. The change in irrigation methods over the course of the project was quite amazing. In 2002, all growers in all regions were using sprinkler irrigation at planting. During crop growth growers in Cudgen and Mareeba continued with sprinklers whereas in Bundaberg the majority of growers changed to travelling winch. Travelling winch was used by Bundaberg growers as it was perceived the most efficient to water the large areas being grown and the technology was widely adopted in the district (sugar cane industry). By 2005, all Bundaberg growers and 60% of the Cudgen growers surveyed had changed to trickle irrigation. It is likely the initial adoption of trickle irrigation was driven by water savings and then by growers fully realising the increased management options trickle gave them in sweetpotato production.

The response to monitoring irrigation was itself enlightening with growers basing when to irrigate on experience. A number of growers had trialled water measuring devices eg. tensiometers and Enviroscan after adopting trickle irrigation, however, no one had taken up the technology.

In 2003, a separate HAL funded DPI&F project had begun with one of the aims looking at the physiology of planting material and method of planting. The apparent success of this projects results were also captured in this survey with 60% of Bundaberg and 40% of Cudgen growers changing to flat planting compared to a V plant. Flat planting will be a major recommendation of this project.

The response to soil and plant tissue testing again yielded interesting results. The majority of growers carried out soil testing with an increase over the period of the project. By project end some growers were testing every block before planting sweetpotato. Certainly one of the recommendations of the project is for growers to carry out frequent soil testing particularly in relation to nitrogen use. However, the results for plant tissue testing (sap and leaf) were very different with the majority of growers not using plant tissue testing. When asked why? Growers considered it an unreliable decision making tool basically a “waste of money”. Results from this project would not support this comment certainly in relation to nitrogen and potassium leaf analysis.

Of all the responses to the survey perhaps the most pleasing to project officers was the change in fertiliser use by growers. A major recommendation from the project was that growers should not use more than 100 kg ha^{-1} of N (nitrogen) and need not use more than 180 kg ha^{-1} K (potassium). The results in table 6.2 show that in Bundaberg N and K use dropped by 42 and 28% respectively and by 20 and 50% in Cudgen. Mareeba showed no change in N usage and an increase in K. Results for Bundaberg and Cudgen also show growers should be careful not to reduce N and K application any further, as average basal amounts are starting to reach levels where deficiencies could be encountered (depending on soil levels). Reduction in P application in Bundaberg and Cudgen is thought to be due to change in fertiliser make up to achieve lower N and K levels and grower understanding that sweetpotato does not require large amounts of P.

Over the course of the project industry market specifications changed dramatically. The two major retailers (Woolworths and Coles) adopted stringent product specifications. This influenced not only the way growers graded their product but also the method the project team used to grade trials. The project team adopted the Woolworths product specifications as their grading standard. It was this adoption that assisted in our understanding of how virus affected sweetpotato shape and consequently grower pack out (reported elsewhere). By 2005 retailer quality demands were having their biggest impact in Mareeba and Cudgen. The majority of Bundaberg growers did not consider the quality demands a serious issue reflecting their rapid adoption of new management practices eg. PT material, trickle irrigation, planting methods and fertiliser addition.

Critical issues did not change greatly over the project period with the most critical issues perceived by growers being pests and virus in both surveys. It is considered that this project has answered many of the virus and fertiliser issues for growers, pests especially soil insects will be studied in the next HAL funded sweetpotato project.

7. PROJECT TECHNOLOGY TRANSFER

The basic principle underlying the project was, not only that the project must find answers to questions posed, but also, that industry should adopt the answers for the project to be considered successful. Adoption of research results is in the domain of adult learning. Adult learning studies point out that there is no one preferred method adults use to source information. To maximise adoption a suite of technology transfer methods were used during the course of the project, these are outlined in this report.

Methods used were:
1. On farm variety evaluations
2. Media news releases
3. Farmnotes
4. Newsletter
5. Visit by Dr Mike Cannon Louisiana State University
6. PT scheme/Farm visits
7. Information sessions

1. On Farm Variety Evaluations

Objective of the evaluations was threefold:
a) Carry on varietal evaluation from project VG 9702
b) Demonstrate advantages of pathogen tested planting material
c) Involve industry (growers) in evaluations

Evaluations were carried out at Mareeba in far north Queensland, Bundaberg in South East Queensland and Cudgen northern NSW. At all technology transfer events handout material was given to participants.

Year	Objective	Technology Transfer Methodology
2002	Evaluate 10 DPI&F selections including Pathogen Tested (PT) material and grower selections	**Mareeba:** Project team harvested trial and evaluated treatments using weight grading system. On farm presentation made on growers' property. **Bundaberg**: Project team harvested trial and evaluated using weight grading system. Key growers invited to evaluate selected treatments using commercial system being introduced by major customers. In shed presentation made at cooperating growers' property.
2003	As for 2002	**Cudgen:** Project team harvested trial and evaluated using commercial grading system. Field walk carried out followed by presentation in Agribusiness shed.
2004	Evaluate non PT grower Beauregard selections and DPI&F PT Beauregard line	**Bundaberg**: Project team harvested trial and evaluated using commercial grading system. Results analysed and included in 2005 technology transfer presentations.
2005	AS for 2004 but grown during different time of year (Bundaberg) and location (Cudgen)	**Bundaberg**: Project team harvested trial and evaluated using commercial grading system. Field walk carried out followed by in shed presentation. **Cudgen**: Project team harvested trial and evaluated using commercial grading system. Results presented as information session at leagues club.

2. Media News Releases

The following media outlets were utilized during the course of the project to highlight RD&E project results.

- Bundaberg Fruit and Vegetable Growers newsletter (regional coverage)
- ABC radio (regional)
- Growcom Fruit and Vegetable News (industry publication)
- Vegetable News (Vegetable IDO newsletter funded by Growcom and Horticulture Australia)
- Good Fruit and Vegetable Magazine (national)
- DPI&F media liaison section (target all regional newspapers and state)

3. Farmnotes

Web based, downloadable written information notes managed by DPI&F communication and information section (http://www.dpi.qld.gov.au/thematiclists/1198.html)

Farmnotes have a long term life cycle as they are updated by DPI&F communication processes. Farmnotes written as part of the project are:

1. Sweetpotato varieties: Beauregard
2. Sweetpotato seedbeds: producing sprouts as planting material
3. Pathogen tested planting material: Production of pathogen tested sweetpotato planting material
4. Soil and plant analysis: interpretations for sweetpotato var. Beauregard

4. Newsletters

Six editions of the "Sweetpotato Newsletter" have been produced during the course of the project (April 2002, August 2002, April 2003, January 2004, January 2005 and October 2005). The newsletter is distributed to all Australian states with a distribution list of 149 growers and 32 Market merchants, Retailers and Agribusiness.

5. Visit by Dr Mike Cannon Louisiana State University

In December 2002 Dr Mike Cannon from the Louisiana State University visited Australian sweetpotato production districts funded in part by this project. The aim of the visit was to give growers, researchers and re-sellers involved in the Australian industry the opportunity to gain valuable insights into a large mechanised sweetpotato production system. The US industry since 1999 had moved to the use of pathogen tested (PT) planting material with all growers finding major benefits from the use of PT material.

In the three sweetpotato production areas of Mareeba, Bundaberg and Cudgen Dr Cannon visited selected farms and delivered a presentation at the following information sessions:

- 9/12/2002 Cudgen leagues club
- 11/12/2002 Bundaberg DPI&F conference room
- 13/12/2002 Mareeba DPI&F conference room

6. PT Scheme/Farm Visits

As reported in the survey section of this report in 2002 only 20% of growers were using PT material every year, 25% had never used PT material with the remainder using PT material infrequently. There were a number of reasons for this poor uptake and they are reported elsewhere. In the first year of the project a decision was made for project staff to visit as many farms as possible in the major production areas of Bundaberg and Cudgen. The reason for this was twofold, firstly to find out growers' experience on the use of PT material and secondly to hand deliver foundation seed roots to interested growers and highlight advantages of PT material on one is to one basis.

In 2003, farm follow up visits and delivery of foundation seed roots was carried out on key growers' properties with some roots posted to growers. In 2004 on farm delivery was reduced with an increase in postage of roots to growers. By 2005, growers in Bundaberg were given the option of picking up roots from DPI&F or having them posted. For all other regions foundation seed roots were posted to growers.

7. Information Sessions

Information sessions are defined as sessions which involved large numbers of growers, in an off farm environment usually a dedicated meeting room (as distinct from on farm activities).

Date	Venue	Content Presented
May 2002	Gatton DPI&F meeting room	Sweetpotato nutrition First grower survey report Market evaluation report Insect management Development of industry R&D priorities
November 2003	Bundaberg DPI&F meeting room	First year nutrition trials Variety trials
December 2003	Cudgen Leagues club	First year nutrition trials Variety trials
July 2003	Mareeba	Seedbeds Nutrition
May 2004	Bundaberg Research Station	Development of Australian Sweetpotato Industry Group
October 2004	Cudgen leagues club	Second year nutrition trials Seedbeds
December 2004	Bundaberg DPI&F Research Station	Second year nutrition trials Seedbeds
July 2005	Bundaberg DPI&F Research Station	All nutrition trials Best management options trials Irrigation
August 2005	Cudgen leagues club	All nutrition trials Best management options trials Irrigation
September 2005	Mareeba	Best management options trial Summary of project results

Impact and Adoption

If meeting attendance is a measure of impact and adoption then the technology transfer activities would be rated as extremely successful with 70% to 80% of growers in each region attending events. However, a more realistic measure of adoption would be to survey growers. As reported elsewhere surveys were conducted at the beginning and again at the completion of the project. That the technology transfer methodology was successful is shown by the following (taken from the survey final report).

'It was pleasing to note that all growers (except one Mareeba grower) in 2005 indicated they were aware of the results of the project. Not unexpectedly, growers became most aware of project results through direct project officer contact either in a group format (information days and field days) or farm visits compared with written information eg newsletters. As discussed later the greatest adoption of project results occurred in Bundaberg and Cudgen where the bulk of the project work, information days and grower visits occurred.'

8. Conclusions and Recommendations

Key outcomes from the project were use of Pathogen Tested (PT) planting material, nitrogen and potassium usage, importance of soil, plant and tissue testing and grower preference for hands on activities to maximise learning.

It is recommended that growers introduce PT planting material yearly into their farming systems and avoid using planting material that is more than three generations removed from PT status.

For cv. Beauregard it is recommended that on low N soils (<5 mg kg^{-1} NO_3-N) a maximum 100 kg ha^{-1} N be used. Growers need to recognise that sweetpotato is in essence a perennial plant that is being grown as an annual. The suggested N rate is an optimal developed under experimental conditions but the rate should be used in conjunction with soil testing and the rate modified accordingly. Growers should only add half of the total N at planting and delay any further applications until 8 weeks after planting. Growers need also be aware of environmental influences on efficiency of N applications (eg. excess rainfall, and, the time taken between application at ground preparation and planting). For cv. Northern Star the timing and quantity of N applied is even more critical as problems with cracking appear to be related to N application rate and or timing.

