# Development of smooth skinned, easy to peel sweet potato using smart state technology

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Project Number: VG02114

**VG02114**

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# Developing smooth skin easy to peel sweetpotatoes.

Final report
HAL project VG02114 May 2006

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Queensland Government DPI&F

HAL project No. VG02114

# Developing smooth skin easy to peel sweetpotatoes.

This report outlines the findings of project VG02114 that evaluated the physiology of early plant establishment for sweetpotato production

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# Media Summary

The aim of this project was to establish if improving planting technique and establishment increased the yield of easy to peel sweetpotatoes. Shape of sweetpotato is a key market characteristic as smooth even shape sweetpotatoes are easier for consumers to prepare. Major retailers in Australia have developed product specifications for producers that reflect this consumer demand.

A 50% improvement in the yield of smooth skin easier to peel sweetpotatoes was achieved for the cv. Beauregard. This was achieved by using a flat planted vine that had frequent irrigation in the first 5 days after planting.

Seven experiments over a 3 year period evaluated a range of planting techniques including length and thickness of planting material, herbicide effects, planting orientation, planting method, number of nodes underground, seedling potential and irrigation.  Results indicated that many of the techniques had the potential to either reduce or improve final root shape. Until this project there was no research in Australia linking root quality to early plant establishment. Factors important in early plant establishment have been shown to be linked to vine type, vine length, planting method, temperature, moisture and leaf area at or just after planting.

Before this project the majority of the Australian industry used a stick to push the sweetpotato vine into the soil resulting in a V shape plant. Crops would be initially irrigated and then not really looked after until six weeks after planting. It is now estimated that 80% of the Australian industry has adopted a flat planting technique and frequent early irrigation. Many growers now use mechanical planters for flat planting and have adopted trickle irrigation.

Several new experimental techniques were pioneered in this project to reduce plant to plant variability and measure changes in root development. These include; source, length and node number of planting material and sampling experimental plots at key times throughout the crops development.

# Technical Summary

The aim of this project was to establish if improving planting technique and establishment increased the yield of easy to peel sweetpotatoes. A series of experiments demonstrated that using a flat planting technique and a daily irrigation regime for the first 2 weeks after planting could deliver a 50% improvement in the premium medium grade of the cultivar Beauregard. It also showed that a range of planting techniques could be detrimental to early root establishment and hence had the potential to extend time to maturity and/or reduce final root shape. This project has drawn a strong linkage between early plant establishment physiology and final root quality.

In 2003 two experiments were used to test a range of early plant establishment techniques. These included length and thickness of planting material, herbicide effects, planting orientation, planting method, number of nodes underground, and seedling potential. The experiments showed that flat planting at 169 DAP (Days After Planting) improved marketable yield compared to a vertical cutting orientation. Short cuttings at 30 DAP produced no bulking roots, cold stored cuttings produced fewer roots and weight of bulking roots compared to the industry standard 450mm vertical cutting. In the same experiment Seedlings produced the most Bulking roots at 30 DAP and went on to have no yield penalty at final harvest.

The 2004 experiments confirmed that at 40 DAP short cuttings have the potential to reduce yield. Planting with a flat orientation at a depth of 50mm helps to buffer the plant from the impact of soil heat in summer plantings and reduced node to node variability in root weight. Although seedlings establish well there was evidence contrary to the 2003 experiment to suggest that constriction of early adventitious roots produce a final root shape penalty, making the use of seedlings a practice not suitable for the Australian industry. Reductions in establishment for pigmented vine vs. non-pigmented vine indicated that the pigmentation is a stress reaction and that this plant material should be avoided where possible. The herbicide Simazine while not producing any final yield penalty set the plants back in the early establishment phase whereas the herbicide Stomp improved establishment.

In 2005 a final experiment was conducted to assess irrigation effects on early establishment using a 50mm deep flat planted vine. This experiment resulted in large improvements in yield of the cv. Beauregard in Australia of over 1800 cartons/Ha (cf to 990cartons/Ha before the project) of the commercially important premium medium grade and 3300 carton/Ha (cf to 2100cartons/Ha before the project) of small medium and large grades combined at 128 DAP.

During this project new experiemental techniques were developed to reduce plant to plant variability. These techniques included multiple sampling at critical growth stages i.e. root initiation, early bulking and optimal maturity, standardisation of planting material length, node count, planting depth and source. These techniques are considered critical to obtaining useful agronomic information about this highly variable crop.

A link between temperature and establishment performance has been revealed; soil temperatures in excess of 43ºC were recorded in the root zone in the plant establishment phase. The planting strategy developed as part of this project i.e. flat, using mechanical planter with regular irrigation has been successful in ameliorating these temperature extremes. While initially there seemed a potential use of short range predictive systems in managing these climate extremes, the planting system developed has overcome this need. There may however be a case for limited use of predictive use of forecasting systems when their accuracy improves. Such systems could be used to estimate a changeover time for reducing planting depth in autumn crops, to help root growth when deeper soil temperatures are too low.

Further experimentation in temperature and the possible use of climatic forecasting is suggested. The use of a grower management committee helped focus and maintain industry relevance and has resulted in high levels of adoption.

## Experiment 1: Physiology of commercial sweetpotato planting techniques. 3rd April to 4th November 2003

### Introduction

This experiment was targeted at evaluating the effect on early plant establishment of a range of common commercial practises and to assess some alternative planting techniques after a review of published literature (Coleman et al 2003). At the time of this experiment the majority of the Australian industry was planting sweetpotato vine that was a mixture of tip and back cuttings and these were pushed into a ridge using a stick/thin timber pole. This resulted in the underground part of the vine resembling a V-shape and the planting depth ranged from 75-200 mm. A V-shape cutting 485 mm long with three nodes in the first 200 mm from the cut end was planted as an industry standard to provide a reference point for other treatments used.

### Methodology, Results and Discussion

The experiment site was managed by a fourth year University of Queensland student and the report on the experiment covers the methodology, results and discussion in detail and is included as Appendix 1.

### Conclusion

Young leaves found at the terminal ends of vine i.e. tips are known to have higher levels of the auxin indole acetic acid (IAA). IAA has a known role in activating adventitious root growth on many plant cuttings and it is found in higher levels in young and newly developed leaves (Salsbury and Ross 1992). Back cuttings (taken approximately 50 cm from the tip) therefore lack this auxin and this has clearly affected the back cuttings performance in this experiment. The demonstration of these effects was a turning point in the reduction of back cutting use in Australia.

The broken cutting treatment was used to simulate what often occurred when sticks were used for planting; the data clearly shows reduced early plant establishment by broken cuttings. A further observation made in this experiment illustrated that nodes are often damaged and form calluses from the stick pushing on them at planting. These nodes then go on to produce few if any roots that go onto the bulking stage.

There was a clear improvement in marketable yield when a flat planting technique is used compared to a vertical planting technique. As discussed in detail in Appendix 1 this is due to less crowding around the nodes particularly in hard setting soils. This finding opens the way for implementing mechanisation of sweetpotato planting which has the advantages of being more economical while improving product quality.

The early advantage of the long V shape cutting for bulking roots demonstrated the importance of early leaf area and the positive effect of leaf area at and just after planting for rapid establishment and development of storage roots.

## References

Coleman E, McCrystal R, Maltby J, O'donnell W (2003) HAL project VG02114 Development of smooth skinned easy to peel sweetpotato literature review. Horticulture Australia Report.

Salsbury F and Ross C (1992) Plant Physiology.  Chapter 17 Hormones and growth regulators gibberellins and auxins. Plant Physiology 4th edition Wadsworth publishing company Belmont California.

## Experiment 2: Physiology of sweetpotato planting methods in winter 28th May to 23rd December 2003

### Introduction

This experiment was the second of two experiments conducted in 2003 to test a number of treatments suggested by Australian sweetpotato growers and researchers that may influence early plant establishment. These treatments were selected based on feedback from growers and an international literature review (Coleman et al 2003).

### Methodology

The experiment was conducted on a commercial sweetpotato grower's property outside of Rockhampton, Queensland. The experimental area had previously been cropped with sweetpotato for several years. The grower managed the crop from planting to harvest with the exception of those treatments that required post planting treatment applications.

### Treatments

The experimental design was a randomized block with three replicates and 14 treatments. Experimental plots consisted of two rows 5.1m long by 1.95 m wide which is equivalent to a plant density of 34188 plants/Ha. The only exception was T5 (Treatment 5, 45 cm plant spacing) having a plot length of 7.65 m, this was equivalent to a plant density of 22791 plants/Ha. There was a double row buffer between plots (Diagram 1).

Planting material for the experimental treatments was standardised to a length of 450 mm with three nodes in the first 200 mm from the cut end with the exception of T9 (Treatment 9 Very short) and T13 (Treatment 13 Short). T9 was planted with only two nodes in the ground as the length used did not allow enough leaf to be exposed if three nodes were buried. This treatment was included as growers wanted information on using very short cuttings as these are easier to plant using mechanical transplanters. T13 had three nodes buried along the first 150 mm of the cutting and this makes it slightly different to the remainder of the treatments. This length cutting was tested as it was seen as an upper limit in length for efficient use in mechanical transplanters. Full details of the treatments are shown in Table 2.

**Diagram 1.** Trial plan layout

| Guard rows | Datum Rep1 (row 1,2) | Guard rows | Datum Rep 2 (row 3,4) | Guard rows | Datum Rep 3 (row 5,6) | Guard rows |
|---|---|---|---|---|---|---|
| | 11 | | 4 | | 7 | |
| | 3 | | 2 | | 10 | |
| | 4 | | 6 | | 8 | |
| | 12 | | 1 | | 13 | |
| | 6 | | 3 | | 4 | |
| | 5 | | 14 | | 9 | |
| | 13 | | 5 | | 14 | |
| | 1 | | 12 | | 6 | |
| | 7 | | 7 | | 5 | |
| | 2 | | 13 | | 11 | |
| | 10 | | 8 | | 1 | |
| | 9 | | 11 | | 3 | |
| | 14 | | 9 | | 12 | |
| | 8 | | 10 | | 2 | |

**Table 2. Treatment descriptions**

| **Treatment No.** | ***Treatment applied*** | ***Treatment description**** |
|---|---|---|
| 1 | Old seedbed | Tip cuttings 450 mm length, three nodes first 200 mm taken from old seed bed planted in October 2002 |
| 2 | Fresh seedbed | Tip cuttings 450 mm length, three nodes first 200 mm taken from fresh seed bed planted in April 2003 |
| 3 | Seedling | Seedling propagated 7days prior to planting 450 mm length, three nodes first 200 mm |
| 4 | 30 cm spacing | Tip cuttings 450 mm length, three nodes first 200 mm (industry standard) |
| 5 | 45 cm spacing | Tip cuttings 450 mm length, three nodes first 200 mm planted at 45 cm spacing |
| 6 | Dual Gold | Tip cuttings 450 mm length, three nodes first 200 mm with herbicide Dual Gold applied at 2 l/Ha at planting. |
| 7 | Luxury Phosphorous | Tip cuttings 450 mm length, three nodes first 200 mm with 100 kg/Ha of P soil incorporated at planting |
| 8 | Foliar potassium | Tip cuttings 450 mm length, three nodes first 200 mm with 10 l/Ha of Mega K (commercial foliar K product) at 21 DAP |
| 9 | Very short | Tip cuttings 200 mm length, 2 nodes first 100 mm |
| 10 | Ambient stored cutting | Tip cuttings 450 mm length, three nodes first 200 mm that had been cut 7 days prior to planting and stored at ambient temperature |
| 11 | Cold stored cutting | Tip cuttings 450 mm length, three nodes first 200 mm that had been cut 7 days prior to planting and stored at 5ºC |
| 12 | Cool stored cutting | Tip cuttings 450 mm length, three nodes first 200 mm that had been cut 7 days prior to planting and stored at 12ºC and 95 RH. |
| 13 | Short | Tip cuttings 300 mm length, three nodes first 150 mm |
| 14 | Long | Tip cuttings 600 mm length, three nodes first 200 mm |

*All treatments except T9and T13 were cut with 3 nodes in the first 200 mm as measured from the cut. These cuttings were pushed in to a depth of 175 mm which meant 3 nodes were covered by soil. T9 had only 2 nodes in the first 100 mm covered by soil and T13 had 3 nodes in the first 150 mm covered by soil.

## Planting

The experiment was planted 28/05/2003.

The planting material for all treatments (except the two seedbed treatments) was collected from a first generation vegetative plot at Gatton research station. This material was propagated from pathogen tested tissue culture in 2002 and had only been in the field for approximately 80 days prior to collection for the experiment. The seedbed material was generated from seedbeds as described in Table 2. Immediately following planting the experimental block was overhead irrigated with follow up establishment irrigation occurring at 3 and 7 DAP (Days After Planting). Further irrigation was monitored by the grower co-operator. Due to the location of the experiment all the cuttings prepared prior to the planting date were held for 48 hours and layered in moist Hessian bags with the exception of T9 (seedling). These were propagated 5 days prior to the rest of the cuttings being collected and were transported in their seedling container to the experimental site Figure 1.

## Sampling

At 21 DAP an establishment rating was made for top growth (see Table 5). This was a subjective evaluation based on predetermined levels of leaf growth and was rated on a scale of 1-5 that was developed as part of Experiment 1.

Treatment plots were sampled at 30, 48, 127 and 209 DAP. A four plant sub sample was taken from each plot at the first 3 sampling times and for the final sampling a 12 plant sample was collected. For the 30 and 48 DAP sampling the roots at each of the first three nodes were sorted, counted and weighed as shown in Table 3, fresh weight of tops was also recorded.

**Figure 1.** Seedling container used.

**Table 3. Description of root evaluation method for 30 DAP**.

| Root type* | Number | Weight |
|---|---|---|
| Adventitious (A) | x | |
| Initiated (I) | x | |
| Setting (S) | x | |
| Bulking (B) | x | x |

*Adventitious roots: thick white lateral roots that develop from the nodes after planting
Initiated roots: adventitious roots that had started to develop pigmentation
Setting roots: roots that had developed full pigmentation and had not started to bulk i.e. < 5 mm diameter
Bulking roots: roots that had started to bulk i.e. >5 mm

For the 127 DAP sampling roots were sorted into three bulking grades only i.e. G1 diameter <20 mm, G2 diameter 20-50, and G3 >50 mm. These bulking grades were different to all other samplings and experiments in the project due to this extra sampling coming into winter.

For the 209 DAP sampling roots at each of the three nodes were sorted into, Undersize, Small, Medium, Large, Second and Reject grades, counted and then weighed as shown in Table 4. Undersize, Small, Medium, Large, Second and Reject grades were defined as per commercially available product specifications. The primary evaluation used a grading system based on dimensions i.e. length and diameter. If an individual sweetpotato could not be distinguished from its nearest grade a secondary parameter i.e. weight was used.

**Table 4. Descriptions of root evaluation method for 209 DAP.**

| Grade |
|---|
| Small (S): Length 130-180 mm, diameter 50-60 mm, weight 170-310 g |
| Medium (M): Length 180-250 mm, diameter 60-75 mm, weight 310-620 g |
| Large (L): Length greater than 250 mm long and/or diameter greater than 75 mm, weight 620-860) g |
| Undersize: Length shorter than 130 mm diameter less than 50 mm, weight 63-170 g |
| Second Grade: S+M+L(shape does not meet first grade specification) |
| Reject Grade |

## Statistical Analysis

The design was a randomised complete block, comprising fourteen planting treatments replicated in three blocks. The treatments were randomly assigned within each block to each treatment plot.

Results for the four samplings (30, 48,127 and 209 DAP) were analysed for treatment effects by analysis of variance (ANOVA). The analysis results are shown in Tables 6 to 10. Comparisons of treatment means used an unprotected LSD (Least Significant Difference) test.

**Table 5. 21 DAP plant establishment ratings.**

| Trt No. | Treatment | No. of Plants | Establishment score |
|---|---|---|---|
| 1 | Old Seedbed | 31.3 | 77.7 |
| 2 | Fresh Seedbed | 31.3 | 80.0 |
| 3 | Seedling | 32.0 | 121.7 |
| 4 | 30 cm spacing (Industry standard) | 32.0 | 88.7 |
| 5 | 45 cm spacing | 32.0 | 88.0 |
| 6 | Dual Gold | 32.0 | 86.7 |
| 7 | Luxury Phosphorous | 31.7 | 93.3 |
| 8 | Foliar potassium | 31.0 | 86.3 |
| 9 | Very short | 30.0 | 51.3 |
| 10 | Ambient stored cutting | 31.7 | 92.7 |
| 11 | Cold stored cutting | 31.3 | 71.0 |
| 12 | Cool stored cutting | 32.0 | 89.3 |
| 13 | Short | 32.0 | 83.7 |
| 14 | Long | 31.7 | 90.7 |
|  | F test | * | *** |
|  | LSD | 1.11 | 7.71 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

### Table 6. 30 DAP Treatment effects per plant square root transformed with back transformed data represented in brackets

| Trt No. | Treatment | A Count | | I Count | | S Count | | AIS Count | | B Count | | B Weight(g) | | Plant Wt (g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Old Seedbed | 1.55 | (2.39) | 1.63 | (2.66) | 0.68 | (0.47) | 2.54 | (6.46) | 0.08 | (0.01) | 0.08 | (0.01) | 3.70 | (13.69) |
| 2 | Fresh Seedbed | 1.61 | (2.58) | 0.87 | (0.75) | 1.04 | (1.08) | 2.54 | (6.45) | 0.39 | (0.16) | 0.39 | (0.16) | 4.00 | (15.99) |
| 3 | Seedling | 2.14 | (4.58) | 1.63 | (2.64) | 1.71 | (2.93) | 3.36 | (11.28) | 2.00 | (4.01) | 2.61 | (6.80) | 7.30 | (53.35) |
| 4 | 30 cm spacing (Industry standard) | 1.97 | (3.87) | 1.38 | (1.91) | 1.26 | (1.58) | 2.94 | (8.64) | 1.07 | (1.14) | 1.11 | (1.24) | 5.28 | (27.85) |
| 5 | 45 cm spacing | 1.58 | (2.50) | 1.51 | (2.29) | 1.27 | (1.62) | 2.74 | (7.49) | 0.89 | (0.80) | 0.93 | (0.86) | 5.12 | (26.26) |
| 6 | Dual Gold | 1.73 | (3.00) | 1.08 | (1.17) | 1.16 | (1.35) | 2.70 | (7.30) | 0.43 | (0.18) | 0.43 | (0.18) | 4.53 | (20.48) |
| 7 | Luxury Phophorous | 1.88 | (3.52) | 1.43 | (2.05) | 1.17 | (1.36) | 2.86 | (8.19) | 0.76 | (0.58) | 0.82 | (0.67) | 5.14 | (26.41) |
| 8 | Foliar potassium | 2.06 | (4.22) | 1.31 | (1.72) | 0.98 | (0.95) | 2.79 | (7.78) | 0.29 | (0.08) | 0.29 | (0.08) | 4.25 | (18.03) |
| 9 | Very short | 1.20 | (1.45) | 1.25 | (1.57) | 0.42 | (0.17) | 2.05 | (4.19) | | | | | 2.35 | (5.50) |
| 10 | Ambient stored cutting | 1.81 | (3.27) | 1.30 | (1.70) | 1.05 | (1.10) | 2.89 | (8.34) | 0.43 | (0.18) | 0.38 | (0.14) | 4.72 | (22.23) |
| 11 | Cold stored cutting | 1.86 | (3.46) | 0.84 | (0.71) | 0.49 | (0.24) | 2.30 | (5.31) | 0.35 | (0.12) | 0.29 | (0.08) | 3.71 | (13.73) |
| 12 | Cool stored cutting | 1.45 | (2.10) | 1.27 | (1.62) | 1.00 | (0.99) | 2.51 | (6.28) | 0.84 | (0.70) | 0.87 | (0.76) | 4.86 | (23.64) |
| 13 | Short | 1.47 | (2.15) | 0.94 | (0.88) | 1.18 | (1.40) | 2.36 | (5.55) | 0.71 | (0.51) | 0.77 | (0.60) | 3.94 | (15.55) |
| 14 | Long | 2.11 | (4.45) | 1.27 | (1.61) | 0.57 | (0.33) | 2.79 | (7.78) | 0.51 | (0.26) | 0.40 | (0.16) | 4.36 | (19.04) |
| | F test | n.s. | | n.s. | | *** | | P=0.095 | | *** | | *** | | *** | |
| | LSD(P=0.05) | 0.82 | | 0.69 | | 0.49 | | 0.69 | | 0.61 | | 0.61 | | 0.89 | |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

**Table 7. 48 DAP Treatment effects per plant square root transformed with back transformed data represented in brackets**

| Trt No. | Treatment | A | | I | | S | | AIS | | B | | | | Plant Wt(g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Count | | Count | | Count | | Count | | Count | | Weight(g) | | Count | |
| 1 | Old Seedbed | 1.46 | (2.13) | 0.69 | (0.47) | 1.32 | (1.74) | 2.22 | (4.92) | 1.81 | (3.27) | 3.59 | (12.89) | 8.56 | (73.27) |
| 2 | Fresh Seedbed | 1.53 | (2.33) | 0.94 | (0.89) | 0.99 | (0.98) | 2.23 | (4.99) | 1.64 | (2.68) | 3.57 | (12.74) | 7.61 | (57.91) |
| 3 | Seedling | 2.20 | (4.83) | 1.61 | (2.58) | 0.87 | (0.75) | 2.95 | (8.69) | 3.16 | (9.99) | 7.93 | (62.88) | 12.21 | (149.08) |
| 4 | 30 cm spacing (Industry standard) | 1.64 | (2.70) | 1.08 | (1.16) | 0.80 | (0.64) | 2.29 | (5.25) | 2.32 | (5.40) | 4.07 | (16.56) | 8.84 | (78.15) |
| 5 | 45 cm spacing | 1.70 | (2.88) | 1.34 | (1.80) | 1.09 | (1.19) | 2.62 | (6.88) | 2.58 | (6.64) | 5.14 | (26.42) | 10.61 | (112.57) |
| 6 | Dual Gold | 1.74 | (3.02) | 1.20 | (1.45) | 1.36 | (1.84) | 2.76 | (7.61) | 2.45 | (6.00) | 4.14 | (17.14) | 9.65 | (93.12) |
| 7 | Luxury Phophorous | 1.87 | (3.48) | 1.34 | (1.79) | 0.74 | (0.54) | 2.74 | (7.52) | 2.57 | (6.58) | 5.60 | (31.36) | 10.15 | (103.02) |
| 8 | Foliar potassium | 1.32 | (1.75) | 0.92 | (0.84) | 1.06 | (1.12) | 2.09 | (4.37) | 1.75 | (3.05) | 3.43 | (11.76) | 9.48 | (89.87) |
| 9 | Very short | 0.45 | (0.20) | 0.29 | (0.08) | 0.25 | (0.06) | 0.76 | (0.58) | 1.73 | (2.98) | 2.91 | (8.47) | 6.39 | (40.83) |
| 10 | Ambient stored cutting | 1.71 | (2.94) | 1.02 | (1.05) | 1.10 | (1.21) | 2.54 | (6.46) | 2.29 | (5.24) | 4.35 | (18.92) | 9.79 | (95.84) |
| 11 | Cold stored cutting | 1.31 | (1.71) | 0.69 | (0.47) | 0.93 | (0.86) | 1.98 | (3.90) | 1.89 | (3.57) | 3.83 | (14.67) | 7.87 | (61.94) |
| 12 | Cool stored cutting | 1.67 | (2.78) | 1.25 | (1.57) | 1.00 | (1.00) | 2.48 | (6.17) | 2.31 | (5.35) | 4.91 | (24.11) | 9.87 | (97.42) |
| 13 | Short | 1.18 | (1.40) | 0.60 | (0.36) | 0.43 | (0.19) | 1.56 | (2.42) | 2.28 | (5.22) | 3.70 | (13.69) | 8.32 | (69.22) |
| 14 | Long | 1.89 | (3.56) | 1.22 | (1.50) | 1.43 | (2.04) | 2.92 | (8.52) | 2.05 | (4.19) | 3.75 | (14.06) | 9.21 | (84.82) |
| | F test | P=0.092 | | * | | ** | | *** | | *** | | *** | | *** | |
| | LSD(P=0.05) | 0.88 | | 0.68 | | 0.54 | | 0.84 | | 0.44 | | 1.18 | | 1.46 | |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

**Table 8. 127 DAP Treatment effects per plant square root transformed with back transformed data represented in brackets (weights are in grams)**

| Trt No. | Treatment | G1 |  | G2 |  | G3 |  | Total |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Counts | Weights | Counts | Weights | Counts | Weights | Counts | Weights |
| 1 | Old Seedbed | 0.98 (0.95) | 3.77 (14.21) | 1.65 (2.72) | 19.04 (362.52) | 0.65 (0.43) | 12.63 (159.52) | 2.22 (4.92) | 26.31 (692.22) |
| 2 | Fresh Seedbed | 0.94 (0.88) | 2.84 (8.07) | 1.34 (1.78) | 14.87 (221.12) | 0.81 (0.65) | 16.17 (261.47) | 2.10 (4.43) | 26.15 (683.82) |
| 3 | Seedling | 1.90 (3.62) | 6.02 (36.24) | 2.28 (5.21) | 26.90 (723.61) | 0.63 (0.40) | 11.89 (141.37) | 3.18 (10.14) | 32.55 (1059.50) |
| 4 | 30 cm spacing (Industry standard) | 1.49 (2.21) | 6.42 (41.22) | 1.82 (3.30) | 23.26 (541.03) | 0.77 (0.59) | 14.21 (201.92) | 2.68 (7.19) | 30.32 (919.30) |
| 5 | 45 cm spacing | 1.72 (2.95) | 5.60 (31.36) | 2.02 (4.07) | 21.74 (472.63) | 1.01 (1.02) | 20.28 (411.28) | 3.01 (9.05) | 33.11 (1096.27) |
| 6 | Dual Gold | 1.96 (3.84) | 6.77 (45.83) | 2.05 (4.18) | 24.49 (599.76) | 0.45 (0.20) | 8.90 (79.21) | 2.99 (8.93) | 28.95 (838.10) |
| 7 | Luxury Phophorous | 1.44 (2.08) | 4.31 (18.58) | 1.79 (3.22) | 18.67 (348.57) | 1.14 (1.30) | 19.41 (376.75) | 2.68 (7.17) | 28.91 (835.79) |
| 8 | Foliar potassium | 2.06 (4.26) | 8.23 (67.73) | 1.56 (2.45) | 15.75 (248.06) | 1.00 (1.00) | 19.27 (371.33) | 2.93 (8.60) | 29.54 (872.61) |
| 9 | Very short | 0.56 (0.31) | 1.98 (3.92) | 1.43 (2.05) | 16.42 (269.62) | 0.67 (0.44) | 11.58 (134.10) | 1.90 (3.60) | 23.69 (561.22) |
| 10 | Ambient stored cutting | 1.43 (2.04) | 5.63 (31.70) | 1.86 (3.47) | 21.98 (483.12) | 0.94 (0.88) | 17.95 (322.20) | 2.68 (7.18) | 30.71 (943.10) |
| 11 | Cold stored cutting | 1.47 (2.17) | 4.73 (22.37) | 1.61 (2.59) | 17.31 (299.64) | 0.58 (0.34) | 12.00 (144.00) | 2.39 (5.69) | 24.49 (599.76) |
| 12 | Cool stored cutting | 1.67 (2.78) | 5.50 (30.25) | 1.84 (3.37) | 21.50 (462.25) | 0.77 (0.59) | 15.19 (230.74) | 2.72 (7.40) | 29.54 (872.61) |
| 13 | Short | 1.39 (1.92) | 4.79 (22.94) | 1.95 (3.80) | 23.01 (529.46) | 0.62 (0.39) | 11.91 (141.85) | 2.62 (6.88) | 29.40 (864.36) |
| 14 | Long | 1.47 (2.15) | 4.54 (20.61) | 2.02 (4.10) | 19.65 (386.12) | 0.72 (0.52) | 13.68 (187.14) | 2.74 (7.52) | 26.99 (728.46) |
|  | F test | *** | ** | ** | ** | n.s. | n.s. | *** | * |
|  | LSD(P=0.05) | 0.51 | 2.62 | 0.37 | 5.29 | 0.52 | 10.50 | 0.35 | 5.30 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Table 9. 209 DAP Treatment effects per plot (weights are in kilograms)