The K requirements for cv. Beauregard appear lower than that reported in the literature and it is suggested that 150 kg ha^{-1} is adequate for growth. Unlike N, higher application rates of K were not detrimental to growth but will increase K soil reserves.

Soil and plant analysis should be promoted within the industry as they are useful tools in making informed fertiliser application decisions. The critical leaf N% for cv. Beauregard is in the range of 4.2% to 4.5%.

To maximise grower learning it is strongly recommended that wherever possible face to face contact be incorporated into delivery of research results.

Commercial activities to enhance adoption of the outcomes of the project would be the trialling of split applications of N utilising fertigation through trickle lines combined with monitoring of soil N levels post planting.

For all future sweetpotato experimentation it is recommended that yield evaluation be based on the shape based grading scheme developed in this project. Furthermore, the PT status of planting material needs to be closely monitored as high disease levels in planting material has the potential to confound results and give high variability. The specificity of the cv. Beauregard for different rates of N and the crucial nature of timing also suggest that future cultivar evaluations need to consider the strong genetic influence that exists in the agronomy of sweet potatoes.

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Appendix 1

HAL Market Evaluation Report – Eric Coleman

Retail buying preferences surveyed and evaluated

Principal outcomes

Retail outlets

The evaluation of retail outlets showed that a large proportion of sweetpotatoes in retail outlets at the time of the survey were defective. The largest proportion of the defects encountered was due to poor shape. This poor shape was in the form of root elongation ribbing and bulbing (thin at one end and large at the other).
An evaluation of root size against a common retail specification revealed a high proportion of the sweetpotato on display was in the small size range.
Approximately one-fifth of stores had red skin sweetpotato on display with even fewer carrying lines of white sweetpotato.
There was virtually no point of sale or promotional material available in store for consumers, and labelling of categories was quite confusing with many stores describing gold skin, gold flesh sweetpotatoes as red.

Retail buyers

Retail buyers when surveyed all agreed improvements in root quality improved sales dramatically. These buyers have seen large increases in the size of the sweetpotato market in the last ten years and attribute a lot of this increase to improvements in uniformity particularly with the introduction of the variety Beauregard.
The retailers saw a reduction in the amount of small and elongate roots as very important. Size and shape were noted as issues that hold back the sales of the product in today's market. One major retailer cited a recent trial they had conducted that showed tightening their specification had improved sales dramatically.
Other retailers also made comments on quality and a number have found that regular turnover ie level of freshness on the display had a major impact on their sales.
Due to the often-high level of defective sweet potatoes in a carton retailers often regrade the produce in their premises and bag up smalls and off types as specials to improve the appearance of their premium loose display.
Very little was mentioned about promotion and market research into buyer preferences and other issues that may be used to further promote sweetpotato. Retailers had a very poor knowledge of sweetpotato varietal characteristics and correct storage and handling conditions for sweetpotato.
Some independent retailers found sweetpotato packaging a problem and complained of bottoms coming out of boxes when carrying them.

Wholesalers and agents

A number of wholesalers interviewed wanted information on new varieties and saw supplies of clean rootstock as a way of helping their growers to improve quality and consistency.

The wholesalers interviewed saw continuous supply of quality product as the industries biggest weakness. Most wholesalers were interested in any agronomic changes that could improve quality and wanted to help in dissemination of information to growers where they could.

Merchant/wholesaler understanding of varieties and storage and handling conditions for sweetpotatoes was limited. Most were not interested in new varieties but more in improving the quality of the current gold line.

Implications for project research

This initial evaluation clearly shows that consistency particularly of shape and size is the main area for improvement. Any agronomic work therefore needs to have a clear focus on improving marketable size and shape. Improvements in plant stock, irrigation, nutrition, root initiation and factors that influence root initiation are all agronomic issues that may contribute to the quality issues found in this study.

Although there was interest at the retail and wholesale level in new varieties this did not seem to be a burning issue.

HAL Market Evaluation Report

Retail buying preferences surveyed and evaluated

Summary

The buying preferences of retailers and an evaluation of the retail display and presentation of sweetpotatoes was conducted by:

- Surveying retail sweetpotato displays
- Interviews with market agents and pre-packers
- Interviews with retailers.

Retail Evaluation

The objective of this investigation was to improve understanding of retail buying preferences and to assess the quality of produce on sale. This information will, when combined with agronomic survey information help the project team to determine what agronomic practices/research is needed to improve sweetpotato quality and hence increase product sales.

Project Evaluation

Evaluation of retail displays has been used to quantify the quality issues that are prevalent at the consumer retailer interface. Where these defects can be linked to production issues, the project team can focus research activities on addressing these issues in the production phase.

At the end of the project a further evaluation will help the project team to quantify any change at retail level that may have arisen from the work conducted during the life of the project.

HAL Market Evaluation Report

Retail buying preferences surveyed and evaluated

Introduction

Sweetpotato is available on the Australian domestic market for 12 months of the year. Current Australian production is estimated at approximately 16000 tonnes with the main production area Bundaberg producing approximately 7000 tonnes.
The Market is dominated by the bronze skin gold flesh variety Beauregard, with a number of red skin and white skinned varieties available in variable quantities throughout the year. The market for sweetpotatoes has increased dramatically in recent years and exact reasons for this increase have not yet been quantified.
Quality of sweetpotato on the Australian market is often inconsistent and further agronomic research is aimed at addressing some of these issues.
The aim of this evaluation was to quantify some of these quality issues at the start of a four year research project to help target project research in key areas. This evaluation will also provide a quantifiable means of measuring the projects impact at the consumer level at the project conclusion.

Method

Retail buying preferences were surveyed by conducting point of sale evaluations of retail displays and by interviewing retailers and wholesalers to gauge their perception of issues that affect quality.
In the last week of Nov 2002 52 stores in Sydney and Melbourne were visited and displays evaluated. The aim of the evaluation was to objectively measure the level of defects, the size of the roots and the shelf space taken up by sweetpotatoes. The evaluation was based on a retail specification being used by a major retailer. The sweetpotatoes were grouped into 4 sizes:

- **Undersize** (less than 130mm long and/or diameter less than 50mm)
- **Small** (length 130-180mm and/or diameter 50-60mm)
- **Medium** (length 180-250mm and/or diameter 60-75mm)
- **Large** (greater than 250mm long and/or diameter greater than 75mm)

Defect categories used were:

- **Shape** (included long thin, ribbed, bulbed, bent)
- **Mechanical damage** (breaks, cuts, and skinning)
- **Insect damage**
- **Old/Aged**
- **General** (skin blemishes such as nematodes and scurf)

It must be noted that this evaluation provides a measurement of market performance at a single point and has not been conducted over an extended length of time. At the time of the survey there were no specials running or promotional activities across and group or chain that may bias the results.
The store evaluations used a rating based on the percentage of defects and the percentage of the various size categories on display.

Results

Retail Evaluation

The retail evaluation figures were combined for gold sweetpotatoes and weighted to allow for variations in display size. Therefore all results presented are as a percentage of total shelf space surveyed.
Results were not calculated for the white and red categories as not enough displays were seen to generate meaningful data for these categories.
Data has been broken into two key groups ie chain stores and retail stores. This was done to gain a better understanding of these individual retail segments.
Figure one compares the size of sweetpotatoes on display in chain and independent stores.

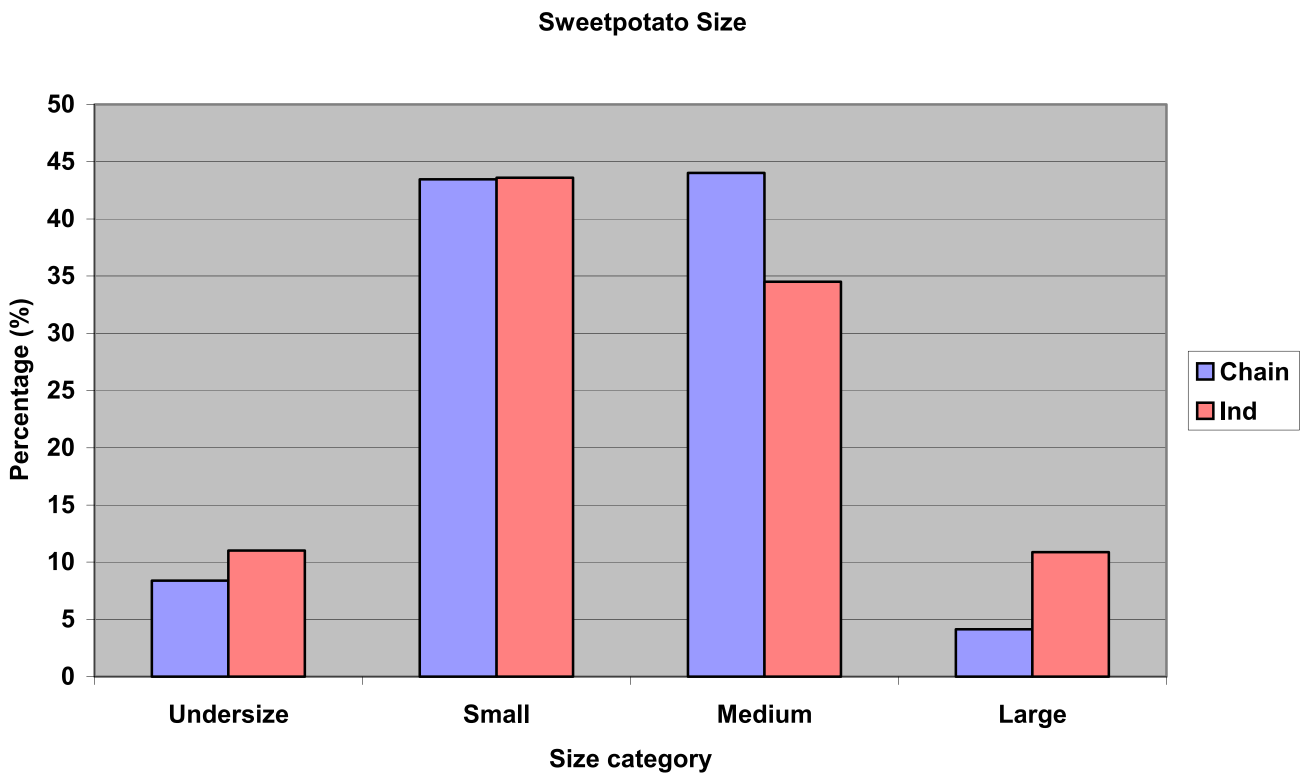

Figure 1. Differences in size of sweetpotato on display in chain and independent stores

Figure two gives a comparison of defects and good quality sweetpotatoes (ie. sweetpotatoes that meet the specification given in the method) in chain stores and retail stores.