| Trt No. | Treatment | Undersize |  | Small |  | Medium |  | Large |  | Seconds |  | Total Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Counts | Weight | Counts | Weight | Counts | Weight | Counts | Weight | Counts | Weight |  |
| 1 | Old Seedbed | 12.70 | 1.31 | 16.67 | 5.75 | 12.00 | 9.40 | 3.00 | 4.49 | 14.70 | 7.75 | 28.70 |
| 2 | Fresh Seedbed | 19.20 | 1.73 | 16.72 | 5.66 | 14.40 | 11.01 | 3.55 | 5.01 | 18.00 | 9.55 | 33.00 |
| 3 | Seedling | 31.30 | 2.41 | 24.00 | 6.63 | 21.00 | 15.56 | 2.00 | 2.62 | 23.70 | 11.61 | 38.80 |
| 4 | 30 cm spacing (Industry standard) | 32.30 | 3.17 | 20.33 | 7.55 | 13.67 | 8.77 | 3.33 | 3.65 | 18.00 | 10.60 | 33.70 |
| 5 | 45 cm spacing | 25.70 | 2.18 | 14.33 | 5.42 | 15.00 | 12.00 | 6.67 | 9.80 | 24.70 | 13.13 | 42.50 |
| 6 | Dual Gold | 14.00 | 1.19 | 11.67 | 3.45 | 10.67 | 7.67 | 5.67 | 8.08 | 22.70 | 11.26 | 31.70 |
| 7 | Luxury Phophorous | 19.70 | 1.87 | 15.00 | 5.20 | 12.67 | 9.43 | 2.67 | 3.19 | 18.00 | 12.03 | 31.70 |
| 8 | Foliar potassium | 20.00 | 2.02 | 15.00 | 5.10 | 16.33 | 13.94 | 1.33 | 1.99 | 18.30 | 10.48 | 33.50 |
| 9 | Very short | 6.70 | 0.71 | 10.67 | 2.95 | 14.00 | 11.73 | 2.33 | 3.08 | 10.00 | 6.10 | 24.60 |
| 10 | Ambient stored cutting | 17.00 | 1.54 | 23.33 | 9.11 | 15.67 | 13.07 | 3.67 | 5.90 | 12.30 | 8.01 | 37.60 |
| 11 | Cold stored cutting | 19.30 | 2.17 | 11.67 | 3.54 | 10.67 | 8.34 | 7.67 | 11.85 | 16.30 | 7.72 | 33.60 |
| 12 | Cool stored cutting | 15.60 | 1.08 | 17.72 | 6.19 | 14.90 | 10.91 | 3.12 | 4.26 | 25.30 | 10.31 | 32.70 |
| 13 | Short | 14.00 | 1.19 | 15.00 | 5.00 | 16.33 | 11.99 | 2.33 | 3.18 | 11.30 | 5.63 | 27.00 |
| 14 | Long | 21.70 | 1.62 | 22.00 | 7.74 | 14.33 | 10.39 | 2.33 | 3.11 | 18.30 | 9.55 | 32.40 |
|  | F test | ** | n.s. | * | n.s. | n.s. | n.s. | P=0.077 | P=0.063 | n.s. | n.s. | n.s. |
|  | LSD(P=0.05) | 11.20 | 1.45 | 8.82 | 3.94 | 8.44 | 6.30 | 3.99 | 6.18 | 11.96 | 8.71 | 12.32 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Results and Discussion

### 21 DAYS AFTER PLANTING (DAP)

A plant establishment rating based on visual top growth at 21 DAP (Table 5) showed T3 (Treatment 3 Seedling) to have more top growth than T4 (Treatment 4 Industry standard). T9 had the lowest establishment rating while T11 (Treatment 11 Cold stored) had the second lowest. T1 (old seedbed) and T2 (fresh seedbed) were also lower than T4. The clear difference in establishment ratings at this stage of growth may be a useful tool for growers to assess plant establishment (Figure 2).

**Figure 2**. A clear difference is visible at 21 DAP top growth for T3 (Seedling) and T9 (Very short).

### 30 DAYS AFTER PLANTING (DAP)

Plants were sampled at 30 DAP to coincide with storage root initiation and bulking root formation i.e. the stage when early adventitious roots initiate and then begin bulking to form sweetpotato storage roots (Wilson 1982). At this sampling stage high bulking root weights and numbers show improved early plant establishment and potential acceleration of storage root development. Plant weight should also be high for well established plants and is seen as a positive factor except if it is not matched by root bulking. If plant weights are high and bulking weights are low this is a clear indication of excess vegetative growth i.e. too much assimilate being directed in to top growth. Results in Table 6 show the main treatment effects in this sampling were caused by cutting length, storage of plant material and improved early plant establishment by use of a seedling.

*Length*
Compared to T4, T9 had substantially lower counts for all categories except A and I and at this sampling was the only treatment to produce no B roots. T9 was by far the slowest treatment to establish and this can be clearly seen in (Figure 2 & 3). T13 had lower Plant weight and comparable weights and counts for all other categories, which makes it’s establishment very similar to the industry standard. The longer cutting T14 (Treatment 14 Long) had a lower Plant weight, B weight and S numbers, but comparable B counts and AIS. There is a clear response to length suggesting that cuttings shorter than 30 cm will not establish as well as cuttings in the 30-60 cm range. This result could be due to the number of nodes underground with T9 having only two nodes in the ground not compensating by growing as many roots per plant as the plants with three nodes buried. Alternatively it could

be due to less leaf area available at establishment for the production of assimilate for subsequent conversion into plant growth.

*Seedlings*

T3 had higher Plant weight, B weight and B numbers than all other treatments (Figure 2) and demonstrates the differences that can be achieved by providing optimal moisture and temperature in the first 7 days of growth. This method of establishment would help to eliminate planting stress if final root quality is suitable.

**Figure 3**. 30 DAP Replication 1 Sample for T9 (Very short), T4 (Industry standard) and T3 (Seedling) showing the difference in tops and roots.

*Seedbed*

There was no difference in any category between T1 (old seedbed) and T2 (fresh seedbed). Overall the performance of the seedbed material compared to the vegetative material used in the industry standard. T1 and T2 had less B count and weight and a lower plant weight than T4. This clearly indicates that both the seedbed treatments did not establish and reach root bulking as fast as the Industry standard, this difference may have been due to the vegetative T4 vine being harder than the seedbed material in an overhead irrigated environment. Subsequent experiments have shown that the establishment irrigation regime used in this experiment may also have been too dry for ‘soft’ seedbed material compared with vegetative vine.

*Cutting storage*

The three types of cutting storage treatments assessed were T10 (Treatment 10 Ambient stored), T11 (Treatment 11 Cold stored), and T12 (Treatment 12 Cool stored). Of these T11 had consistently less roots and weights for all categories compared to T4. T10 had comparable Plant weight and AIS. T12 had comparable Plant weight and B weight and count to T4. At this early development stage cold storage of cuttings clearly had a negative impact on establishment. The cool stored cutting has performed slightly better than the ambient as it has matched the growth of the industry standard for bulking roots. This would suggest that if cuttings need to be stored a cool storage regime is preferable.

*Phosphorous and Potassium*

There was no response to T7 (Treatment 7 luxury phosphorous) in the data at this early stage compared to T4. In contrast there appeared to be a negative response to T8 (Treatment 8 Foliar potassium) in Plant weight and B weight and count. This result is perplexing as the K application occurred 9 days before sampling. It is possible this product may have caused a leaf reaction leading to a detrimental effect on root production.

*Herbicide*

T6 (Treatment 6 Dual Gold) performed consistently with T4 for all categories apart from B count and weight. This suggests that the use of this product in accordance with its label is not influencing early plant establishment and root development. As Dual Gold is incorporated for weed control the result also suggests weeds were not influencing growth at 30 DAP in this experiement.

*Spacing*
T5 was no different to T4. This is as expected as any differences with this treatment were not expected until later in crop development when leaf area competition is increased.

## 48 DAYS AFTER PLANTING (DAP)

Plants were sampled at 48 DAP to coincide with the completion of early root initiation and to gather data before the plants started growing into the cooler months. At this sampling stage high bulking root weights and numbers show a clear acceleration of storage root development. Plant weight should also be high for well established plants and is seen as a positive factor except if it is not matched by root bulking. If plant weights are high and bulking weights are low this is a clear indication of excess vegetative growth i.e. too much assimilate being directed into top growth.

*Length*
Similarly to 30 DAP length of cutting was important with T9 different to T4 for A, I, S, AIS, B count and Plant weight. The other two cutting lengths T13 and T14 were similar to T4. These results confirm findings for length at 30 DAP.

*Seedlings*
T3 remained higher for B counts, B Weights and Plant weights than all other treatments. This confirms that the early plant establishment gains seen at 30 DAP are still evident seven weeks into the crop development.

*Seedbed*
There were no differences between the two seedbed treatments (T1 and T2) at 48 DAP reflecting the result for 30 DAP. However different to 30 DAP was T1 and T2, were now no different to T4 in all results apart from B counts. It is assumed that whatever was affecting their development at 30 DAP has been overcome.

*Cutting storage*
There were no differences between any of the storage treatments (T10, 11, 12) and T4. This result suggests the initial negative influence of cold storage (T11) has been overcome.

*Phosphorous and Potassium*
T7 now has higher B weights than T4 and although I, AIS, B count and Plant weight are not different to the control they are all higher in value. This suggests there may be some response to luxury phosphorus under these conditions. T8 had similar results to 30 DAP and showed a reduction in B counts compared to T4 and a reduction in B counts and weight compared to T7.

*Herbicide*
At 48 DAP T6 had more setting roots than T4.

*Spacing*
T5 was higher than T4 for Plant weight. This change may be signalling the start of this treatment experiencing reduced leaf area competition due to the reduced plant density allowing it to develop a larger plant.

## 127 DAYS AFTER PLANTING (DAP)

Due to the late planting of this crop and although we did not expect full maturity to be reached until after winter i.e. approximately 200 days, a sampling was performed at or about optimum maturity for cv Beauregard in Australia. At this sampling bulking roots were graded into three size grades with the expectation that the most advanced treatments would have a higher proportion of the larger G3 grade. Although the G3 grade (>50 mm diameter) did not show any significant differences between treatments there were significant differences for the G1 and G2 grades (Table 7). The nil response to G3 grade suggests that temperatures experienced up to 127 DAP were not conducive to optimum growth of Beauregard.

### *Length of cutting*

The treatment effect seen in the earlier samplings for cutting length has continued to this sampling with T9 having less G1, G2 and Total counts and weights compared with T4. T13 and T14 had similar results to T4 suggesting that a lower length limit for cuttings is 30 cm, confirming earlier results.

### *Seedlings*

At 127 DAP T3 had higher G2 count and Total count compared with T4 confirming the early plant establishment effects observed at 30 and 48 DAP had continued to 127 DAP.

### *Seedbed*

Again there were no differences between seedbeds (T1 and T2). Differences were apparent when both treatments were compared with T4. T4 had higher G1 weights and counts than both T1 and T2. T4 had higher G2 counts, weights and Total counts than T2. There were no differences for T4 when compared to T1 and T2 for G3 count, weight and total root weight. At this stage of growth differences in total root weight and G3 would provide the most powerful signal of major differences between treatments. This is not the case and there are only subtle differences to the industry standard suggesting that Fresh seedbed may be falling behind the industry standard for the G1 and G2 categories.

### *Cutting Storage*

T11 had less Total weight and G2 weight than T4 while T12 and T10 had comparable results with T4. This shows that the effects of cold storage are still evident at this stage of the crop. The storage of these cuttings cool and at ambient has had no negative impact and may well be a useful way to maintain cuttings when planting is delayed due to unforseen circumstances.

### *Phosphorus and Potassium*

The suggestion of a positive response to luxury phosphorus (T7) compared to T4 is not found at 127 DAP. Any suggestion of a negative response to foliar potassium (T8) is also not found.

### *Herbicide*

Result mirrors 48 DAP with no difference between T6 and T4 suggesting again weed competition is not influenced by herbicide application.

### *Spacing*

No difference was found between T5 and T4 which is surprising as it was expected plant competition would have been influencing results by this stage of crop development.

### 209 DAYS AFTER PLANTING (DAP)

By 209 DAP few differences were evident between treatments. The Small grade is the only commercially relevant grading to show any treatment response with T9 having a lower count than T4, T14, T10 and T3. This lack of treatment response is thought to be due to the suboptimal root development during the colder months i.e. June to July and water limitation. This extended time to maturity leaves the crop more vulnerable to pests and diseases and reduces land availability for the grower (for re-planting). It is likely that the genetics of cv. Beauregard are not well matched to this production window and this may be an area where further research into agronomy and new cultivars will be important in reducing the time the crop is in the ground.

## Conclusion

Due to the late planting of this experiment coming into winter many of the early establishment differences did not carry through to the two later harvests. There is a strong case however to suggest that marked establishment differences have occurred and are comparatively consistent at both 21 and 30 DAP.

At 30 DAP short cuttings were behind the industry standard.  This result suggests that a minimum cutting length of 30 cm may be needed to match the industry standard of a 45 cm cutting. Storage of cuttings although not a common practice seems feasible providing cuttings are not refrigerated at 5 ºC. This is not surprising as sweetpotato is susceptible to frost and can experience cell and tissue breakdown when stored below 7 ºC.

Establishment of the seedling treatment was superior to all other treatments and this is not surprising as by propagating the material in a seedling container optimum soil moisture can be maintained until adventitious roots are developed. What is even more interesting was that there was little evidence of early adventitious root constriction in the seedling container (something found in a later experiment). This is most probably due to the time of year (May) where cooler conditions slowed the growth of the adventitious roots in the seedling container (see Figure 1).

It was reassuring to note that the herbicide Dual gold did not cause measurable root deformation something that has been reported by some growers in Autumn plantings.

Some minor nutrient responses were seen and further evaluation of these need to be done before any meaningful conclusions can be made about their use.

Treatment differences that were measurable at early establishment once again were not found at later sampling times. This has been a common theme in the project and suggests the use of sampling in the early establishment phase is a sound experimental technique. Previous research where data was only recorded at final commercial harvests does not reflect what we now understand as optimal maturity for the cv. Beauregard i.e. 120 days. Limiting this cultivar due to season, location, leaf area competition, moisture etc has restricted our understanding of the yield capacity of the cultivar to date. It is our belief that rapidly establishing treatments are being limited by the production system we were using (e.g. the seedling treatment). Experiment 7 conducted in a non-limiting environment provides a true indication of yield potential of the cv. Beauregard.