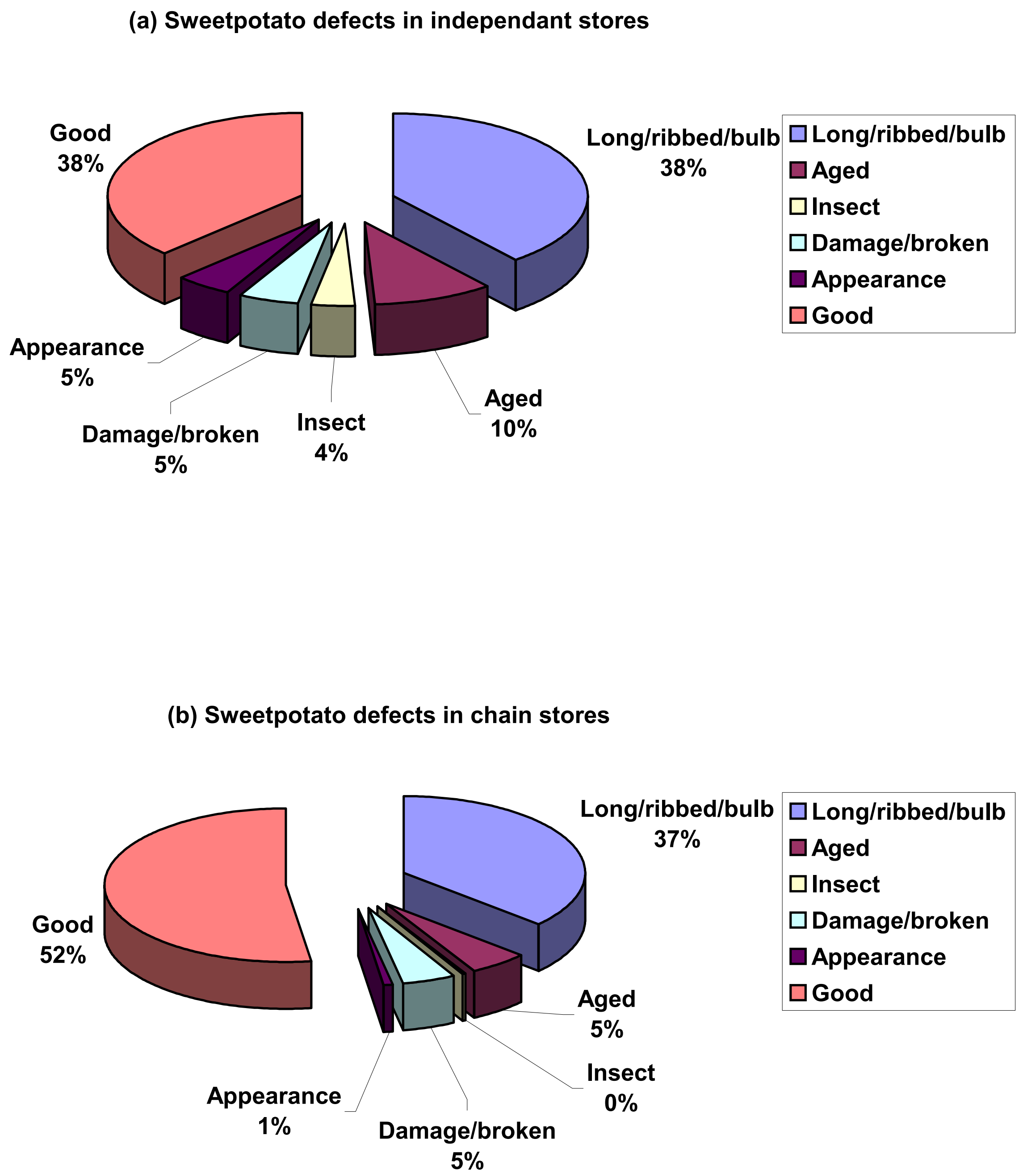

Figure 2. Percentage of sweetpotato defects for (a) independent, (b) chain stores.

Discussion

Marketing issues

This survey of sweetpotato buying preferences clearly indicates that a large proportion of sweetpotato available at the retail level was either small or exhibited characteristics of poor shape. These observations raise a number of questions that directly relate to sweetpotato marketing.

How are sales affected by sweetpotato shape?

Although documented consumer research is not available for sweetpotato previous market assessments (Lewis 1994, Market Equity 1999) of consumer perceptions of potatoes, show that smooth even shape is important for preparation especially for peeling.

Major retailers have set specifications that preclude bent, long thin, and ribbed sweetpotatoes. Retailers interviewed were conscious of consumers wanting product that is easy to peel and prepare. Thin, long, bent and deeply ribbed product does not obviously fit into the retailer's perception of what consumers are looking for. Some retailers also attribute increasing popularity of sweetpotato to even smoother product due to the variety Beauregard compared to old varieties such as NC-3.

Another way to gauge consumer perception of shape is to look at what is left behind. When consumers purchase vegetables from a loose display they are performing the final quality control check and therefore it is entirely possible they are removing the better grade and leaving the defects they don't like behind.

What size sweetpotatoes do consumers prefer?

As with shape major retailers have set a size specification based on recent experience. Even though different consumers will have different uses and may buy sizes to suit a particular purpose most retailers find small sweetpotatoes are left behgind on displays and are often then bageed and discounted heavily to remove them. Once again specific quantifiable evidence of consumer preferences for sweetpotato size in the Australian domestic market does not exist.

Why is there such a high level of defective product on display?

The high level of defect product on the display at the time of this evaluation can be attributed to one or a combination of the following:

- This is what is left after the consumers have taken what they like
- Retailers are not removing defective product from displays regularly
- A large proportion of sweetpotato being packed at the time of the survey was defective.

Observations made suggest that the later issue was the root cause. Inspection of product quality in 2 major growing districts the week before the evaluation and at the central markets the same week of the evaluation showed that large quantities of product on the market at this time had poor shape and were small. Observations in stores of freshly filled displays also revealed that on the majority of occasions product being tipped onto displays exhibited these characteristics when displays were being filled. The level of old material on the display does show that stock rotation is not as good as it could be particularly in independent stores.

Research development and extension issues

The large amount of small and defective sweetpotato in retail outlets needs to be addressed at a number of points in the supply chain:

- During production (ie in the growing phase)

- At harvesting and packing
- Management of retail displays

The high level of poorly shaped and small roots present on the market at the time of the evaluation needs further investigation in relation to it's affect on consumption. If as suggested by retailers the affect of this poorly shaped produce on display is as detrimental to sales as they suggest then there is a major opportunity to increase the consumption of sweetpotato by improving shape and size through new and improved agronomic practices.

At the farm level we already know that at various times during the season as much as 40% of harvested crop is discarded due to various defects. To reduce these defects changes in agronomic practices that improve size, uniformity of shape and generally improve appearance of sweetpotatoes must be a priority.

Other defects such as mechanical damage, insect damage and appearance due to skin blemishes were not seen in large quantities at the time of this survey. This does not mean that some of these other issues do not need addressing as this may be due to timing and removal of these defects when packaging. Results of an agronomic survey will hopefully provide direction on other agronomic issues that affect marketable yield at the packing shed.

The level of Aged stock does not appear to be an on-farm issue with market and in-store inspections of boxed product always exhibiting fresh firm produce.

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Appendix 2.1

Sweetpotatoes
Producing pathogen tested sweetpotato planting material

Bill O'Donnell, Scott Boreel, Eric Coleman, John Maltby and Stephen Harper, Department of Primary Industries and Fisheries, Queensland.

On this page:

Introduction

Sweetpotatoes are highly susceptible to virus and virus like diseases that reduce crop vigour and marketable yield. The major diseases are sweetpotato feathery mottle virus (SPFMV) and sweetpotato little leaf disease (SPLL). Viruses are spread by aphids and through infected planting material.

To provide growers with a source of low disease plant material each year the Department of Primary Industries and Fisheries (DPI&F) produces pathogen tested foundation seed roots for sprout production. The mother material for seed root production is maintained by DPI&F in a germplasm bank of disease free tissue cultured sweetpotato plantlets (Figure 2). Currently there are 40 accessions in the collection.

Producing mother material is a detailed process requiring a number of controlled steps. This DPI&F Note outlines the steps involved.

Collection of propagative material

Material is collected within Australia from commercial sweetpotato crops, and also imported as sweetpotato plants or tissue culture material under the control of the Australian Quarantine and Inspection Service. Irrespective of how propagative material is obtained it is subjected to the same steps to eliminate disease.

Heat treatment

Collected material is first grown in pots for 6 to 8 weeks to establish an actively growing plant. The plant is then subjected to heat treatment in a growth cabinet (Figure 1) for 7 weeks during which time the virus is eliminated or greatly reduced.

The heat treatment schedule is as follows:

1. plants are held at 25°C for 7 days
2. plants are then held at 29°C for 14 days
3. plants are then held at 39°C for 28 days.

The heat treatment is severe on plants and death of plants particularly during the 39°C treatment is not uncommon.

Figure 1. Plants in growth cabinet undergoing heat treatment

Plantlet production

After heat treatment tips are cut from the shoots that have grown. The apical meristem (growing point of the shoot tip) is viewed under a microscope and a section of about 20 cells is excised and placed in nutrient media. The media is kept in a controlled environment room for approximately 8 weeks until a plantlet (Figure 2) is produced.

Figure 2. Plantlets

Grafting

When the vine is 3 to 5 mm in diameter the plantlets are potted and grown in a minimal disease glasshouse. Plants are grown until a shoot is big enough to be grafted onto a virus indicator plant (Figure 3). *Ipomoea setosa*, a species closely related to sweetpotato, is used as the virus indicator plant because it vividly displays foliar symptoms of infection caused by sweetpotato viruses and virus-like diseases.

It is possible for a heat treated plant to have traces of virus present in different shoots from the same plant, so grafting multiple shoots improves the chances of detecting a positive virus infection. Virus symptoms appear as vein clearing, distortion and mottling in the leaves of the grafted plant.

Figure 3. Sweetpotato graft on *Ipomea setosa*

The grafted material is examined regularly for 2 to 6 weeks after grafting and compared to a control, non-grafted plant. If the grafted material shows positive for virus symptoms the whole process of heat treating and grafting is repeated until no virus symptoms are expressed. The grafted shoot is then removed, propagated by tissue culture and placed in the germplasm bank.

Plant material entering the country through quarantine is also examined by a virologist, serologically evaluated using the Elisa technique and checked for virus particles using electron microscopy.

Germplasm bank

Every 2 to 3 months the tissue cultured plant material in the germplasm bank is divided into single node stem sections and propagated in nutrient media to retain plant vigour. Five of the new plantlets are kept to provide mother plants for further multiplication when needed.

Vegetative planting material

Each year the mother plants of the main commercial varieties in the germplasm bank are divided into single node cuttings and tissue cultured to produce about 150 to 200 plantlets. These plantlets are planted into large containers of potting mix in an aphid proof shadehouse that prevents infection from insect transmitted viruses. The plants are then grown to provide vegetative planting material (Figure 4). Cuttings from these plants are planted into the field and grown to produce the pathogen tested foundation seed roots that are sold to growers.

Figure 4. Vegetative planting material in aphid proof shadehouse

DPI&F information and services

- To access DPI&F's information and services, Queensland residents can contact the **DPI&F Call Centre** on **13 25 23** for the cost of a local call. The Call Centre is open 8 am to 6 pm Monday to Friday (excluding public holidays); E-mail callweb@dpi.qld.gov.au. Non-Queensland residents phone (07) 3404 6999.

- This Note is also published on the DPI&F's PrimeNotes CD-ROM .

- Other horticultural information is available on the Horticulture home page.

Appendix 2.2. Experiment details

Experiment Site	Mareeba A (Grower site)	Mareeba B (Grower site)	Bundaberg Varieties (Grower site)	Cudgen evaluation 2003 a pathogen tested non-pathogen tested comparison (Grower site)	Bundaberg evaluation 2004 a pathogen tested non-pathogen tested comparison (Research Station)	Bundaberg evaluation 2005 pathogen tested comparison (Research Station)	Cudgen evaluation 2005 pathogen tested comparison (Grower site)
Experiment Type	Variety evaluation	PT non PT comparison plus variety evaluation	PT non PT comparison plus variety evaluation	PT non PT comparison plus variety evaluation	PT non PT Reselection comparison	All PT grower selections	All PT grower selections
Longitude	145°23'E	145°23'E	152°20'E	153°33'E	152°20'E	152°20'E	153°33'E
Latitude	17°00'S	17°00'S	24°52'S	28°17'S	24°52'S	24°52'S	28°17'S
Altitude	406m	406m	14m	20m	14m	14m	20m
Date Planted	26/04/02	14/05/02	12/03/02	08/01/03	28/01/04		19/01/05
Date Harvested	09/10/02	24/10/02	12/11/02	27/07/03	15/06/04	12/07/05	02/08/05
Growing Days	166	163	245	200	139		196
Plot size	1 x 3m row 1.32m inter-row	1 x 3m row 1.32m inter-row	2 x 3m rows 1.47m inter-row	2 x 3m rows 1.4m inter-row	2 X 3m row 1.5 m inter-row	2 X 2.7m row 1.5 m inter-row	1 x 2.1m rows 1.4m inter-row
Plant spacing	30cm	30cm	30cm	30cm	30cm	30cm	30cm
No plants / plot	20	20	22	22	20	18	7
Plant density/ha	27778	27778	24943	26190	22222	22222	23809
Planting method	Vertical with stick	Vertical with stick	Vertical with stick	Vertical with stick	Flat plant by hand	Flat plant by hand	Vertical with stick
Trial Design	Randomised block 3 rep	Randomised block 3 rep	Randomised block 3 rep	Randomised block 3 rep	Randomised block 3 rep	Randomised block 3 rep	Randomised block 4 rep
Irrigation	Overhead solid set	Overhead solid set	Overhead travelling gun	Rainfall plus some Overhead	Trickle	Trickle	Rainfall plus some Overhead
Soil Type	Grey sandy soil	Grey sandy soil	Grey sand/clay duplex	Red Loam	Red Loam	Red Loam	Red Loam

Appendix 2.3 Data tables for experiments conducted using weight based grading system
Mareeba A Yield in tonnes ha^{-1}.

[1]Variety	Yield in tonnes per hectare <151g	151-250g	251-600g	601g-1Kg	>1Kg	Total	Marketable 251g-1Kg
DPI&F Beauregard	6.87	3.61	11.95	5.18	1.05	28.66	17.13
Darby (L87-59)	10.23	3.56	4.66	0.63	1.17	20.25	5.30
L86-33-Q5	11.50	4.33	7.30	2.31	0.66	26.10	9.61
L93-93-Q9	5.73	3.81	11.64	2.46	0.00	23.65	14.10
L93-93-Q14	13.83	7.42	5.33	1.21	0.00	27.79	6.54
L93-93-Q24	8.67	4.10	6.15	1.20	0.00	20.12	7.35
Northern Star	7.31	6.99	23.74	9.91	6.53	54.48	33.65
Q 95-3	8.88	5.40	12.71	4.66	1.38	33.02	17.37
WSPF	2.88	1.82	2.82	0.30	0.00	7.82	3.11
Hawaii	3.51	3.51	2.35	0.29	0.00	9.66	2.63
F value	**	**	**	**	**	**	**
LSD (P=0.05)	3.158	1.638	3.467	2.907	1.579	4.531	3.989

Mareeba A root numbers/plant

NS denotes not significant at P=0.05, * denotes significant at p=0.05 and ** denotes significant at p=0.01

Variety	Root number per plant <151g	151-250g	251-600g	601g-1Kg	>1Kg	Total	Marketable 251g-1Kg
Beauregard	4.35	0.68	1.10	0.25	0.03	6.42	1.35
Darby (L87-59)	8.88	0.65	0.48	0.03	0.03	10.08	0.52
L86-33-Q5	9.03	0.83	0.75	0.12	0.02	10.75	0.87
L93-93-Q9	3.90	0.68	1.22	0.12	0.00	5.92	1.33
L93-93-Q14	13.23	1.48	0.63	0.07	0.00	15.42	0.70
L93-93-Q24	6.15	0.78	0.65	0.07	0.00	7.65	0.72
Northern Star	3.73	1.28	2.25	0.45	0.20	7.92	2.70
Q 95-3	4.63	0.95	1.25	0.23	0.05	7.12	1.48
WSPF	2.12	0.35	0.30	0.02	0.00	2.78	0.32
Hawaii	2.92	0.65	0.22	0.02	0.00	3.80	0.23
F value	**	**	**	**	**	**	**
LSD (P=0.05)	2.832	0.307	0.331	0.146	0.044	2.665	0.342

NS denotes not significant at P=0.05, * denotes significant at p=0.05 and ** denotes significant at p=0.01

[1] All cultivars in Mareeba A experiment were PT no grower selections assessed

Mareeba B Yield in tonnes/hectare

Variety	Yield in tonnes per hectare <151g	151-250g	251-600g	601g-1Kg	>1Kg	Total	Marketable 251g-1Kg
[2]PT sprout Beau	11.83	7.34	16.51	6.85	1.57	44.11	23.36
[3]Nicolosi (Beau.)	9.89	9.28	16.86	6.37	1.31	43.70	23.23
[4]Sabin (Beau.)	9.03	6.75	20.45	4.07	1.32	41.61	24.51
Darby (L87-59)	12.55	11.66	18.27	2.62	1.26	46.36	20.90
L86-33-Q5	12.99	9.50	15.01	3.25	0.00	40.75	18.26
L86-33-Q7	0.81	0.81	0.72	0.00	0.00	2.33	0.72
L93-93-Q14	18.32	8.65	7.20	0.00	0.00	34.17	7.20
L93-93-Q24	9.69	8.23	10.18	0.94	0.00	29.04	11.12
Northern Star	8.10	11.97	28.94	18.12	8.39	75.52	47.06
Q 95-3	12.94	12.73	20.37	1.66	0.00	47.70	22.03
WSPF	8.51	5.70	3.73	0.00	0.00	17.94	3.73
Hawaii	8.76	2.80	5.15	0.00	0.00	16.71	5.15
F value	**	**	**	**	*	**	**
LSD (P=0.05)	4.70	4.98	11.66	4.54	4.50	16.56	11.77

NS denotes not significant at P=0.05, * denotes significant at P=0.05 and ** denotes significant at P=0.01

Mareeba B root numbers/plant

Variety	Root number per plant <151g	151-250g	251-600g	601g-1Kg	>1Kg	Total	Marketable 251g-1Kg
PT spout Beau	3.15	0.53	0.60	0.12	0.02	4.42	0.72
Nicolosi (Beau.)	2.88	0.68	0.65	0.13	0.02	4.36	0.78
Sabin (Beau.)	2.92	0.67	1.03	0.12	0.03	4.77	1.15
Darby (L87-59)	3.45	0.83	0.72	0.05	0.02	5.07	0.77
L86-33-Q5	2.88	0.70	0.60	0.07	0.00	4.25	0.67
L86-33-Q7	2.48	0.82	0.42	0.00	0.00	3.72	0.42
L93-93-Q14	4.93	0.63	0.33	0.00	0.00	5.89	0.33
L93-93-Q24	2.47	0.58	0.38	0.02	0.00	3.45	0.40
Northern Star	1.67	1.18	1.35	0.48	0.17	4.85	1.83
Q 95-3	2.55	0.92	0.75	0.03	0.00	4.25	0.78
WSPF	3.38	0.60	0.23	0.00	0.00	4.21	0.23
Hawaii	2.43	0.22	0.20	0.00	0.00	2.85	0.20
F value	**	*	**	**	NS	NS	**
LSD (P=0.05)	1.14	0.40	0.44	0.16			0.50

NS denotes not significant at P=0.05, * denotes significant at P=0.05 and ** denotes significant at P=0.01

[2]PT Veg tip Beau was a treatment of pathogen tested Beauregard terminal vine cut from a whole plant as opposed to the PT sprout Beau that was also a pathogen tested Beauregard terminal vine but was produced from a seedbed i.e. a sprouted sweetpotato root planted in the ground.