## References

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## Experiment 3: Physiology of Sweetpotato vine type and orientation 30th January to 25th August 2004

### Introduction

The treatments in this experiment were selected to examine establishment performance of flat and vertical cutting orientations in different lengths and also to test three treatments with possible altered physiology i.e. thin vine, pre rooted vine and pigmented vine. A vertically planted 485 mm long treatment was planted as an industry standard to provide a reference point for other treatments used. The treatments were chosen to apply findings of a previous literature review (Coleman et al 2003) and confirm findings of two experiments conducted in 2003.

### Methodology

#### Treatments

The experimental design was a randomized block with nine treatments and three replicates. Plot size consisted of two rows 2.7 m long, treatments ran down the row with each row (rep) separated by one guard row that resulted in a 1.5 metre buffer between datum rows as shown in Diagram 1. The plant spacing used was 30 cm this is equivalent to 22220 plants/Ha.

**Diagram 1. Trial plan layout**

| Guard row | Datum Rep 1 (row 1,2) | Guard row | Datum Rep 2 (row 3,4) | Guard row | Datum Rep 3 (row 5,6) | Guard row |
|---|---|---|---|---|---|---|
| | 8 | | 7 | | 7 | |
| | 2 | | 9 | | 8 | |
| | 5 | | 2 | | 1 | |
| | 6 | | 4 | | 2 | |
| | 9 | | 6 | | 6 | |
| | 4 | | 8 | | 5 | |
| | 3 | | 3 | | 9 | |
| | 1 | | 1 | | 3 | |
| | 7 | | 5 | | 4 | |

Treatments applied are shown in Table 1. These treatments are split into a vertical planting cutting orientation and a flat planting cutting orientation. T9 (Treatment 9 485 mm Vertical) was chosen as a reference point as it represented what was considered the industry standard at the time (i.e. 450 mm long plus a 35 mm tail for ease of planting). Three vine treatments with possible altered physiology were tested and these were T1 (Treatment 1 Thin vine), T2 (Treatment 2 Pigmented) and T3 (Treatment 3 Pre-rooted). Thin vine was selected out of the cuttings and is shown in Figure 1. Pigmented vine treatments were taken from plants grown on widely spaced rows to allow runners to grow in the open and develop pigmentation (Figure 2). The pre-rooted treatment was produced by cutting the vine three days prior to the remaining treatments and holding at ambient temperature layered in moist Hessian bags (Figure 3). All other treatments were cut from a [1]sprout bed.

**Figure 1.** Thin vine used for T1 was selected from a sprout bed.

**Figure 2.** Pigmented vine used for T2 was selected from widely spaced plants**.**

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[1] Spouts are defined as sweetpotato vine cuttings taken from sweetpotatoes that have been planted in a bed (often referred to as a seedbed) for the sole purpose of producing plant material. The other common source of plant material is to take cuttings from a established sweetpotato plant and is referred to as vegetative vine.

**Figure 3.** Pre–rooted vine used for T3 was held in moist Hessian bags for 3 days prior to planting to initiate roots.

**Table 1. Treatment descriptions**

| **Treatment Number** | ***Treatment applied**   ***** | ***Treatment description ****** |
|---|---|---|
| 1. | 635 mm Thin vertical | 3 nodes in 200 mm, 400 mm out of ground. Planting depth 175 mm |
| 2. | 635 mm Pigmented vertical | 3 nodes in 200 mm, 400 mm out of ground. Planting depth 175 mm |
| 3. | 635 mm Pre-rooted vertical | 3 nodes in 200 mm, 400 mm out of ground. Planting depth 175 mm. Held for 3 days prior to other cuttings in a moist environment |
| 4. | 285 mm Very short vertical | 1 node in first 100 mm, 150 mm out of ground. Planting depth 100 mm |
| 5. | 435 mm Short vertical | 1 node in first 100 mm, 300 mm vine out of ground. Planting depth 100 mm |
| 6. | 635 mm Flat | 3 nodes in 200 mm, 400 mm out of ground. Planting depth 100 mm |
| 7. | 635 mm Flat shallow | 3 nodes in 200 mm, 400 mm out of ground. Planting depth 25 mm |
| 8. | 335 mm Flat Short | 3 nodes in 200 mm, 100 mm out of ground. Planting depth 25 mm |
| 9. | 485 mm Vertical (Industry standard) | 3 nodes in 200 mm, 250 mm out of ground. Planting depth 175 mm |

*Vertical refers to pushing the cutting into the soil vertically with a stick until the desired number of nodes are under the soil
**Flat refers to placing cutting into a trench of desired depth and covering with soil by hand
*** All treatments with the exception of T4and T5 had three nodes buried. T4 and T5 had only one node buried

**Planting**
The experiment was planted 30/01/2004.

The treatments were hand planted and the guard row cuttings were vertically planted by the grower.

All planting material was generated at Gatton research station using pathogen tested sweetpotatoes from plants taken out of tissue culture in 2003.

Immediately following planting the trial block was overhead irrigated and was subsequently trickle irrigated.

**Sampling**

Treatment plots were sampled at 40, 68 and 208 DAP (Days After Planting). A four plant sub sample was taken from each plot at each sampling time. Two plants in the plot were left as buffers for the next four plant sub sample. For the 40 DAP sampling the roots at each of the first three nodes were sorted, counted and weighed as shown in Table 3. Fresh weight of plant tops were also recorded at 40 DAP.

**Table 2. 40 DAP sampling criteria**

| Root type* | Number | Weight |
|---|---|---|
| Adventitious (A) | x | |
| Initiated (I) | x | |
| Setting (S) | x | |
| Bulking (B) | x | x |

*Adventitious roots: thick white lateral roots that develop from the nodes after planting
Initiated roots: adventitious roots that had started to develop pigmentation
Setting roots: roots that had developed full pigmentation and had not started to bulk ie < 5 mm diameter
Bulking roots: roots that had started to bulk ie >5 mm

For the 68 DAP sampling the roots at each of the first three nodes were sorted, counted and weighed into two categories i.e. Marketable and Non-marketable where the sum of these was the Total. These categories were based on shape and any roots that were bent or had uneven surfaces were considered to be part of the Non-marketable category.

For the 208 DAP sampling roots at each of the three nodes were sorted into Small, Medium, Large, Undersize, Second and Reject grades, counted and then weighed as shown in Table 4. Small, Medium, Large, Undersize, Second and Reject grades were defined as per commercially available product specifications. The primary evaluation used a grading system based on dimensions i.e. length and diameter. If an individual sweetpotato could not be distinguished from its nearest grade a secondary parameter, i.e. weight, was used.

**Table 3. 208 DAP sampling criteria**

| Grade |
|---|
| Small (S): Length 130-180 mm, diameter 50-60 mm, weight 170-310 g |
| Medium (M): Length 180-250 mm, diameter 60-75 mm, weight 310-620 g |
| Large (L): Length greater than 250 mm long and/or diameter greater than 75 mm, weight 620-860) g |

Undersize (U): Length shorter than 130 mm diameter less than 50 mm, weight 63-170 g

Second Grade: S+M+L(shape does not meet first grade specification)

Reject Grade

**Temperature measurement**
Tiny tag temperature probes were placed in the in the centre of the experiment at 25 mm, 125 mm and 175 mm depths. Temperature readings were automatically recorded every 30 minutes. Results for the first 35 DAP are shown in Figure 4. Rainfall events at 1 and 4 DAP produced drops in soil temperatures.

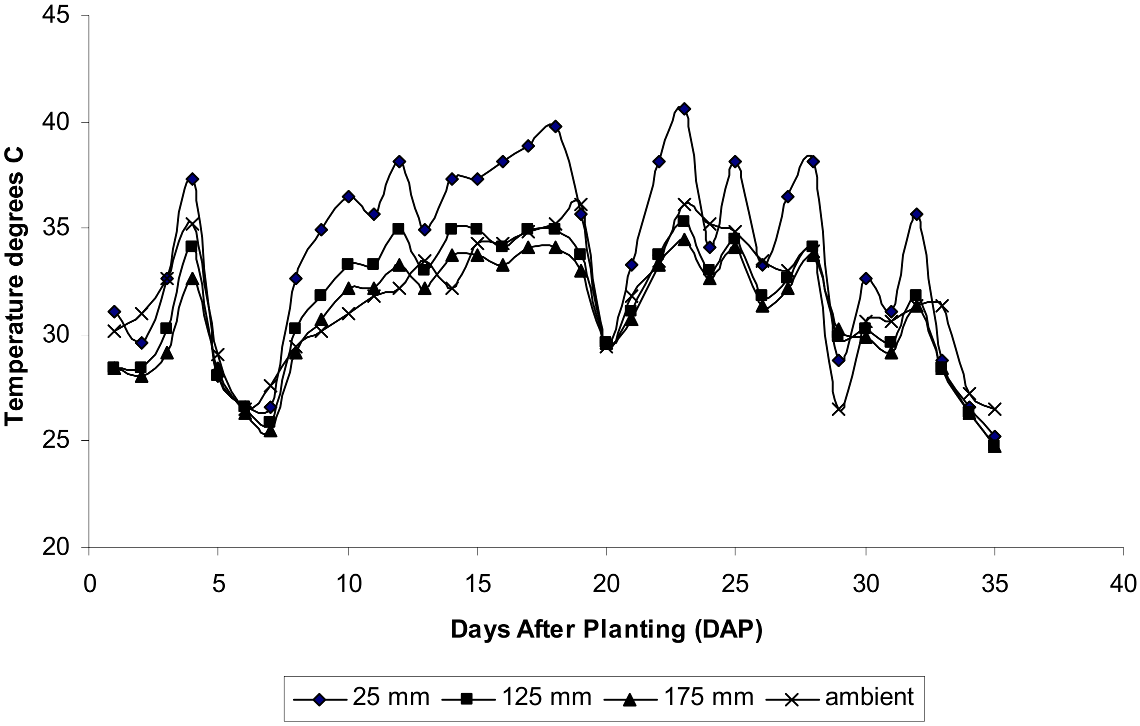

**Figure 4** Maximum daily soil and ambient (air) temperature for experimental site until 35 DAP.

**Statistical Analysis**

ANOVA was performed on the 40 DAP and 60 DAP results. The 208 DAP results were analysed by REML, rather than ANOVA, due to the lack of balance caused by missing plots. Subsequently LSDs have been substituted by the standard error of difference (sed) for 208 DAP results.

## Table 4: 40 DAP Treatment effects per plant

| Trt No. | Treatment | A | I | S | A+I+S | B | | Total | Plant Weight (g) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | count | Weight(g) | | Wet | Dry |
| 1 | 635 mm thin vertical plant | 3.75 | 2.42 | 3.17 | 9.33 | 6.58 | 58.2 | 15.92 | 525 | 65.1 |
| 2 | 635 mm pigmented vertical plant | 4.58 | 2.25 | 5.58 | 10.42 | 8.33 | 106.4 | 18.75 | 588 | 71.4 |
| 3 | 635 mm pre rooted vertical plant | 6.33 | 3.33 | 4.08 | 13.75 | 6.33 | 69.9 | 20.08 | 528 | 67.3 |
| 4 | 285 mm very short vertical plant | 1.83 | 1.00 | 1.67 | 4.50 | 4.58 | 49.9 | 9.08 | 409 | 51.7 |
| 5 | 435 mm short vertical plant | 3.42 | 1.83 | 2.92 | 8.17 | 5.92 | 98.5 | 14.08 | 605 | 75.4 |
| 6 | 635 mm flat deep plant | 4.92 | 1.33 | 3.17 | 9.42 | 8.75 | 86.6 | 18.17 | 568 | 73.6 |
| 7 | 635 mm flat shallow plant | 5.75 | 0.67 | 2.67 | 9.08 | 7.25 | 72.0 | 16.33 | 465 | 54.5 |
| 8 | 335 mm flat short plant | 3.58 | 0.42 | 2.25 | 6.25 | 6.00 | 57.3 | 12.25 | 393 | 47.4 |
| 9 | 485 mm vertical plant (Industry standard) | 4.25 | 3.75 | 3.58 | 11.58 | 7.42 | 119.6 | 19.00 | 630 | 75.2 |
| | F test | * | ** | n.s. | * | n.s. | n.s. | *** | n.s. | n.s. |
| | LSD | 2.49 | 1.61 | 2.47 | 4.26 | 3.08 | 53.8 | 3.07 | 181.4 | 23.39 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

**Table 5: 68 DAP treatment effects per plant (weights are in grams)**

| Trt No. | Treatment | Marketable | | Total | |
|---|---|---|---|---|---|
| | | Weight | count | Weight | count |
| 1 | 635 mm thin vertical plant | 820 | 6.0 | 3000 | 27.0 |
| 2 | 635 mm pigmented vertical plant | 1046 | 8.7 | 3372 | 36.7 |
| 3 | 635 mm pre rooted vertical plant | 1300 | 7.3 | 3965 | 39.7 |
| 4 | 285 mm very short vertical plant | 1341 | 4.7 | 3242 | 19.0 |
| 5 | 435 mm short vertical plant | 701 | 4.0 | 2708 | 21.7 |
| 6 | 635 mm flat deep plant | 718 | 9.3 | 3023 | 40.0 |
| 7 | 635 mm flat shallow plant | 1649 | 19.0 | 2603 | 35.0 |
| 8 | 335 mm flat short plant | 617 | 8.3 | 1988 | 25.0 |
| 9 | 485 mm vertical plant (Industry standard) | 893 | 10.0 | 3509 | 41.3 |
| | F test | n.s. | ** | n.s. | * |
| | LSD | 1302 | 7.8 | 1458 | 15.7 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