[3] Nicolosi (Beau) is a grower selection from the Mareeba district

[4] Sabin (Beau) is a grower selection from the Mareeba district

Bundaberg 2002 Yield in tonnes/ha

Variety	Yield in tonnes per hectare <151g	151-250g	251-600g	601g-1Kg	>1Kg	Total	Marketable 251g-1Kg
PT Veg tip Beau	6.00	7.49	26.50	4.75	1.25	45.99	31.25
PT Sprout Beau	6.67	10.19	26.18	8.54	0.82	52.40	34.71
[5]Local long tip (Beau.)	6.15	12.27	25.23	2.53	0.38	46.55	27.76
[6]Local short tip (Beau.)	5.75	11.92	24.27	2.46	0.00	44.41	26.73
Darby (L87-59)	8.23	11.47	22.46	9.09	1.53	52.79	31.55
L86-33-Q5	10.26	14.75	14.30	0.51	0.00	39.82	14.81
L86-33-Q9	4.30	8.44	21.87	2.55	0.00	37.16	24.42
L93-93-Q14	20.46	7.09	0.00	0.00	0.00	27.55	0.00
L93-93-Q24	6.63	11.46	6.69	0.00	0.00	24.78	6.69
Northern Star	3.87	8.33	36.58	15.07	12.14	75.99	51.65
Q 95-3	4.65	11.33	26.57	2.80	0.39	45.74	29.37
WSPF	2.53	8.70	21.68	3.19	0.42	36.52	24.87
F value	**	NS	**	**	**	**	**
LSD (P=0.05)	2.50		7.03	2.93	2.07	8.96	8.22

NS denotes not significant at P=0.05, * denotes significant at P=0.05 and ** denotes significant at P=0.01

Bundaberg 2002 root numbers/plant

Variety	Root number per plant <151g	151-250g	251-600g	601g-1Kg	>1Kg	Total	Marketable 251g-1Kg
PT Veg tip Beau	_	1.85	3.12	0.26	0.05	5.27	3.38
PT Sprout Beau	_	2.30	2.91	0.44	0.03	5.68	3.35
Local long-tip (Beau.)	_	3.00	3.20	0.12	0.02	6.33	3.32
Local short-tip (Beau.)	_	2.76	2.89	0.14	0.00	5.79	3.03
Darby (L87-59)	_	2.62	2.42	0.50	0.05	5.59	2.92
L86-33-Q5	_	3.41	2.12	0.03	0.00	5.56	2.15
L86-33-Q9	_	1.92	2.64	0.15	0.00	4.71	2.79
L93-93-Q14	_	1.73	0.00	0.00	0.00	1.73	0.00
L93-93-Q24	_	2.89	0.86	0.00	0.00	3.76	0.86
Northern Star	_	1.76	3.55	0.83	0.41	6.55	4.38
Q 95-3	_	2.77	2.97	0.15	0.02	5.91	3.12
WSPF	_	1.97	2.11	0.18	0.02	4.27	2.29
F value		*	**	**	**	**	**
LSD (P=0.05)		1.05	0.90	0.19	0.09	1.31	0.96

NS denotes not significant at P=0.05, * denotes significant at P=0.05 and ** denotes significant at P=0.01

[5] Local long tip (Beau) is a grower selection from Moore park in the Bundaberg district
[6] Local short-tip (Beau) is a grower selection from Moore park in the Bundaberg district

Appendix 3.1. Mean total yield, marketable yield (MktYld), Total root no per plant, Marketable root number per plant (MktRt), mean yield across weight grades and root number per plant across weight grades for sweetpotato varietal trial grown at Redlands Research Station 2001-2 Harvest 1 (11 April 2002).

	Weight in tonnes per hectare						Root number per plant					
Variety	Total	MktYld	150-250g	250-600g	600g-1Kg	>1Kg	Total	MktRt	150-250g	250-600g	600g-1Kg	>1Kg
L93-9-16	44.8	28.7	5.2	22.5	6.2	3.5	7.5	2.6	1.4	2.2	0.3	0.1
L93-93 Line	53.7	32.0	12.6	28.9	3.1	0.0	10.4	3.2	2.7	3.0	0.2	0.0
Q95-3	52.9	33.2	7.8	20.7	12.4	5.2	7.8	2.8	1.6	2.1	0.7	0.2
WSPF	33.1	19.9	7.8	19.5	0.4	1.4	6.0	2.3	1.9	2.3	0.0	0.1
L87-59	58.6	41.7	8.4	29.1	12.6	3.4	7.4	3.7	1.7	3.0	0.7	0.1
L86-33-5	45.5	23.0	11.0	22.6	0.4	0.0	10.4	2.7	2.3	2.7	0.0	0.0
Hernandez	40.8	27.0	5.4	21.7	5.2	1.6	6.7	2.5	1.2	2.1	0.3	0.1
Beauregard	62.2	37.2	17.7	27.9	9.3	1.4	9.8	4.8	2.2	3.5	1.3	0.1
Northern Star	71.0	43.2	9.9	27.6	15.5	6.9	7.5	4.0	1.9	3.1	0.9	0.2
Significance	**	*	NS	NS	**	NS	**	**	NS	NS	NS	NS
lsd(P=0.05)	17.83	15.06	(F=0.13)	(F=0.72)	7.20	(F=0.07)	2.16	1.18	(F=0.16)	(F=0.18)	(F=0.07)	(F=0.07)

NS denotes Not significant at P=0.05, * denotes Significant at P=0.05 and ** denotes significant at P=0.01

Appendix 3. 2. Mean total yield, marketable yield (MktYld), Total root no per plant, Marketable root number per plant (MktRt), mean yield across weight grades and root number per plant across weight grades for sweetpotato varietal trial grown at Redlands Research Station 2001-2 Harvest 2 (9 May 2002).

	Weight in tonnes per hectare						Root number per plant					
Variety	Total	MktYld	150-250g	250-600g	600g-1Kg	>1Kg	Total	MktRt	150-250g	250-600g	600g-1Kg	>1Kg
L93-9-16	66.2	28.2	9.4	19.8	8.4	1.3	9.9	2.6	2.1	2.2	0.5	0.1
L93-93 Line	64.4	38.8	11.4	29.5	9.2	8.5	11.6	5.2	2.9	4.5	0.7	0.4
Q95-3	47.1	2.9	0.6	2.0	0.9	1.5	7.3	0.3	0.1	0.3	0.1	0.1
WSPF	16.1	1.5	0.0	0.0	1.5	0.0	1.4	0.1	0.0	0.0	0.1	0.0
L87-59	85.8	52.8	6.1	31.1	21.7	19.8	10.0	4.9	1.5	3.6	1.3	0.8
L86-33-5	57.6	35.1	12.6	28.4	6.8	0.0	11.9	3.9	3.1	3.5	0.4	0.0
Hernandez	50.5	33.6	8.1	21.0	12.6	1.0	7.8	2.9	1.5	2.3	0.7	0.0
Beauregard	59.2	40.6	4.3	23.6	16.9	6.4	6.3	3.4	1.0	2.5	0.9	0.2
Northern Star	73.5	44.7	4.3	26.0	18.6	21.8	6.6	3.7	0.9	2.7	1.0	0.5
Significance	**	**	**	**	**	**	**	**	**	**	**	**
lsd(P=0.05)	17.20	15.50	5.39	10.73	7.97	12.22	3.16	2.08	1.20	1.69	0.54	0.43

NS denotes Not significant at P=0.05, * denotes Significant at P=0.05 and ** denotes significant at P=0.01

Appendix 3.3. Mean total yield, marketable yield (MktYld), Total root no per plant, Marketable root number per plant (MktRt), mean yield across weight grades and root number per plant across weight grades for sweetpotato varietal trial grown at Redlands Research Station 2001-2 Harvest 3 (23 May 2002).

	Weight in tonnes per hectare						Root number per plant					
Variety	Total	MktYld	150-250g	250-600g	600g-1Kg	>1Kg	Total	MktRt	150-250g	250-600g	600g-1Kg	>1Kg
L93-9-16	84.1	55.1	9.9	33.8	21.3	11.4	11.4	2.1	2.1	3.8	1.4	0.4
L93-93 Line	75.6	51.4	14.3	37.9	13.6	0.7	12.6	3.0	3.0	4.2	0.9	0.0
Q95-3	65.9	43.3	10.0	35.0	8.3	3.0	11.0	2.2	2.2	3.9	0.5	0.1
WSPF	50.3	36.4	5.4	26.6	9.9	3.8	6.8	1.2	1.2	2.8	0.6	0.2
L87-59	95.3	56.5	4.3	33.4	23.1	31.1	9.1	1.0	1.0	4.1	1.4	1.1
L86-33-5	62.4	38.7	13.1	33.7	5.0	0.7	12.3	3.0	3.0	4.2	0.3	0.0
Hernandez	66.2	43.8	12.6	30.0	13.9	3.4	10.6	2.2	2.2	3.6	0.9	0.2
Beauregard	78.3	52.3	0.8	29.5	22.8	22.3	6.2	0.1	0.1	2.9	1.3	0.8
Northern Star	84.2	53.2	5.3	26.4	26.8	20.7	7.9	0.9	0.9	2.7	1.6	0.7
Significance	**	*	**	NS	**	**	**	NS	**	NS	**	**
lsd(P=0.05)	14.93	12.68	6.13	(F=0.34)	8.15	9.90	2.94	(F=0.46)	0.89	(F=0.31)	0.64	0.36

NS denotes Not significant at P=0.05, * denotes Significant at P=0.05 and ** denotes significant at P=0.01

Appendix 4. 1. Fertiliser forms and application rates (kg ha^{-1}) to achieve required N and K treatment rates at Bundaberg and Rockhampton 2003.

N treatment	K treatment	Urea	KNO3	K2SO4	Amm Sulf
50	50	23	129	0	101
50	100	78	103	134	0
50	150	39	233	134	0
50	200	0	362	134	0
100	50	132	129	0	101
100	100	93	259	0	101
100	150	62	362	22	101
100	200	108	362	134	0
150	50	240	129	0	101
150	100	202	259	0	101
150	150	170	362	22	101
150	200	217	362	134	0
200	50	349	129	0	101
200	100	310	259	0	101
200	150	279	362	22	101
200	200	326	362	134	0

Appendix 4. 2 Fertiliser forms and application rates to achieve required N and K treatment rates at Mareeba 2003.

N Rate (kg ha^{-1})	K rate (kg ha^{-1})	Urea (kg ha^{-1})	Muriate of Potash (kg ha^{-1})
70	80	22	10
70	140	22	130
70	210	22	270
140	80	174	10
140	140	174	130
140	210	174	270
210	80	326	10
210	140	326	130
210	210	326	270

NB The growers basal fertilizer application was 60 kg ha^{-1} of N and 75 kg ha^{-1} of K as Q5 and CK7.

Appendix 4. 3. Total, marketable (Mkt) and Cracked root yields (tonne ha^{-1}) for Beauregard (Beau) and Northern Star (NStar) at varying N rates for field trials grown at Bundaberg, Rockhampton and Mareeba 2003.

Nitrogen rate (kg ha^{-1})	Total (t ha^{-1})		Mkt (t ha^{-1})		Cracked (t ha^{-1})	
	Beau	NStar	Beau	NStar	Beau	NStar
Bundaberg						
50	31.2	55.2	17.3	25.4	0.0	8.8
100	31.5	58.1	18.0	26.0	0.0	12.5
150	34.2	60.3	21.7	19.4	0.0	23.1
200	33.6	57.5	20.0	15.5	0.0	24.3
	NS	NS	NS	*** lsd (p=0.05) = 4.79	NS	*** lsd (p=0.05) = 4.33
Rockhampton						
50	63.8	89.8	42.6	35.0	0.0	20.8
100	66.4	97.3	41.1	32.9	0.0	26.1
150	57.4	87.5	35.9	31.7	0.0	20.1
200	57.5	88.0	36.0	34.8	0.0	20.8
	NS	NS	NS	NS	NS	NS
Mareeba						
70	35.4	20.3	22.1	11.9	--	--
140	26.3	16.2	14.6	8.6	--	--
210	27.9	16.1	16.7	8.5	--	--
	** lsd (p=0.05) = 5.12	** lsd (p=0.05) = 2.66	** lsd (p=0.05) = 4.23	NS p = 0.061		

NS denotes not significant
*** significant at p =0.001, ** significant at p =0.01 and * significant at p =0.05

Appendix 4. 4 Forms of nutrients added to achieve nutrition treatments (kg ha^{-1}) in Bundaberg N and K response trials 2004.