**Table 6: 208 DAP Weights and counts per plant (weights are in grams)**

| Trt No. | Treatment | Small | | Medium | | Large | | Seconds | | Rejects | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Counts** | **Weights** | **Counts** | **Weights** | **Counts** | **Weights** | **Counts** | **Weights** | **Counts** | **Weights** | **Counts** | **Weights** |
| 1 | 635 mm thin vertical plant | 0.417 | 127.92 | 0.583 | 336.00 | 0.167 | 122.42 | 0.500 | 340.00 | 7.000 | 2627.00 | 8.667 | 3553.00 |
| 2 | 635 mm pigmented vertical plant | 0.286 | 103.36 | 0.698 | 307.00 | 0.238 | 211.65 | 1.375 | 691.10 | 6.875 | 2385.00 | 9.625 | 3766.00 |
| 3 | 635 mm pre rooted vertical plant | 0.417 | 111.42 | 0.417 | 266.40 | 0.083 | 66.33 | 0.917 | 471.10 | 6.500 | 2984.00 | 8.333 | 3899.00 |
| 4 | 285 mm very short vertical plant | 0.167 | 54.58 | 0.667 | 312.20 | 0.083 | 73.83 | 0.583 | 328.00 | 6.667 | 2815.00 | 8.167 | 3583.00 |
| 5 | 435 mm short vertical plant | 0.333 | 109.58 | 0.500 | 268.90 | 0.000 | 0.00 | 1.167 | 448.80 | 6.833 | 2188.00 | 8.833 | 3016.00 |
| 6 | 635 mm flat deep plant | 0.250 | 61.17 | 0.417 | 271.80 | 0.083 | 65.75 | 0.417 | 311.60 | 5.583 | 2250.00 | 6.750 | 2960.00 |
| 7 | 635 mm flat shallow plant | 0.566 | 168.12 | 0.339 | 238.40 | -0.036 | -31.28 | 0.625 | 255.90 | 7.250 | 2885.00 | 8.750 | 3509.00 |
| 8 | 335 mm flat short plant | 0.398 | 83.03 | 0.838 | 388.70 | 0.049 | 41.01 | 1.625 | 712.30 | 8.000 | 1350.00 | 10.500 | 2514.00 |
| 9 | 485 mm vertical plant (Industry standard) | 0.083 | 28.50 | 0.500 | 278.30 | 0.083 | 93.00 | 1.667 | 909.40 | 6.500 | 1880.00 | 8.333 | 3189.00 |
| | F test | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| | sed (average) | 0.265 | 80.05 | 0.343 | 189.40 | 0.152 | 128.20 | 0.829 | 425.50 | 1.419 | 638.10 | 1.290 | 621.80 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Discussion

### 40 DAYS AFTER PLANTING (DAP)

Plants were sampled at 40 DAP to coincide with storage root initiation and bulking root formation i.e. the stage when early adventitious roots initiate and then begin bulking to form sweetpotato storage roots (Wilson 1982). Results in Table 4, show that there are no differences between treatments for B weight, B count, S count and Plant weight. For the A, I and potential marketable (A+I+S) and the Total number of roots significant differences were found.

*Thin vine (treatment 1)*
For A roots T1 produced less roots than T3 and was not different to any other treatment. For I roots T1 produced more roots than T7 (Treatments 7 Flat shallow) and T8 (Treatment 8 Flat short). For AIS roots T1 produced less roots than T3 only. For Total roots T1 produced more roots than T4 (Treatment 4 Very short vertical) and T8 and had less roots than T3 and T9. The results for T1 are surprising as anecdotal evidence from growers suggested that thin vine often establishes poorly. This is not strongly supported by these results.

*Vine pigmentation (treatment 2)*
T2 was not different to Industry standard (T9) or for that matter the treatment with the highest numbers for any of the following categories A, I, S, AIS and Total counts, therefore T2 has performed comparably to the best treatment and the industry standard.

T2 had more A, AIS and T than T4 and more Total counts than T8 and T5 (Treatment 5 Short vertical). T4, T5 and T8 are all short treatments with less nodes in the ground and this result is expected. The pigmented treatment does not appear to have any root count or weight penalties at this sampling time. It was expected pigmented vine might establish faster as it is sun hardened and some literature suggests the pigmentation is due to excess assimilate being converted to anthocyanin (Kano and Mano 2002). Spence and Humphries (1971) found that when the sink potential of the roots is limited by over watering the leaves are more purple and this is thought to be due to an accumulation of anthocyanin in the leaf lamina suggesting anthocyanin is an assimilate sink only when other plant sinks cannot accept assimilate and is often related to stress. As the plant is in the process of producing anthocyanin and is not physiologically prepared to redirect assimilate into adventitious roots it may take longer to adjust the assimilate sink. This adjustment time may also be due to the stressed vine having lower levels of IAA the main compound needed for early adventitious root development. This experiment does not support these arguments.

*Pre-rooted (treatment 3)*
T3 produced the maximum root count in the A, AIS and Total count categories and second highest for I. In none of the counts was T3 significantly different to the industry standard (T9). This suggests that pre-rooting cuttings has not improved early plant establishment at this stage of the crop compared to the industry standard. With the exception of the short treatments T4 and T8, T3 does not consistently produce more roots across all categories. This suggests there has been no response to using pre-rooted cuttings and does not support the findings of Lewthwaite (1999) who found that sprouts held in air for six days to have significantly better plant establishment and higher yield at 53 days than sprouts treated with nutrient solution, held for 6 days, held for 9 or treated with anti-transpirant. Lewthwaites research suggests that plant material that is planted with the ability to absorb nutrient and water (via small roots) is an improvement over a conventional cutting. The experiment conducted by Lewthwaite was in a non-irrigated system and this may explain why a response was measured compared with our research in an irrigated system that suffered very little early establishment stress due to rainfall and irrigation events.

*Short Length and Reduced nodes (treatments 4, 5 and 8)*
T4, T5 and T8 were the 3 shortest vine lengths in the experiment and had less I, A+I+S and Total roots than Industry standard (T9). These results show that a short vine length regardless of orientation is not producing the root numbers of the longer vine with more nodes in the ground. Whether this is caused by reduced root primordia (i.e. sites where roots initiate at the nodes) as there are less nodes in the soil or it is due to lower leaf area at or just after planting is not known. However for commercial production this confirms the findings of Experiment 2 in 2003 that showed a short cutting (< 30 cm) produces less potential marketable roots in the early establishment phase.

### 68 DAYS AFTER PLANTING (DAP)

At 68 DAP T7 had a much higher marketable count than all other treatments. Although a previous experiment on this site (Experiment 1 2003) showed flat planting to produce higher numbers of marketable roots than a range of other treatments as large a difference as this was not expected. In this experiment T7 was planted very shallow i.e. 25 mm and early plant establishment was expected to be retarded by high soil temperatures at or just after planting. However in this experiment any effect of high soil temperatures may have been reduced by rainfall at 1 and 4 DAP. This result suggests that flat planting has the potential to substantially increase the number of marketable roots produced. For Total root counts all treatments with the exception of the short treatments (T4, T5, and T8) were the same as Industry standard (T9). These results confirm that short planting material has less yield potential than all other treatments. This again confirms that a key plant material selection criteria is length.

### 208 DAYS AFTER PLANTING (DAP)

The 208 DAP sampling showed no significant differences between treatments. Three treatment plots were accidentally harvested by the grower and a REML analysis was performed due to it's lack of normality. This crop was grown over winter and it is possible that more advanced treatments were limited by environmental conditions allowing other treatments to improve and catch up by 208 DAP.

## Conclusion

This experiment has confirmed the findings of Experiment 2 in 2003 that short cuttings have the potential to reduce yield and furthermore shows that planting shorter cuttings either flat or vertically does not improve their performance.

This experiment has also confirmed that flat planting is either comparable to or slightly better than the industry standard planting method.

Although pre rooted vine had high counts of roots particularly at 40 DAP these did not show a major improvement over the industry standard. There appeared to be few trends supporting or rejecting the use of pigmented, thin, or pre-rooted vine.

Establishment differences that were measurable at early establishment once again were not all found at the final sampling. This is most probably due to missing plots at the 208 DAP sampling and may also be due to limitation of this cultivar due to season, location, leaf area competition, moisture etc. Our understanding of the cultivars yield capacity has since been modified as a result of this project and it is expected if an experiment such as this was repeated a 120 DAP sampling would be more suitable for measuring these differences.

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# Experiment 4. Physiology of sweetpotato planting technique and depth 19th January 2004 to 12th October 2004

## Introduction

An earlier experiment in 2003 had suggested that large gains in final root quality could be obtained by planting cuttings horizontally (flat planting). At the time, the industry standard was to push the cutting into the ground with a stick so that the underground portion resembled the shape of a V with the leafy end protruding from the ground. There was some concern that flat planting while showing promise as a means of improving quality may expose the early adventitious roots to excess heat at all nodes. The aim of this experiment was to test establishment of the new flat planting technique and the industry standard V plant under hot conditions. A seedling treatment was also tested as an earlier experiment had shown some early establishment gains.

## Methodology

### Fertiliser

Nutrients (kg/ha) added and dates applied are shown in Table 1.

**Table 1. Fertiliser added to experimental area**

| Fertiliser | Date applied | N | P | K | S | Mg | Ca | Zn | Fe | B | Mn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| Hydrocomplex | 11/01/04 | 104 | 43 | 130 | 69 | 14 | 22 | 0.17 | 1.7 | 0.13 | 0.17 |
| | | | | | | | | | | | |
| Hydrocomplex | 15/02/04 | 30 | 12 | 37 | 20 | 4 | 6 | 0.005 | 0.05 | 0.037 | 0.005 |
| | | | | | | | | | | | |
| Total | | 134 | 55 | 167 | 89 | 18 | 28 | 0.22 | 1.85 | 0.167 | 0.175 |

### Treatments

The experimental design was a randomized block with three replicates and a factorial treatment structure.

Treatments applied combined four planting methods with two vine lengths (45 cm and 60 cm) giving a total of eight treatments (see Table 2).

Treatment plots were six metres long with treatments running down the row. Each datum row (rep) was separated by guard rows resulting in a 1.5 metre buffer between datum rows as show in Diagram 1.

**Diagram 1.** Trial plan layout

| Guard row | Datum row 1 | Guard row | Datum row 2 | Guard row | Datum row 3 | Guard row |
|---|---|---|---|---|---|---|
| | 8 | | 2 | | 7 | |
| | 2 | | 7 | | 8 | |
| | 5 | | 4 | | 1 | |
| | 6 | | 6 | | 2 | |
| | 4 | | 8 | | 6 | |
| | 3 | | 3 | | 5 | |
| | 1 | | 1 | | 3 | |
| | 7 | | 5 | | 4 | |

**Table 2.** Treatment descriptions

| Treatment Number | Treatment applied |
|---|---|
| 1. | **60 cm** V *shape to depth of 100 mm |
| 2. | **60 cm** flat** shallow at 25 mm |
| 3. | **60 cm** flat deep at 50 mm |
| 4. | **60 cm** seedling*** (5 days) |
| 5. | **45 cm** V shape to depth of 100 mm |
| 6. | **45 cm** flat shallow at 25 mm |
| 7. | **45 cm** flat deep at 50 mm |
| 8. | **45 cm** seedling (5 days) |

*V shape refers to placing the cutting across the row and pushing the cutting in to the desired depth with a pole resulting in a V shape planting.
**Flat refers to placing cutting into a trench of desired depth and covering with soil by hand
***Seedlings consisted of vines planted in a 100x50x50 mm seedling container and grown for 5 days before planting. By planting seedlings had adventitious roots approximately 2-4 cm long

**Planting**
Trial was planted 19/01/2004 at 30 cm plant spacing.

All datum row plants were planted with seedbed vine grown at Gatton research station using pathogen tested sweetpotatoes from plants taken out of pathogen tested tissue culture in 2003. Datum row plants were planted ensuring all treatments had three nodes underground. In guard rows cuttings were V planted using poles.

**Irrigation**
Immediately following planting the trial block was overhead irrigated for one hour. During crop growth the experimental block was overhead irrigated at the cooperating growers'

commercial schedule. In this production area irrigation is used as a supplement to rainfall events.

**Sampling**

Treatment plots were sampled at 30, 63 and 256 DAP (Days After Planting). A four plant sub sample was taken from the southern end of each plot at each sampling time; two plants in the plot were left as buffers for the next four plant sub sample. For the 30 and 63 DAP samplings the roots at each of the first three nodes were sorted, counted and weighed as shown in Table 3. In the 30 DAP sampling fresh weight of tops (leaf and stem) was also recorded.

**Table 3**

| **Root type*** | **Number** | **Weight** |
|---|---|---|
| Adventitious (A) | x | |
| Initiated (I) | x | |
| Setting (S) | x | |
| Bulking (B) | x | x |

*Adventitious roots: thick white lateral roots that develop from the nodes after planting
Initiated roots: adventitious roots that had started to develop pigmentation
Setting roots: roots that had developed full pigmentation and had not started to bulk ie < 5 mm diameter
Bulking roots: roots that had started to bulk ie >5 mm diameter

For the 256 DAP sampling roots at each of the three nodes were sorted into Undersize, Small, Medium, Large, Second and Reject grades, counted and then weighed as shown in Table 4. Small, Medium, Large, Second and Reject grades were defined as per commercially available product specifications. The commercial evaluation used a grading system based on dimensions (length and diameter). If an individual sweetpotato could not be distinguished from its nearest grade by dimensions, weight was then used.

**Table 4. 256 DAP sampling criteria**

| **Grade** |
|---|
| Small (S): Length 130-180 mm, Diameter 50-60 mm, weight 170-310 g |
| Medium (M): Length 180-250 mm, Diameter 60-75 mm, weight 310-620 g |
| Large (L): Length greater than 250 mm long and/or diameter greater than 75 mm, weight 620-860 g |
| Undersize: Length shorter than 130 mm diameter less than 50 mm, weight 63-170 g |
| Second Grade: S+M+L(shape does not meet first grade specification) |
| Reject Grade |

## Temperature measurement

One set of tiny tag temperature probes were placed in the centre of the experimental block at 25 mm, 50 mm and 100 mm depths. Temperature readings were automatically recorded every 15 minutes. Maximum daily soil and ambient air temperature recordings taken for the first 35 days after planting are shown in Figure 1.

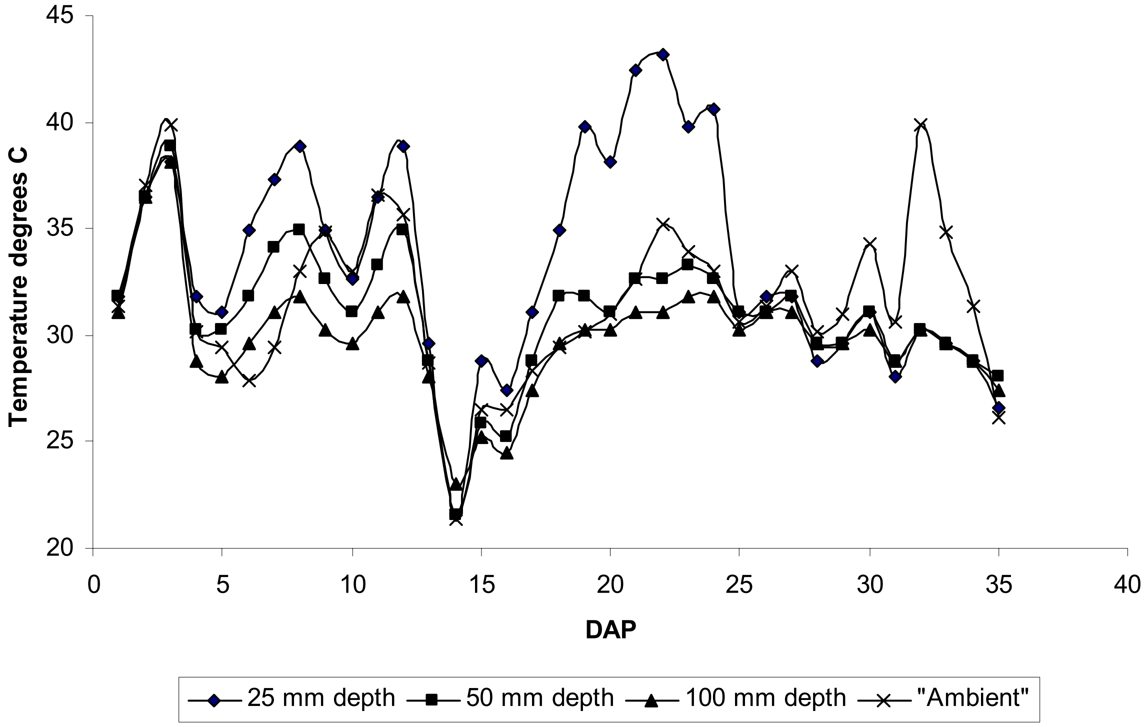

**Figure 1.** Maximum Daily Soil and Ambient (Air) Temperature.

Each temperature recording is from one probe only. The drop in temperatures experienced on day 14 was a result of a 75 mm rainfall event. There were no further rainfall events until after day 35.

## Statistical Analysis

Results for the three samplings (30 DAP, 63 DAP and 256 DAP) were analysed using Analysis of Variance (ANOVA). A square root transformation of the data was used as the data displayed a lack of normality. The analysis results are shown in Tables 5 to 8.

### Table 6. 30 DAP treatment effects per plant square root transformed with back transformed data represented in brackets(weights are in grams)

| Treatment | Top Wt (whole plant) | | Root counts | | | | | | | | | | Root weights | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | A | | I | | S | | A+I+S | | B | | B | |
| **Length** | | | | | | | | | | | | | | |
| 45 | 12.94 | (167.4) | 1.95 | (3.8) | 1.44 | (2.1) | 1.60 | (2.6) | 3.14 | (9.9) | 1.26 | (1.6) | 2.48 | (6.2) |
| 60 | 13.67 | (186.9) | 1.99 | (3.9) | 1.74 | (3.0) | 1.55 | (2.4) | 3.27 | (10.7) | 1.66 | (2.7) | 3.78 | (14.3) |
| F test | P=0.060 | | n.s. | | n.s. | | n.s. | | n.s. | | * | | ** | |
| LSD (P=0.05) | 0.76 | | 0.42 | | 0.37 | | 0.41 | | 0.20 | | 0.38 | | 0.73 | |
| **Planting Method** | | | | | | | | | | | | | | |
| Flat deep 50 mm | 12.64 | (159.8) | 2.13 | (4.5) | 1.59 | (2.5) | 1.41 | (2.0) | 3.21 | (10.3) | 1.31 | (1.7) | 2.76 | (7.6) |
| Flat shallow 25 mm | 10.89 | (118.6) | 1.45 | (2.1) | 1.43 | (2.0) | 1.64 | (2.7) | 2.84 | (8.0) | 1.04 | (1.1) | 1.85 | (3.4) |
| Seedling | 16.09 | (258.9) | 2.05 | (4.2) | 1.52 | (2.3) | 1.41 | (2.0) | 3.20 | (10.2) | 2.05 | (4.2) | 5.36 | (28.7) |
| V shape | 13.60 | (185.0) | 2.23 | (5.0) | 1.83 | (3.3) | 1.86 | (3.4) | 3.57 | (12.7) | 1.45 | (2.1) | 2.55 | (6.5) |
| F test | *** | | P=0.055 | | n.s. | | n.s. | | *** | | ** | | *** | |
| LSD (P=0.05) | 1.07 | | 0.59 | | 0.53 | | 0.58 | | 0.21 | | 0.53 | | 1.03 | |
| **Length X Planting Method** | | | | | | | | | | | | | | |
| 45 cm length | | | | | | | | | | | | | | |
| x Flat deep 50 mm | 12.43 | (154.5) | 2.39 | (5.7) | 1.56 | (2.4) | 1.62 | (2.6) | 3.50 | (12.2) | 0.80 | (0.6) | 1.61 | (2.6) |
| x Flat shallow 25 mm | 10.54 | (111.1) | 1.40 | (2.0) | 1.06 | (1.1) | 1.44 | (2.1) | 2.57 | (6.6) | 1.08 | (1.2) | 1.51 | (2.3) |
| x Seedling | 15.08 | (227.4) | 1.93 | (3.7) | 1.46 | (2.1) | 1.47 | (2.1) | 3.03 | (9.2) | 1.88 | (3.5) | 4.65 | (21.6) |
| x V shape | 13.73 | (188.5) | 2.07 | (4.3) | 1.67 | (2.8) | 1.88 | (3.5) | 3.46 | (12.0) | 1.30 | (1.7) | 2.13 | (4.5) |
| 60 cm length | | | | | | | | | | | | | | |
| x Flat deep 50 mm | 12.85 | (165.1) | 1.87 | (3.5) | 1.61 | (2.6) | 1.19 | (1.4) | 2.93 | (8.6) | 1.81 | (3.3) | 3.91 | (15.3) |
| x Flat shallow 25 mm | 11.25 | (126.6) | 1.51 | (2.3) | 1.80 | (3.2) | 1.83 | (3.4) | 3.10 | (9.6) | 1.00 | (1.0) | 2.19 | (4.8) |
| x Seedling | 17.11 | (292.8) | 2.17 | (4.7) | 1.59 | (2.5) | 1.36 | (1.8) | 3.36 | (11.3) | 2.22 | (4.9) | 6.06 | (36.7) |
| x V shape | 13.46 | (181.2) | 2.39 | (5.7) | 1.99 | (3.9) | 1.83 | (3.3) | 3.68 | (13.5) | 1.60 | (2.6) | 2.97 | (8.8) |
| F test | n.s. | | n.s. | | n.s. | | n.s. | | ** | | n.s. | | n.s. | |
| LSD (P=0.05) | 1.52 | | 0.84 | | 0.75 | | 0.82 | | 0.41 | | 0.76 | | 1.46 | |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

### Table 7. 63 DAP treatment effects per plant square root transformed with back transformed data represented in brackets (weights are in grams)

| | Root counts | | | | | Root weights |
|---|---|---|---|---|---|---|
| | A | I | S | A+I+S | B | B |
| **Length** | | | | | | |
| 45 | 1.46 (2.1) | 1.03 (1.1) | 1.12 (1.3) | 2.33 (5.4) | 2.87 (8.3) | 21.03 (442.3) |
| 60 | 2.13 (4.5) | 1.36 (1.8) | 1.24 (1.5) | 3.00 (9.0) | 3.24 (10.5) | 23.21 (538.7) |
| F test | *** | * | n.s. | *** | ** | P=0.050 |
| LSD (P=0.05) | 0.29 | 0.31 | 0.36 | 0.26 | 0.26 | 2.18 |
| **Planting Method** | | | | | | |
| Flat deep 50 mm | 2.20 (4.9) | 1.43 (2.1) | 1.27 (1.6) | 3.05 (9.3) | 3.37 (11.4) | 22.46 (504.5) |
| Flat shallow 25 mm | 1.41 (2.0) | 0.97 (0.9) | 1.18 (1.4) | 2.32 (5.4) | 2.81 (7.9) | 19.62 (384.9) |
| Seedling | 2.15 (4.6) | 1.30 (1.7) | 1.25 (1.6) | 3.07 (9.4) | 2.96 (8.7) | 24.63 (606.6) |
| V shape | 1.40 (2.0) | 1.07 (1.1) | 1.01 (1.0) | 2.21 (4.9) | 3.10 (9.6) | 21.76 (473.5) |
| F test | *** | n.s. | n.s. | ** | * | * |
| LSD (P=0.05) | 0.41 | 0.43 | 0.50 | 0.37 | 0.37 | 3.09 |
| **Length X Planting Method** | | | | | | |
| 45 cm length | | | | | | |
| x Flat deep 50 mm | 1.98 (3.9) | 1.37 (1.9) | 1.14 (1.3) | 2.80 (7.8) | 3.24 (10.5) | 22.88 (523.5) |
| x Flat shallow 25 mm | 0.78 (0.6) | 0.42 (0.2) | 0.88 (0.8) | 1.54 (2.4) | 2.33 (5.4) | 17.46 (304.9) |
| x Seedling | 1.85 (3.4) | 1.28 (1.6) | 1.23 (1.5) | 2.85 (8.1) | 2.97 (8.8) | 24.16 (583.7) |
| x V shape | 1.23 (1.5) | 1.05 (1.1) | 1.24 (1.5) | 2.11 (4.5) | 2.95 (8.7) | 19.61 (384.6) |
| 60 cm length | | | | | | |
| x Flat deep 50 mm | 2.42 (5.9) | 1.49 (2.2) | 1.40 (2.0) | 3.30 (10.9) | 3.50 (12.3) | 22.04 (485.8) |
| x Flat shallow 25 mm | 2.05 (4.2) | 1.52 (2.3) | 1.48 (2.2) | 3.10 (9.6) | 3.29 (10.8) | 21.77 (473.9) |
| x Seedling | 2.57 (6.6) | 1.32 (1.8) | 1.28 (1.6) | 3.29 (10.9) | 2.94 (8.7) | 25.11 (630.5) |
| x V shape | 1.58 (2.5) | 1.09 (1.2) | 0.79 (0.6) | 2.30 (5.3) | 3.25 (10.5) | 23.92 (572.2) |
| F test | n.s. | P=0.053 | n.s. | ** | P=0.070 | n.s. |
| LSD (P=0.05) | 0.58 | 0.61 | 0.71 | 0.52 | 0.52 | 4.37 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

### Table 8. 256 DAP root weights per plant square root transformed with back transformed data represented in brackets (weights are in grams)

| | Small | | Medium | | Large | | Undersize | | Second | | Reject | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Length** | | | | | | | | | | | | | | |
| 45 | 9.6 | (92) | 13.4 | (180) | 3.0 | (9) | 3.7 | (14) | 13.9 | (193) | 22.0 | (484) | 39.3 | (1545) |
| 60 | 10.2 | (103) | 15.0 | (225) | 5.3 | (28) | 5.7 | (33) | 16.7 | (279) | 21.5 | (461) | 42.1 | (1776) |
| F test | n.s. | | n.s. | | n.s. | | P=0.088 | | n.s. | | n.s. | | * | |
| LSD (P=0.05) | 3.9 | | 4.7 | | 4.3 | | 2.4 | | 4.7 | | 2.8 | | 2.1 | |
| **Planting Method** | | | | | | | | | | | | | | |
| Flat deep 50 mm | 14.6 | (212) | 18.0 | (324) | 6.9 | (48) | 9.2 | (84) | 15.3 | (234) | 17.1 | (293) | 42.8 | (1834) |
| Flat shallow25 mm | 11.4 | (129) | 20.6 | (424) | 2.5 | (6) | 4.7 | (22) | 19.1 | (365) | 16.2 | (263) | 41.0 | (1678) |
| Seedling | 2.2 | (5) | 4.0 | (16) | 3.8 | (14) | 0.0 | (0) | 12.3 | (151) | 33.1 | (1096) | 40.9 | (1675) |
| V shape | 11.4 | (130) | 14.2 | (202) | 3.4 | (12) | 4.9 | (24) | 14.5 | (210) | 20.5 | (421) | 38.2 | (1458) |
| F test | ** | | *** | | n.s. | | *** | | n.s. | | *** | | * | |
| LSD (P=0.05) | 5.5 | | 6.7 | | 6.0 | | 3.4 | | 6.7 | | 3.9 | | 3.0 | |
| **Length X Planting Method**[2] | | | | | | | | | | | | | | |
| F test | n.s. | | n.s. | | n.s. | | n.s. | | n.s. | | ** | | * | |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

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[2] Interaction means for rejects and total weight included in Table10

### Table 9. 256 DAP root counts per plant square root transformed with back transformed data represented in brackets

| | Small | | Medium | | Large | | Undersize | | Second | | Reject | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Length** | | | | | | | | | | | | | | |
| 45 | 0.617 | (0.38) | 0.624 | (0.39) | 0.104 | (0.01) | 0.374 | (0.14) | 0.947 | (0.90) | 2.130 | (4.54) | 2.874 | (8.26) |
| 60 | 0.645 | (0.42) | 0.730 | (0.53) | 0.184 | (0.03) | 0.533 | (0.28) | 1.077 | (1.16) | 2.208 | (4.88) | 3.064 | (9.39) |
| F test | n.s. | | n.s. | | n.s. | | n.s. | | n.s. | | n.s. | | * | |
| LSD (P=0.05) | 0.238 | | 0.219 | | 0.148 | | 0.204 | | 0.279 | | 0.277 | | 0.179 | |
| **Planting Method** | | | | | | | | | | | | | | |
| Flat deep 50 mm | 0.943 | (0.89) | 0.844 | (0.71) | 0.243 | (0.06) | 0.911 | (0.83) | 1.089 | (1.19) | 1.979 | (3.92) | 3.121 | (9.74) |
| Flat shallow 25 mm | 0.717 | (0.51) | 0.967 | (0.94) | 0.083 | (0.01) | 0.416 | (0.17) | 1.225 | (1.50) | 2.030 | (4.12) | 3.021 | (9.13) |
| Seedling | 0.125 | (0.02) | 0.184 | (0.03) | 0.125 | (0.02) | 0.000 | (0.00) | 0.748 | (0.56) | 2.409 | (5.80) | 2.707 | (7.33) |
| V shape | 0.738 | (0.54) | 0.711 | (0.51) | 0.125 | (0.02) | 0.489 | (0.24) | 0.986 | (0.97) | 2.257 | (5.09) | 3.027 | (9.16) |
| F test | *** | | *** | | n.s. | | *** | | n.s. | | n.s. | | * | |
| LSD (P=0.05) | 0.336 | | 0.310 | | 0.209 | | 0.288 | | 0.394 | | 0.392 | | 0.253 | |
| **Length X Planting Method**[3] | | | | | | | | | | | | | | |
| F test | n.s. | | n.s. | | n.s. | | n.s. | | n.s. | | P=0.090 | | * | |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