Treat	N rate	K rate	Basal N	Basal K	Ammn Nitr	Pot Nitr	Pot Sulf	Amm Sulf	Total N	Total K	Total S
			40%	40%	40%	40%	40%	40%	40%	40%	40%
N1	0	180	0	72	0	0	176	0	0.0	72.2	31.7
N2	50	180	20	72	58.8	0	176	0	20.0	72.2	31.7
N3	100	180	40	72	117.6	0	176	0	40.0	72.2	31.7
N4	150	180	60	72	176.4	0	176	0	60.0	72.2	31.7
N5	200	180	80	72	235.2	0	176	0	80.0	72.2	31.7
N6	250	180	100	72	294	0	176	0	100.0	72.2	31.7

Treat	N rate	K rate	Basal N	Basal K	Ammn Nitr	Pot Nitr	Pot Sulf	Amm Sulf	Total N	Total K	Total S
			50%	100%	Basal	Basal	Basal	Basal	50%	100%	100%
K1	130	0	65	0	0	0	0	329	66.5	0.0	79.0
K2	130	60	65	60	65	0	146	220	66.5	59.9	79.1
K3	130	120	65	120	129	0	291	111	66.3	119.3	79.0
K4	130	180	65	180	195	0	439	0	66.3	180.0	79.0
K5	130	240	65	240	136	156	439	0	66.5	239.7	79.0
K6	130	300	65	300	76	313	439	0	66.5	299.9	79.0

Other Basal: 145 kg ha^{-1} triple super phosphate giving 30Kg P/ha and 21.75Kg Ca/ha
4.9 kg ha^{-1} solubor through trickle at planting giving 1Kg B/ha
4.5 kg ha^{-1} zinc sulphate heptahydrate giving 1Kg Zn/ha and 0.5kg S/ha
208 kg ha^{-1} magnesium sulphate giving 20Kg Mg/ha and 26Kg S/ha
769 g ha^{-1} sodium molybdate giving 300g Mo/ha

Side Dressing: N1-N6: N and K applied as 30% 5 weeks, 30% 8 weeks (3/4 of rates above)
Trickle K1-K6: N applied at 65 kg ha^{-1} at 5 weeks as 191Kg ammonium nitrate/ha

Appendix 4. 5 Raw fresh yield data for Bundaberg N nutrition trial 2004.

N Treatment (kg ha^{-1})	Yield (t ha^{-1})							
	Marketable	Total	Undersize	Small	Medium	Large	Seconds	Rejects
0	29.5	54.2	1.1	3.6	4.5	5.4	21.4	18.1
50	34.2	60.8	1.3	2.7	8.3	6.6	23.2	18.8
100	38.4	62.3	1.3	3.7	8.3	6.6	26.3	15.9
150	31.8	57.2	1.5	3.6	6.8	5.7	21.4	18.3
200	33.8	55.5	1.4	4.5	7.1	5.3	22.3	14.9
250	35.6	53.7	1.4	4.5	7.7	2.8	23.4	13.9
F value	NS	*	NS	*	*	NS	NS	NS
LSD (P=0.05)	6.18	6.12	0.99	1.08	2.49	3.56	5.78	5.15

NS denotes Not significant at P=0.05. * denotes Significant at P=0.05

Appendix 4. 6. Calculated dry Matter yield data for Bundaberg N nutrition trial 2004.

N Treatment (kg ha^{-1})	Total Yield (t ha^{-1})	Marketable Yield (t ha^{-1})	Dry Matter	Dry Matter Total Yield (t ha^{-1})	Dry Matter Marketable Yield (t ha^{-1})
0	54.2	29.5	22.5	12.2	6.6
50	60.8	34.2	21.9	13.3	7.5
100	62.3	38.4	23.4	14.5	8.9
150	57.2	31.8	22.1	12.6	7.0
200	55.5	33.8	23.2	12.9	7.8
250	53.7	35.6	22.4	12.0	8.0
F value	*	NS	NS	NS	*
LSD (P=0.05)	6.12	6.18	1.65	1.62	1.29

NS denotes Not significant at P=0.05. * denotes Significant at P=0.05

Appendix 4. 7. Soil and plant tissue data for Bundaberg N nutrition trial 2004.

N Treatment (kg ha^{-1})	% Leaf Tissue N	% Root Tissue N	Soil pre-plant N (mg kg^{-1})	Soil harvest N (mg kg^{-1})
0	4.44	0.83	0.050	0.54
50	4.55	0.78	0.049	0.69
100	4.75	0.96	0.049	0.89
150	4.77	1.22	0.049	1.27
200	4.90	1.29	0.049	1.04
250	5.15	1.46	0.049	1.26
F value	*	*	NS	*
LSD (P=0.05)	0.402	0.138	0.004	0.482

NS denotes Not significant at P=0.05. * denotes Significant at P=0.05

Appendix 4. 8. Raw fresh yield data for Bundaberg K nutrition trial 2004.

Treatment	Yield (t ha^{-1})							
K treatment (kg ha^{-1})	Marketable	Total	Undersize	Small	Medium	Large	Seconds	Rejects
0	38.6	53.9	3.0	6.8	9.1	3.1	22.8	9.1
60	39.0	56.2	2.9	9.0	10.8	4.4	19.1	10.0
120	43.6	62.8	3.3	7.2	13.3	7.6	23.1	8.4
180	40.0	64.7	3.5	6.0	13.7	6.5	20.3	14.7
240	38.5	59.0	2.5	6.1	11.9	6.5	20.4	11.5
300	42.4	64.8	3.7	8.4	12.4	5.2	21.6	13.3
F value	NS	*	NS	NS	NS	*	NS	NS
LSD (P=0.05)	7.18	6.09	1.60	3.95	5.98	2.78	5.00	4.95

NS denotes Not significant at P=0.05. * denotes Significant at P=0.05

Appendix 4. 9. Soil and plant tissue data for Bundaberg K nutrition trial 2004.

K Treatment (kg ha^{-1})	% Leaf Tissue K	Soil pre-plant K (mg kg^{-1})	Soil harvest K (mg kg^{-1})
0	2.31	40.96	37.87
60	2.96	39.73	53.21
120	3.18	40.71	66.40
180	3.36	40.75	83.64
240	3.43	43.95	102.41
300	3.53	41.74	114.66
F value	*	NS	*
LSD (P=0.05)	0.452	4.124	21.35

NS denotes Not significant at P=0.05. * denotes Significant at P=0.05

APPENDIX 6.1: 2002 Survey form

Improving sweetpotato agronomy to meet new market opportunities.

SURVEY

Grower Details - This information is for project records only

Name: ………………………………….

Region ………………………………….

If your contact details are different to that on the address used to mail the survey to you would you pleas add your new details below:

Contact details………………………………….

………………………………….

………………………………….

………………………………….

QUESTIONS

1. What do you consider are the 3 most critical issues in growing sweetpotatoes (eg virus, new varieties, nutrition, insects, diseases, irrigation, plant spacing, weeds)?

1. ……………………………………………………………………………………

2. ……………………………………………………………………………………

3. ……………………………………………………………………………………

Any others?……………………………………………………………………………………

……………………………………………………………………………………

2. Could you please enter the varieties you currently grow, areas grown and yield in the spaces provided?

Variety (if not shown please list)	Area (ac or ha)	Yield (cartons)
Beauregard		

3. **Could you please enter your planting and harvest times**

Planting Times(eg Oct - Dec) ⟶ C. Harvest Times

4. **What planting times do you achieve your (a) best results, (b) your worst results:**

(a) Your best results?……………………………………………………………………………….

(b)Your worst results?………………………………………………………………………………

Any ideas why?
…………………………………………………………………………………………

…………………………………………………………………………………………

5. **How do you obtain or propagate planting material (please circle)?**

   a) Use your own material

   b) Obtain from other growers

   c) Obtain virus free material from DPI
   IF you use virus free planting material from DPI how often do you obtain it?…………………………………………

   d) Other (please specify)……………………………………………………………

6. **What are your thoughts on the quality of your planting material?**

   - ………………………………………………………………………………………

7. **Could you now please supply some information on your current plant spacings.**

   - Bed width (wheel to wheel):……………………………………………………..
   - Plant spacing:…………………………………………………………………..

8. What is your current fertiliser program?

Base Fertiliser

- Type (eg CK 55S):…………………………………………………………………..
- Rate (eg kg/ha):……………………………………………………………………..

Side Dressing

- Type (eg calcium nitrate):…………………………………………………………….
- Rate (eg kg/ha):…………………………………………………………………….
- Timing (eg weeks after planting):……………………………………………………...

Trace elements

- Type (eg zinc sulphate):……………………………………………………………
- Rate (eg kg/ha):……………………………………………………………………..
- Timing (eg weeks after planting):……………………………………………………

9. Could you please indicate how often you use soil testing (eg never, after every crop, when a problem arises)?

- ……………………………………………………………………………………

10. Could you please indicate how often you use plant tissue testing (eg when a problem arises)?

- ……………………………………………………………………………………

11. If you use plant tissue testing can you please indicate if the laboratory tests whole plant tissue (ie leaves) or the sap after it is squeezed from the leaf petiole?

(a) Whole leaf (b) Sap (c) Not sure

12. If you use irrigation could you please indicate what irrigation equipment you use?

a) At plant establishment:……………………………………………………………….

b) During crop growth:…………………………………………………………………..

13. On average how much water would you use per hectare (per ac if you prefer)?

- ……………………………………………………………………………………

14. How do you monitor your irrigation requirements?

(a) Experience (b) Tensiometer (c) Enviroscan (e) C Probe (e) Other

MARKETING

15. What do you see as the critical factors in marketing your produce?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

16. Would you consider exporting (now or in the future)?

(a) Yes (b) No

17. What would you see as the major obstacle(s) to exporting your product?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

18. Are you currently supplying processor and if yes would you mind indicating why?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Are there any other comments you would like to make?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

THANK YOU FOR YOUR TIME IN COMPLETING THIS SURVEY.

Appendix 6.2: 2005 Survey

DPI&F Improving Sweet Potato Agronomy

Grower Name: ………………………… Area sweetpotatoes grown:………… (ac)…………(ha)
Date:…………….

1. **Cartons produced per year**

- ❑ Total Cartons Produced………………………….

- ❑ Average Yield (what grower thinks) …………………

2. **Varieties Grown & % total production**

- ❑ Beauregard % …………
- ❑ Northern Star % …………
- ❑ Other % …………(type……………..…)

3. **Grower awareness of DPI&F work – list first**

- ❑ Heard of agronomy work and aware of results
- ❑ Heard of work but don't know anything about it
- ❑ Never heard of agronomy work

4. **If aware of the work how did you find out?**

- ❑ Presentations by DPI&F project officers
- ❑ Farm visits by DPI&F officers
- ❑ Newsletter
- ❑ Growers
- ❑ Other ………………………………………….

5. **Have you changed any of your growing practices in the last 3 – 4 years?**

- ❑ Yes
- ❑ Not really

If yes please list the major changes
……………………………………………………………………………………………

………………

What influence if any has the DPI&F agronomy work had on the changes listed (give examples)
……………………………………………………………………………………………

………………

6. **How do you obtain planting material?**

- ❑ Own runners and or roots
- ❑ Other growers runners and or roots

- ❑ DPI&F low virus roots scheme

7. If you use DPI&F low virus material how often do you obtain it?

- ❑ Every year
- ❑ Every second year
- ❑ More than two years

Has the project influenced your use of low virus material (why)?

…………………………………………………………………………………
……………

8. What are your current plant spacings?

- ❑ 20 – 25 cm (8 – 10 inches)
- ❑ 25 – 30 cm (10 – 12 inches)
- ❑ 30 – 40 cm (12 – 16 inches)
- ❑ Other ………………………

Have you changed plant spacings in the last 4 years (why)?

…………………………………………………………………………………
……………

9. Seedbeds

- ❑ Never use seedbeds
- ❑ Use seedbeds

If you use seedbeds when did you start using them?

…………………………………………………………………………………

10. Planting Method

- ❑ V plant (with stick) and overhead irrigate
- ❑ V plant and water with trickle
- ❑ Flat plant by hand into moisture
- ❑ Flat plant by hand and water after
- ❑ Plant by machine then overhead
- ❑ Plant by machine then trickle irrigate

Have you changed your planting method in the last 4 years (why)?

…………………………………………………………………………………
……………………………………………………………

11. **Irrigation Method**

- ❑ Hand shift
- ❑ Winch
- ❑ Trickle
- ❑ Solid set
- ❑ Other ……………………………………………

Have you changed your irrigation method in the last 4 years (why)?
……………………………………………………………………………………
…………………………………………………………………

12. How do you monitor your irrigation?

- ❑ Experience
- ❑ Tensiometer
- ❑ Enviroscan
- ❑ Other

13. What is your current fertiliser program?

Base (if a personal blend record N P K etc ratio)
……………………………………………………………………………………

…………………………………………………………………

Side dress

……………………………………………………………………………………

……………………………………………………..…………….

Trace elements

……………………………………………………………………………………

………….

14. Has your fertiliser program changed in the last 4 years?

- ❑ Yes
- ❑ No

If yes what have been the major changes?
……………………………………………………………………………………

…

Has the DPI&F work influenced any fertiliser changes (why)?
……………………………………………………………………………………
……………..….

15. Do you use soil testing?

- ❑ Yes
- ❑ No

If yes when do you use testing?
………………………………………………………………………………………………

………………

If no why not?
………………………………………………………………………………………………

………………

16. Do you use leaf/sap tissue testing?

- ❑ Yes – Sap or leaf (please circle)
- ❑ No

If yes when do you use testing?
………………………………………………………………………………………………

………………

If no why not?
………………………………………………………………………………………………

………………

17. Customer demands (eg major chains) have changed dramatically since 2001; do you have problems meeting specifications?
………………………………………………………………………………………………

18. Could you please rank the list below from (1) most critical to (6) least critical to you in 2005

- ❑ Fertiliser
- ❑ Pests
- ❑ Irrigation
- ❑ Varieties
- ❑ Marketing
- ❑ Clean planting material

Are there any other critical issues you would now add to the list?
………………………………………………………………………………………………
…………………

THANK YOU FOR YOUR TIME

Queensland Government
Department of Primary Industries

Horticulture Australia

HAL Project VG01010
Visit to Australian sweetpotato production areas by Dr Mike Canon from Louisiana State University

Eric Coleman & William O'donnell DPI Gatton Research Station *Tuesday, 2 May 2006*

Queensland Fruit & Vegetable Growers

Elders Limited

Pershouse Produce
growing together

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HAL Project Report

Visit to Australian Production Areas by Dr Mike Canon Louisiana State University

Acknowledgements

This visit to our production areas was put together and funded on very short notice to extend the visit of Dr Mike Canon from Louisiana State University to New Zealand. Richard Ross (Grower Services Manager QFVG) and Rodney Wolfenden (QFVG heavy produce representative and board member) heard of Dr Canon's impending visit when they visited the US in September 2002. Help in funding the trip was then sought from a number of parties and Jonathan Eccles from Horticulture Australia provided prompt and valuable assistance in putting together funding and incorporate the visit into an existing sweetpotato research project namely *VG 01010 Improving sweetpotato agronomy to meet new market opportunities*. John Maughan (Branch Manager Bundaberg) from Primac Elders Ltd and Dave Pershouse (Managing Director) Pershouse Produce provided further assistance in promoting and hosting the tour party in the districts and at the information sessions held. Bill O'Donnell (District Experimentalist Heavy Vegetables Gatton) and I then put the trip together and chauffeured Dr Canon around the major production districts over a very busy week.

At Cudgen Henry Pritchard (Branch Manager Primac Elders Ltd Cudgen) and the local Tweed Valley Growers Association through Sam Rasso (President) provided memorable hospitality. At Bundaberg John Maltby from DPI helped us out along with John Demiano (Primac Elders Ltd Bundaberg). In the North Chris Jones and Mike Hughes (DPI) provided valuable local knowledge and contacts for our visit.

Dr Mike Canon deserves special mention for his endurance and enthusiasm during what was a gruelling week. Many of the images in this report were supplied by Dr Canon and further information supplied since the visit has been appreciated.

Last but not least I would like to acknowledge all the growers who we visited and their hospitality that made this a valuable and enjoyable event for the Australian Sweetpotato Industry.

HAL Project Report

Visit to Australian Production Areas by Dr Mike Canon Louisiana State University

Principal outcomes

Virus Checked Plant Material

The Louisiana industry switched to virus checked seed roots in 1999. The program being run by the Queensland DPI is almost identical to that of the program being run by Dr Canon in Louisiana. Switching to the new program in Louisiana has resulted in marked improvements in both yield and quality

Virus Identification in the field

Dr Canon confirmed several symptoms in the field of feathery mottle virus in Beauregard. While feathery mottle virus on it's own is not a major issue it gives a good indication of disease build-up that may be occurring in the field. Observations on the trip showed increasing presence of the symptom on crops the more generations they were away from the original virus checked material.

Access to new Germplasm

Dr Canon was open to the suggestion of germplasm exchange with the US, but conceded that they have not come up with anything remarkably better than Beauregard.

Mechanisation

Plant propagation

Propagation from sprout beds may have specific applications in Australia particularly at times of year when lower temperatures are experienced. Sprout beds lend themselves to mechanisation of planting in particular.

Mechanisation of planting

Nearly all sweetpotato planted in Louisiana is planted mechanically. The whole Louisiana system is geared to a short season where massive areas are planted. Many growers have 8 row planters.

Mechanised Harvesting

Nearly all sweetpotato harvesting in Louisiana is done mechanically, 4,6 and 8 row harvesters are common.

Other Agronomic issues

Nutrition issues identified during the visit related to possible zinc and potassium deficiencies.

Marketing

The requirements of the US market are similar to the Australian market where smooth skinned blemish free sweetpotatoes are preferred. This has driven the US market almost totally to the production and marketing of Beauregard. The US market is predominantly a stored market and the peak times for marketing are based around the public holidays with sweetpotato very much a holiday food consumed at Easter Thanksgiving and Christmas.

HAL Project Report

Visit to Australian Production Areas by Dr Mike Canon Louisiana State University

Summary

In December 2002 Dr Mike Canon from the Louisiana State University visited Australian sweetpotato production districts. The organisation funding and hosting of the visit was made possible by the co-operation of a range of stakeholders in the Australian sweetpotato. The trip by Dr Canon consisted of the following,

- Slide presentations in Cudgen, Bundaberg and Mareeba
- Farm visits and district inspections
- Visit to DPI virus checked plant production facility at Gatton Research Station.
- Visit to the Brisbane markets and QFVG.

Sweetpotato production in Louisiana and the rest of the United States is carried out in a distinct season. Crops are planted grown and harvested over a short time period compared to almost year round production in Australia.
This concentrated production system has led to the development of new planting and harvesting technologies that may well have a place in Australia as the areas being produced by individuals expand.
The US industry since (1999) has moved to use of virus checked plant material with all growers now finding major benefits in introducing virus tested plant material to minimise virus incidence and it's effects on yield and quality.
Although plant breeding as a genetic improvement method continues in Louisiana there is now also increased emphasis on selections out of existing lines.
The aim of this visit was to give growers, researchers, and re-sellers involved in the Australian industry the opportunity to gain valuable insights into a large mechanised sweetpotato production system.
The focus of this report will be on the major points of difference between our industries and the areas where different technology and production methods are employed that may be of use to the Australian industry.

HAL Project Report

Visit to Australian Production Areas by Dr Mike Canon Louisiana State University

Production of Virus Checked Roots

Virus checked roots are produced at the Louisiana State University (LSU) Agricultural Experiment Station located at Chase in Louisiana. This experiment station is almost entirely devoted to sweetpotato research and supplies foundation sweetpotato seed stock (i.e. roots) to growers in Louisiana. Keeping vine year round is not an option in Louisiana's climate and fresh seed must be planted and sprouts grown every season. The steps involved in this program are almost identical to our Australian program.

General Overview

The program starts with plants grown from tissue culture that are multiplied in an aphid free environment (Figure 1). This consists of a large screened igloo that is heated by gas heaters to create enough heat to get the first tissue culture plants established in winter.

Figure 1. Sweetpotato plants being propagated in aphid proof enclosure at Sweetpotato Research Station, Chase Louisiana.

Cuttings are taken from the aphid proof enclosure and planted out to produce seed roots for growers. This program is almost identical to that being run by the DPI at Gatton, however it is on a larger scale, with more sophisticated equipment.

The roots harvested from this are then stored during the winter and sold to growers for sprout production in the following season. The sale of these roots provides operational income for the experiment station of approx $100000 US per annum.

What did we learn?