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[3] Interaction data for rejects and total weight included in table10

**Table 10. 256 DAP Interaction for counts and weights of rejects and total root s per plant (weights are in grams)**

| | Reject number | | Reject weight | | Total number | | Total weight | |
|---|---|---|---|---|---|---|---|---|
| **Length X Planting Method** | | | | | | | | |
| 45 | | | | | | | | |
| Flat deep 50 mm | 2.17 | (4.7) | 21.05 | (443.1) | 3.12 | (9.7) | 43.02 | (1850.7) |
| Flat shallow 25 mm | 1.72 | (2.9) | 12.11 | (146.7) | 2.69 | (7.2) | 36.31 | (1318.4) |
| Seedling | 2.42 | (5.9) | 35.72 | (1275.9) | 2.67 | (7.1) | 39.92 | (1593.6) |
| V shape | 2.21 | (4.9) | 19.19 | (368.3) | 3.03 | (9.2) | 37.98 | (1442.5) |
| 60 | | | | | | | | |
| Flat deep 50 mm | 1.79 | (3.2) | 13.20 | (174.2) | 3.13 | (9.8) | 42.63 | (1817.3) |
| Flat shallow 25 mm | 2.35 | (5.5) | 20.35 | (414.1) | 3.36 | (11.3) | 45.60 | (2079.4) |
| Seedling | 2.40 | (5.7) | 30.50 | (930.3) | 2.75 | (7.5) | 41.95 | (1759.8) |
| V shape | 2.31 | (5.3) | 21.85 | (477.4) | 3.03 | (9.2) | 38.40 | (1474.6) |
| F test | P=0.090 | | ** | | * | | * | |
| LSD (P=0.05) | 0.55 | | 5.52 | | 0.36 | | 4.27 | |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Results and Discussion

### 30 DAYS AFTER PLANTING (DAP)

*Treatment effects*

Plants were sampled at 30 DAP to coincide with storage root initiation i.e. the stage when early adventitious roots initiate and start to form sweetpotato storage roots (Wilson 1982). Results in Table 6 show a difference in the number and weight of bulking roots for the [4]45 and 60 cm lengths with the longer cutting producing more bulking roots. This is not unexpected as higher leaf areas enable the plant to produce more assimilate for subsequent conversion into starch. Significantly higher numbers and weight of bulking roots were also produced by the Seedling at 30 DAP compared with other planting methods. The Seedling treatment was propagated in a greenhouse for 5 days prior to planting in the field and would not have experienced the same level of transplant shock as bare root cuttings. The Seedling treatment top weight and root weight was also much higher than all other treatments and suggests that this is an establishment option that may be of some interest to industry. Bouwkamp and Hassam (1988) have shown there is a strong yield correlation between the amounts of vine and the amount of storage roots produced in sweetpotato and our data here suggests that this is particularly the case during the very early plant establishment phase (0-5 days).

There is some evidence that Adventitious root numbers were lower for Flat shallow than other planting methods (P=0.055). As shown in Figure 1 soil temperatures at the 25 mm depth are often up to 10 degrees higher than the 50 and 100 mm depth until 25 DAP. It is suggested these excessive soil temperatures appear to be reducing the plants ability to develop adventitious roots. Spence and Humphries (1971) found for the cultivar C9/9 that root zone temperatures between 20 and 30 ºC produced the highest rate of storage root development while temperatures below 15 and above 35 ºC retarded storage root development. This difference is most probably due to poor starch synthesis. Most cultivars have an ideal temperature range for the necessary enzyme to convert sugars to starches. If this temperature is exceeded assimilate is often directed to top growth. In this experiment there was significantly lower top weight produced by the Flat shallow 25 mm planting method than for all other planting methods. This suggests that the growth limitation caused by high temperature is not linked to starch synthesis. Pardales et al (1999) demonstrated that root zone temperatures of 40 ºC or higher can result in overall reduced length and development in adventitious roots and any development that does occur tends to be greater at deeper nodes (lower soil temp). In this experiment the 25 mm planting depth may well have exceeded the optimum temperature required for healthy adventitious root growth.

The 25 mm depth also shows the heat sink effect of soil. The soil temperature in the 25 mm depth was consistently above the ambient air temperature until 25 DAP. Reduction in soil temperature after 25 DAP is assumed due to leaf growth covering the soil surface.

*Interactions*

An interaction between planting method and cutting length was also observed. The Flat shallow 25 mm treatment with 45 cm cutting length had significantly less AIS (adventitious initiating and setting or [5]potential marketable roots) than the 60 cm cutting length. It would appear that the longer cutting is ameliorating the reductions seen in the shorter cutting. As discussed earlier the additional leaf area of the longer cutting enables the plant to produce more assimilate for subsequent conversion into starch.

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[4] The four planting methods were tested as a 45 cm and 60 cm long cutting

[5] A combination of adventitious initiating and setting root numbers in early plant establishment ie 0 to 60 days has been used to measure the number of roots that have the potential to continue to the bulking phase and have been called potential marketable roots.

The interaction for the Flat deep 50 mm treatment was the opposite of the Flat shallow 25 mm. The Flat deep 50 mm cutting produced significantly less AIS when planted as a long cutting (60 cm) compared with a shorter cutting (45 cm). This result is unexpected and by 63 DAP the results for the Flat deep treatment had reversed with the longer cutting producing more AIS roots than the shorter cutting.

Comparing the 60 cm cutting treatment lengths the V-shape treatment had greater numbers of AIS than both the flat treatments. A possible explanation for this effect in the V-shape is the greater planting depth of node 2 and hence less exposure of at least 1 node to the higher temperatures experienced in the shallower depths (Figure 1) of the Flat treatments. The Seedling 60 cm treatment was only greater than the Flat deep 60 cm treatment. This result is unexpected for the Seedling as it has had a longer establishment period under optimal conditions.

## 63 DAYS AFTER PLANTING (DAP)

### *Treatment effects*

Plants were sampled at 63 DAP to coincide with the rapid bulking phase of storage root development. Results in Table 7 show a significant difference in the weight of bulking roots for the 45 and 60 cm lengths with the longer cutting producing a larger quantity of bulking roots, higher numbers of adventitious and initiating roots. This result is similar to that found at 30 DAP and as explained previously is not unexpected as higher leaf areas enable the plant to produce more assimilate for subsequent conversion into starch (Bouwkamp et al 1988).

Results in Table 7 also show the Flat shallow treatment had significantly less bulking root weight than the Seedling treatment. The Flat deep treatment had higher bulking root counts than the Flat shallow and Seedling treatments. Furthermore the Seedling and Flat deep 50 mm treatment had significantly higher numbers of adventitious roots than the other treatments. This suggests that the Flat deep 50 mm treatment regardless of length has by 63 DAP a well established root system and has equalled any advantage the Seedling treatment may have had in early plant establishment.

### *Interactions*

The interactions seen at 63 DAP are now well defined as the Flat shallow 25 mm x 45 cm treatment has significantly less AIS and [6]bulking roots than all other treatments. Similarly to the 30 DAP results the 60 cm long cutting appears to be improving the number of AIS roots produced by the Flat shallow 25 mm treatment.

It is worth noting that when comparing cutting lengths the V shape 45 cm cutting length treatment produced more AIS roots then the Flat shallow 25 mm treatment but less than the Seedling and Flat deep 45 cm treatments. When planted as a 60 cm length cutting the V shape treatment produced less than all other 60 cm cutting length treatments (except for bulking root numbers and weights). The reduction in AIS roots for the V shape treatment is thought due to the way the V shape planting technique results in 2 nodes close to the surface and hence may be experiencing heat effects similar to the Flat shallow 25 mm treatment.

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[6] Bulking root interaction (P=0.070)

### 256 DAYS AFTER PLANTING (DAP)

Final sampling yields (Table 8) and counts (Table 9) for all bulking roots were taken at 256 DAP which is well past normal maturity for Beauregard (120 DAP). The reason for the late sampling is at this time of year the crop had to bulk in the coolest months of the year and hence the time to commercial maturity has been extended. The Flat shallow 25 mm treatment which had reduced vigour at the earlier sampling times of 30 and 60 DAP has now improved with less rejects than Seedling and V-shape and only different to Flat deep for the less important size grade of undersize. The Small and Medium weight categories for the Seedling treatment had significantly less weights and counts than for all other treatments. The Seedling treatment had significantly higher weights of Rejects than all other treatments due to roots being twisted and bent and is clearly shown in Figure 2. This affect on shape is due to the constriction of the seedling in it's container before transplanting and confirms previous research (Ching 2000) that shows any restriction to adventitious roots in early plant establishment translates to poorly shaped storage roots later. Total yield of all grades (Table 8) was significantly higher for 60 cm cuttings than the 45 cm cuttings regardless of the planting method used.  This affect of extra vine at planting further reinforces the findings at 30 and 63 DAP and confirms the importance of maintaining as many healthy leaves at and just after planting as possible.

**Figure 2.** 256 DAP Sample for T8 (Seedling 45 cm), T5 (Vshape 45 cm) and T7 (Flat deep 45 cm) showing root shape.

## Conclusion

When planting with a flat orientation a planting depth of 50 mm helps to buffer the plant from the impact of soil heat in summer plantings. Flat planting also has the potential to improve overall root shape and quality by reducing root crowding around the nodes.

Seedlings establish well and attain bulking roots much earlier than conventionally planted vine however as the early adventitious roots can quickly become confined in the seedling container there seems little merit for this technique to be adopted in Australia.

The impact of different length cuttings and the ability of the extra vine to reduce the impact of other detrimental impacts on the plant clearly demonstrate the importance of leaf area at or just after planting. This result shows that the industries current approach to weed control where many leaves can be destroyed early using contact herbicides is potentially increasing time to maturity and the ability of the plant to establish large number of adventitious roots after planting. This is possibly one of the most important findings of the project.

Establishment differences that were measurable at early establishment once again were not all found at the final sampling. This has been a common theme in the project and suggests the use of sampling in the early establishment phase is a sound experimental technique. Previous research where data was only recorded at final commercial harvests does not reflect what we now understand as optimal maturity for the cv Beauregard i.e. 120 days. Hence limiting this cultivar due to season, location, leaf area competition, moisture etc has restricted our understanding of the yield capacity of the cultivar to date. It is our belief that rapidly establishing treatments are being limited by the production system we were using. Experiment 7 conducted in a non-limiting environment provides a true indication of yield potential of the cv Beauregard.

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# Experiment 5. Physiology of Sweetpotato vine type and planting orientation Bundaberg 13th February to September 8th 2004

## Introduction

This was the 5th experiment in a series of experiments conducted during 2003 and 2004. This experiment was planted in February to coincide with typical (high) summer soil temperatures experienced in Australia's sweetpotato production areas. The research team was particularly interested in assessing the effect of summer planting temperatures on flat vine orientation. Experiment 1 in 2003 had suggested that a flat planting had the potential to greatly improve final sweetpotato shape and hence quality. However the research team was concerned that using a flat orientation in summer may expose the early adventitious roots to high soil temperatures resulting in reduction of adventitious roots and or permanent damage. The second part of the experiment was designed to test an assumption that pigmented vine may perform better than non-pigmented vine as it was a common belief among growers that green vine particularly from seed beds was soft and could not handle high temperatures at planting. Further to this there appears to be differing opinions from other authors as to what is causing the anthocyanin accumulation (pigmentation). The third aspect was the comparison to the growers planting method. The grower co-operator selected was and still is recognised as having the highest final product quality in Australia. The comparison with the grower material was therefore used to test if the grower had healthier vine than the pathogen tested vine used for the remainder of the treatments.

## Methodology

The experiment was conducted on a red soil, on a commercial sweetpotato grower's property at South Kolan, Queensland. The experimental area had previously been cropped with sweetpotato for several years. The property manager managed the crop from planting to harvest and the crop was irrigated by trickle irrigation.

### Treatments

The experimental design was a randomized block with four replicates of five treatments in a nested factorial treatment structure. Each plot consisted of two rows of sweetpotatoes 1.5 m wide and 2.7 m long. Plots were separated by guard rows which resulted in a 3 metre buffer between datum rows as show in Diagram 1.

**Diagram 1.** Trial plan layout

| Guard row | Datum Rep 1 | Guard row | Datum Rep 2 | Guard row | Datum Rep 3 | Guard row | Datum Rep 4 | Guard row |
|---|---|---|---|---|---|---|---|---|
| | 5 | | 5 | | 2 | | 3 | |
| | 2 | | 2 | | 1 | | 4 | |
| | 1 | | 3 | | 4 | | 1 | |
| | 3 | | 4 | | 3 | | 2 | |
| | 4 | | 1 | | 5 | | 5 | |

Vine pigment was visually assessed and Figure 1 shows a comparison of pigmented and non-pigmented vine used for the experiment.

**Table 1. Treatment descriptions**

| Treatment Number | Treatment applied |
|---|---|
| 1. | 45 cm Non pigmented vertical* plant to 175 mm |
| 2. | 45 cm Pigmented vertical plant to 175 mm |
| 3. | 45 cm Pigmented flat** plant to 50 mm |
| 4. | 45 cm Non Pigmented flat plant to 50 mm |
| 5. | 30 cm grower control flat plant to 50 mm |
| | *Vertical refers to pushing the cutting into the soil vertically with a stick until the desired number of nodes are under the soil.<br>**Flat refers to placing cutting into a trench of desired depth and covering with soil by hand |

**Figure 1.** Pigmented vine is shown on the left and non-pigmented vine on the right.

### Planting

The experiment was planted 13/02/2004.

In datum rows the vine cuttings were planted ensuring all treatments had three nodes underground and plant spacing was 30 cm. In guard rows cuttings were flat planted by the grower.

All datum row plants were planted with vegetative vine grown at Gatton research station using pathogen tested sweetpotatoes from plants taken out of tissue culture in 2003. The vegetative vine was grown on widely spaced rows to allow runners to grow in the open and develop pigmentation. The vine was taken from these plants and sorted into pigmented and non-pigmented.

Immediately following planting the experiment was trickle irrigated and from then on as per the growers commercial irrigation schedule.