It is nearly impossible to keep the field generated roots 100% virus free. Dr Canon showed us many symptoms of the sweet potato feathery mottle virus (SPFMV) he is familiar with during his visit. This has provided us with a useful tool to monitor our initial root production bed and eliminate any plants with virus. Dr Canon and his team regularly monitor their root production block and rogue out possible virus infected plants a practice we have now started. This is why our program and the Louisiana program are not 100% virus free and no program with field generations can claim to be. Interestingly enough we have not been at this stage able to find any infected plants in our root production block but small amounts can be found in second-generation blocks we have planted for experiments. This is also a useful tool for growers as they can now move towards recognition of symptoms in the paddock and where possible refrain from using this material for planting (figure 2).

While touring the districts with Dr Canon we noticed higher and higher levels of virus in each generation that was further removed from the original material supplied by DPI.

The growers in Louisiana have seen major improvements in yield somewhere in the order of 150%. Shape and skin quality has also improved since going to the virus checked seed roots. In Australia by comparison we are still only introducing small amounts of clean material. To see the benefits seen in the U.S we may have to start introducing larger amounts of clean material.

Figure 2. Photograph on the left shows the purple mottling and on the right distinct vein clearing both symptoms of SPFMV in Beauregard.

Sweetpotato feathery mottle on its own is not always a major problem but becomes particularly important when it complexes with other diseases such as sweetpotato little leaf disease (SPLLD) figure 3. Since Dr Canon's visit we have been able to identify distinctly different symptoms of SPFMV and this is thought to indicate the presence of the various strains of this one virus pers comm. Persley 2003. We have also found sweetpotato little leaf/sweetpotato feathery mottle complexes in both Bundaberg and Cudgen.

Dr Canon also suggested that we might have a number of other sweetpotato viruses present, as was the case when they started looking for them in Louisiana.

Figure 3. Plant on the left with no disease has larger roots than SPLLD infected plant on the right. Also note stunted leaves in the plant on the right.

HAL Project Report

Visit to Australian Production Areas by Dr Mike Canon Louisiana State University

Mechanisation in the Louisiana sweetpotato industry

Due to the climate in Louisiana the entire industry is geared to a set sweetpotato production season. This is of course unlike the almost year round production we have in Australia. This difference in seasonal conditions has impacted greatly on the plant propagation, planting and harvesting methods employed by farmers in Louisiana. The entire crop needs to be planted over 4-6 weeks and then harvested in a similar period at the end of the crop. This has resulted in almost total mechanisation of the sprout harvesting and planting while all sweetpotato harvesting is mechanised.

Sprout production for commercial planting

General Overview

Propagation of plant material is the process in the production system that differs the most between the US and Australia. Louisiana growers produce almost all their planting material in seedbeds. The sweetpotatoes used for the seedbed are pre-sprouted i.e. held at 70-80°F (21-26.6°C) for 2-3 weeks before planting to induce sprouting.

The seedbeds are planted mechanically by distribution out of the back of a bin into a bed (figure 4). Approximately 30 cartons weighing 40lb (18kg) are planted to the acre. The sweetpotatoes are sprayed with fungicide and then covered over with soil. A plastic cover is placed over the bed to concentrate the heat in the bed figure 5(a). When sprouts come through, holes are punched in the cover for ventilation figure 5(b), this is all done when maximum day temperatures are 75°F (23.8°C). A row cover of lightweight frost mesh is placed over the sprouting beds to protect from frost. From planting to first sprout cutting takes 8-10 weeks.

Figure 4. Step 1 of sprout production, automated planting of roots for sprout bed

(a) (b)

Figure 5.(a) Sprout beds being covered by plastic. (b) Note fresh sprouts in foreground on the right. Beds on the right have holes punched in them once sprouts have emerged for ventilation.

Figure 6. Sprouts being mechanically harvested.

When sprouts are approximately 18inches (450mm) long they are groomed to even out their length a couple of days prior to cutting. Sprouts are then mechanically harvested with a plant cutter that uses a sickle bar mower to cut the sprouts. Sprouts are always cut at least 1-2 inches (25-50mm) above the ground to minimise pest and disease transfer into the commercial crop.

What did we learn?

Careful management of the sprout beds can establish sprouts when there is still significant frost risk. This sprout production system may well be of use in our conditions and could be employed late in winter for early spring sprouts or in autumn for the production of vigorous tips for planting going into May. Perhaps the biggest drawback with sprouts in our production system would be their use in the summer time when their softness may not be as good as field hardened vine. Sprout beds may also only be good for about 3-4 cuts after this they tend to run out of vigour.

The obvious advantage with this system is that you know that every piece of vine used has come from a marketable root. When selecting vine in the paddock like we do in Australia you never know what you are selecting from i.e. the plant material may be coming from a genetically inferior plant that will not set good quality marketable roots.

This full replacement of material every year also significantly benefits crop quality as diseases such as SPFMV and SPLLD are reduced.

Planting

General Overview

Planting is done with large mechanical planters. To cover the areas needed multiple rows are added to the planters with some reportedly doing 16 rows at a time. The majority are 8 row as mechanical difficulties have been experienced with the 16 row models, water injection is used on the planters to improve the health of the establishing plants. If the sweetpotato plants are planted properly under the right conditions root initiation should take place 30 DAP(days after planting).

What did we learn?

Mechanical planting can give greater control over factors such as plant spacing, depth and the number of nodes under the ground. The injection of water at planting has been shown even under somewhat milder planting conditions in Louisiana to produce much more healthy fibrous root material early in the plant establishment phase. We therefore must consider the softness of the cuttings in more detail to establish healthy/vigorous plants early.

Harvesting

General Overview

Harvesting of sweetpotato in Louisiana is another area in their production system that differs greatly to the Australian industry. Tops are removed with a vine snapper. The vine snapper pulls the main stem away from the sweetpotato cluster to allow easier flow through the harvester and a primary grade on the harvester. Harvesting is then done with 4 and 6 row harvesters. A common yield is 250-300 40lb cartons per acre.

What did we learn?

The vine snapper is a piece of equipment that is new to Australian producers. Dr Canon has offered to supply drawings of this device for anyone interested. The use of harvesters for sweetpotato is also something that not many Australian growers have gone into. There seems to be no resistance to their use in The US and they still seem to be able to produce a premium quality sweetpotato with mechanical harvesters.

Marketing curing and storage

As in Australia quality is the most important factor in the fresh market. In the US there is a large cannery/processing market for poorer quality material but this is of low value. To provide the market with sweetpotatoes out of season major capital investment is required in curing and storage facilities.

Marketing issues

General overview

The smooth even shaped sweetpotatoes with few blemishes make up the US No.1 category while the longer bent sweetpotatoes end up in processing and the Jumbo's go to the food service sector (restaurants like Lone Star etc). US No 1 has to be 1.75-3.5 inches (43.75mm-87.5mm) in diameter and 3-9 inches (75mm-225mm) long. Jumbos are anything over 3.5 inches (87.5mm) in diameter. Canner's are anything with a diameter less than 1.75 inches (43.75mm). figure 7.

Figure 7 US grade standards for gold sweetpotatoes.

The majority of the fresh market or US No.1's are consumed on public holidays. Sweetpotato is traditionally eaten at Christmas, Easter and Thanksgiving. When we visited Cudgen Dr Canon graded out a line in the field (figure 8) and the grading/quality requirements for the USNo.1's was comparable to a combined small medium category a retailer here like Woolworth would accept.

Figure 8 Sweetpotatoes graded in the field by Dr Canon, on the left US#1's, middle Jumbo's and on the right canners.

What did we learn?

The characteristics of Beauregard that make it the number one choice of retailers in Australia are also the key to it's success in Louisiana. Although breeding is still progressing the best improvements recently have come out of selections made from Beauregard. Dr Canon was open to suggestions of exchange of germplasm and suggested that some of their selections may be worth a look in Australia.

This specification means that US No 1 takes in both the small and medium Woolworth's specification. This may reflect a preference in the US for a smaller sweetpotato than in the Australian market.

Curing and Storage

General overview

To supply the market at peak times out of season curing and storage is essential. Curing takes place within 4 hours after harvest by holding the sweetpotatoes at 85-96°F (29-35.5°C) and 85-90% relative humidity for 4 days. This helps the sweetpotato to heal any wounds before storage. Storage then takes place at 55-60°F 10-14°C and 90% relative humidity for anything up to 8 months. The sweetpotatoes are stored unwashed and washed and final graded on removal from storage.

HAL Project Report

Visit to Australian Production Areas by Dr Mike Canon Louisiana State University

General Agronomy

The damage caused by soil-borne insects and the use of higher rates of potassium are the two agronomic issues of most relevance to the Australian industry. The Louisiana industry relies heavily on Chlorpyrifos (Lorsban) for soil insect control and they are starting to use more potassium in fertilisers than they have in the past.

General Overview

Perhaps one of the major risks of crop failure in Louisiana is due to wet weather. Toward the end of their growing season large amounts of rain can fall, 10-20 inches (250-500mm) is common. This results in problems with soil rots and a number of growers here experienced similar problems due to wet conditions in some areas that experienced higher than normal rainfall in early 2003. One of the less desirable traits of Beauregard is it's susceptibility to rots and breakdown in wet conditions.

The trueness of Beauregard genetics in Australia and in particular the material distributed by DPI is always an issue of importance to growers. We were pleased to see Dr Canon when visiting a paddock at Rockhampton comment on the twining nature of the tips figure 9 (The paddock contained material that had originated from the DPI). This was a true characteristic of Beauregard according to Dr Canon. This twining top is not a most preferred characteristic when cutting vine but it is reassuring to know that this is a true genetic trait of Beauregard. He also advised caution with too much nitrogen and commented on a crop he had experienced with tops as high as his waist that grew lots of top but no storage roots due to over application of nitrogen.

Figure 9. Dr Canon points out twining of tops in true Beauregard at Rockhampton

What did we learn?

Soil incorporation method for chlorpyrifos is crucial. Work in Louisiana has shown that any exposure to light markedly reduces the effectiveness of this soil insecticide.

Dr Canon noted both Potassium and Zinc deficiencies in a couple of crops (figure 10 and 11). In another location stunted plants were seen (figure 12) another typical zinc deficiency in Beauregard.

Figure 10. Leaves showing typical irregular interveinal chlorosis of potassium deficiency in Beauregard

Figure 11. Leaves showing size reduction and interveinal chlorosis typical of zinc deficiency in Beauregard.

Figure 12. Plants showing size reduction typical of zinc deficiency in Beauregard.

Another leaf symptom that a number of growers have contacted us about in the last 12 months where leaves show white specks around the margins was confirmed by Dr Canon as *Fusarium Latericium.* We had identified this earlier but Dr Canon assured us it is not of commercial significance.

In North Queensland there are a lot of non-Beauregard gold type varieties growing. A number of these appear to be generated from self-set seed that have been multiplied over time.