**Sampling**

Treatment plots were sampled at 34, 68 and 208 DAP (Days After Planting). A four plant sub sample was taken from each plot starting at the northern end. At subsequent sampling times, two plants in the plot were left as buffers for the next four plant sub sample working from north to south. For the 34 DAP sampling the roots at each of the first three nodes were sorted, counted and weighed as shown in Table 3. At 34 DAP the fresh weight of tops was also recorded.

**Table 3. 34 DAP sampling criteria**

| Root type* | Number | Weight |
|---|---|---|
| Adventitious (A) | x | |
| Initiated (I) | x | |
| Setting (S) | x | |
| Bulking(B) | x | x |

*Adventitious roots: thick white lateral roots that develop from the nodes after planting
Initiated roots: adventitious roots that had started to develop pigmentation
Setting roots: roots that had developed full pigmentation and had not started to bulk ie < 5 mm diameter
Bulking roots: roots that had started to bulk ie >5 mm

For the 68 DAP sampling the roots at each of the first three nodes were sorted, counted and weighed into two categories i.e. marketable and non-marketable. These categories were based on shape and any roots that were bent or had uneven surfaces were considered to be part of the non marketable category.

For the 208 DAP sampling roots at each of the three nodes were sorted into Small, Medium, Large, Undersize, Second and Reject grades, counted and then weighed as shown in Table 4. Small, Medium, Large Undersize, Second and Reject grades were defined as per commercially available product specifications. The primary evaluation used a grading system based on dimensions i.e. length and diameter. If an individual sweetpotato could not be distinguished from its nearest grade a secondary parameter i.e. weight was used.

**Table 4. 208 DAP sampling criteria**

| Grade |
|---|
| Small (S): Length 130-180 mm, diameter 50-60 mm, weight 170-310 g |
| Medium (M): Length 180-250 mm, diameter 60-75 mm, weight 310-620 g |
| Large (L): Length greater than 250 mm long and/or diameter greater than 75 mm, weight 620-860 g |
| Undersize (U): Length shorter than 130 mm diameter less than 50 mm, weight 63-170 g |
| Second Grade: S+M+L (shape does not meet first grade specification) |
| Reject Grade |

**Temperature measurement**

Tiny tag temperature probes were placed in the centre of the experiment area at 25 mm, 100 mm and 175 mm depths. Temperature readings were automatically recorded every 30 minutes. The temperature recordings taken for the first 35 days after planting are shown in Figure 1.

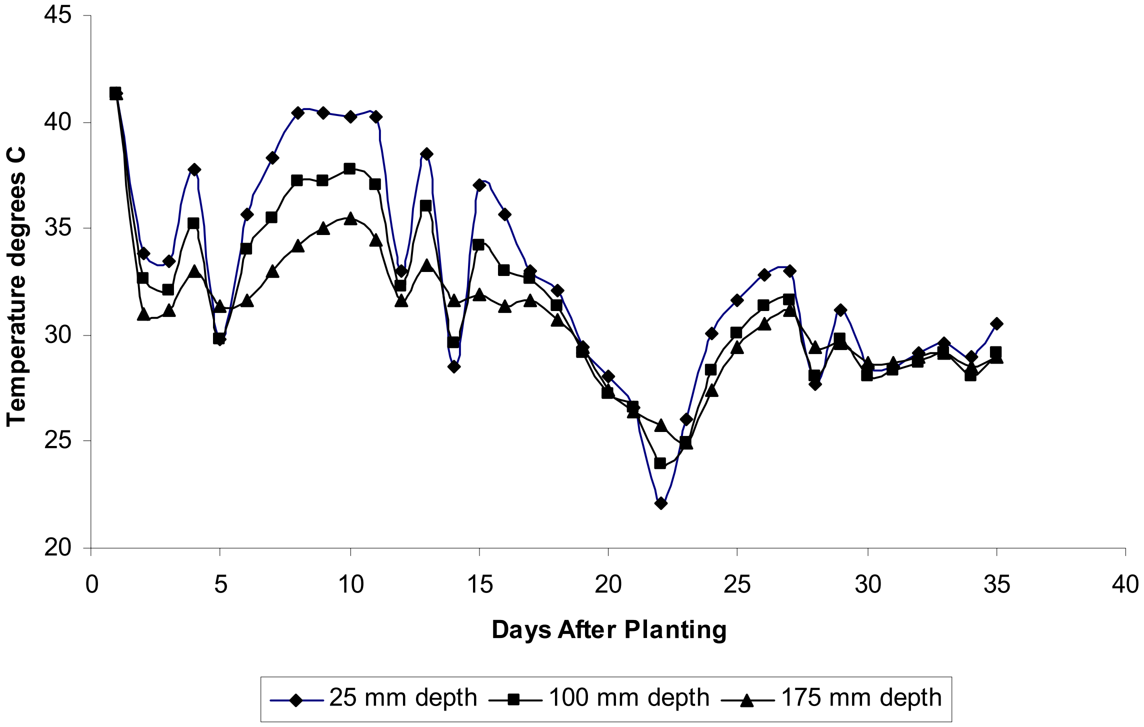

**Figure 1.** Soil temperatures for the first 35 days after planting.

Each temperature recording is from one probe only. Rainfall events occurred on days 5, 14, 19, and 22 to 24. Reflected in significant temperature drops at the three soil depths.

## Statistical Analysis

Results for the three harvest (34, 68 and 208 DAP) were analysed using ANOVA with a nested factorial treatment structure. The analysis results are shown in Tables 5 to 7.

**Table 5. 34 DAP Treatment effects per plant (weights are in grams)**

| **Treatment** | **A** | **I** | **S** | **B** | | **Total** | | **Top Dry Weight** |
|---|---|---|---|---|---|---|---|---|
| | **Count** | **Count** | **Count** | **Count** | **Weight** | **Count** | **Dry Weight** | |
| **Control** | | | | | | | | |
| Grower Control | 5.56 | 1.31 | 2.25 | 1.81 | 4.30 | 10.94 | 0.81 | 112 |
| Mean of all other Treatments | 6.80 | 2.72 | 3.27 | 5.20 | 27.10 | 17.98 | 5.13 | 300 |
| F Value | n.s. | n.s. | P=0.094 | *** | *** | ** | ** | *** |
| LSD (P=0.05) | 1.78 | 1.72 | 1.22 | 1.51 | 11.27 | 3.63 | 2.57 | 51 |
| **Pigmentation** | | | | | | | | |
| Pigmented | 6.00 | 2.25 | 3.25 | 4.25 | 19.20 | 15.75 | 3.19 | 263 |
| Non pigmented | 7.59 | 3.19 | 3.28 | 6.16 | 35.10 | 20.22 | 7.06 | 336 |
| F Value | * | n.s. | n.s. | * | ** | * | ** | ** |
| LSD (P=0.05) | 1.59 | 1.54 | 1.09 | 1.35 | 10.08 | 3.24 | 2.30 | 46 |
| **Orientation** | | | | | | | | |
| Flat plant | 6.16 | 2.47 | 3.16 | 5.63 | 29.60 | 17.41 | 5.44 | 294 |
| Vertical plant | 7.44 | 2.97 | 3.38 | 4.78 | 24.70 | 18.56 | 4.81 | 305 |
| F Value | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| LSD (P=0.05) | 1.59 | 1.54 | 1.09 | 1.35 | 10.08 | 3.24 | 2.30 | 46 |
| **Control X Pigment X Orientation** | *** | n.s. | n.s. | n.s. | n.s. | * | n.s | n.s. |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Table 6. 68 DAP treatment effects per node per plant (weights are in grams)

| Treatment | Marketable root weight |  |  |  | Number of marketable roots |  |  |  | Total weight |  |  |  | Total number of roots |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  | [7]N1 | N2 | N3 | Total | N 1 | N2 | N3 | Total | N1 | N2 | N3 | Total | N1 | N 2 | N3 | Total |
| **Control** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Control | 329.0 | 180.0 | 122.0 | 682.0 | 3.00 | 2.25 | 2.75 | 9.00 | 811.0 | 685.0 | 428.0 | 2092.0 | 10.5 | 11.3 | 11.0 | 35.8 |
| Mean of all other treatments | 612.0 | 538.0 | 236.0 | 1379.0 | 4.73 | 6.69 | 4.31 | 18.20 | 1532.0 | 1209.0 | 569.0 | 3332.0 | 14.2 | 17.1 | 12.1 | 46.2 |
| F Value | P=0.087 | P=0.066 | P=0.076 | * | n.s. | ** | n.s. | * | ** | * | n.s. | ** | n.s. | ** | n.s. | * |
| LSD(P=0.05) | 330.6 | 384.7 | 129.0 | 568.7 | 2.79 | 2.67 | 2.39 | 7.84 | 437.4 | 507.2 | 277.4 | 802.7 | 5.5 | 3.1 | 4.6 | 8.0 |
| **Pigmentation** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Pigmented | 314.0 | 417.0 | 203.0 | 911.0 | 3.09 | 6.12 | 3.88 | 17.50 | 1347.0 | 1081.0 | 583.0 | 3029.0 | 13.9 | 17.1 | 11.6 | 45.8 |
| Non Pigmented | 910.0 | 659.0 | 270.0 | 1847.0 | 6.38 | 7.25 | 4.75 | 19.00 | 1716.0 | 1337.0 | 554.0 | 3636.0 | 14.6 | 17.1 | 12.5 | 46.8 |
| F Value | ** | n.s. | n.s. | ** | * | n.s. | n.s. | n.s. | P=0.062 | n.s. | n.s. | P=0.090 | n.s. | n.s. | n.s. | n.s. |
| LSD(P=0.05) | 295.7 | 344.1 | 115.4 | 508.7 | 2.50 | 2.39 | 2.14 | 7.01 | 391.3 | 453.7 | 248.1 | 718.0 | 4.9 | 2.7 | 4.1 | 7.1 |
| **Orientation** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Flat plant | 591.0 | 386.0 | 395.0 | 1357.0 | 5.09 | 5.62 | 5.75 | 21.40 | 1265.0 | 960.0 | 852.0 | 3122.0 | 14.8 | 15.9 | 16.0 | 52.0 |
| Vertical plant | 632.0 | 690.0 | 78.0 | 1401.0 | 4.38 | 7.75 | 2.88 | 15.10 | 1798.0 | 1457.0 | 286.0 | 3543.0 | 13.8 | 18.4 | 8.1 | 40.5 |
| F Value | n.s. | P=0.078 | *** | n.s. | n.s. | P=0.076 | * | P=0.076 | * | * | *** | n.s. | n.s. | P=0.069 | ** | ** |
| LSD(P=0.05) | 295.7 | 344.1 | 115.4 | 508.7 | 2.50 | 2.39 | 2.14 | 7.01 | 391.3 | 453.7 | 248.1 | 718.0 | 4.9 | 2.7 | 4.1 | 7.1 |
| **Control X Pigment X Orientation** | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | P=0.098 | n.s. | n.s. |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

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[7] N1=node 1, N2=node 2, N3=node 3

**Table 7. 208 DAP Weights and counts per plant (weights are in grams)**

| Treatment | Small | | Medium | | Large | | Undersize | | Second | | Reject | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | Weight | Count | Weight | Count | Weight | Count | Weight | Count | Weight | Count | Weight | Count | Weight |
| **Control** | | | | | | | | | | | | | | |
| Grower Control | 0.31 | 78.00 | 0.56 | 231.00 | 0.00 | 0.00 | 0.50 | 71.00 | 1.25 | 364.00 | 3.75 | 615.00 | 6.31 | 1360.00 |
| Mean of all other treatments | 0.67 | 180.00 | 1.09 | 523.00 | | | 1.67 | 173.00 | 1.67 | 550.00 | 4.75 | 504.00 | 9.64 | 2212.00 |
| F Value | n.s. | n.s. | n.s. | n.s. | | | * | P=0.051 | n.s. | n.s. | n.s. | n.s. | P=0.062 | * |
| LSD | 0.55 | 142.40 | 0.78 | 361.30 | | | 1.14 | 102.60 | 1.15 | 335.40 | 2.28 | 296.40 | 3.52 | 712.20 |
| **Pigmentation** | | | | | | | | | | | | | | |
| Pigmented | 0.50 | 149.00 | 1.03 | 481.00 | 0.28 | 262.00 | 1.44 | 164.00 | 1.78 | 608.00 | 4.81 | 580.00 | 9.56 | 2245.00 |
| Non Pigmented | 0.84 | 211.00 | 1.16 | 565.00 | 0.31 | 301.00 | 1.91 | 182.00 | 1.56 | 492.00 | 4.69 | 428.00 | 9.72 | 2179.00 |
| F Value | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| LSD | 0.49 | 127.40 | 0.70 | 323.20 | 0.37 | 341.00 | 1.02 | 91.70 | 1.03 | 300.00 | 2.04 | 265.10 | 3.15 | 637.00 |
| **Orientation** | | | | | | | | | | | | | | |
| Flat plant | 0.63 | 165.00 | 1.06 | 503.00 | 0.34 | 304.00 | 1.56 | 143.00 | 1.69 | 517.00 | 5.00 | 352.00 | 9.97 | 2165.00 |
| Vertical plant | 0.72 | 195.00 | 1.12 | 543.00 | 0.25 | 259.00 | 1.78 | 203.00 | 1.66 | 582.00 | 4.50 | 477.00 | 9.31 | 2259.00 |
| F Value | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |
| LSD | 0.49 | 127.40 | 0.70 | 323.20 | 0.37 | 341.00 | 1.02 | 91.70 | 1.03 | 300.00 | 2.04 | 265.10 | 3.15 | 637.00 |
| **Control X Pigment X Orientation** | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Results and Discussion

### 30 DAYS AFTER PLANTING (DAP)

*Control*

Plants were sampled at 30 DAP to coincide with storage root initiation i.e. the stage when early adventitious roots initiate and start to form sweetpotato storage roots (Wilson 1982). Results in Table 5 show the Control has significantly lower numbers and weights of B (Bulking) roots, Top weights and T (Total) roots compared to the mean of all other treatments. These differences are highly significant ($P<0.01$) and suggest that the grower control plant material has much less vigour than the other treatments in the early establishment phase.

*Pigmentation*

The pigmented vine (when planted in two different orientations i.e. flat and vertical) has reduced the number and weight of B, Top weight and T root weight. It was assumed that the pigmented[8] vine would establish faster under hot conditions as it is sun hardened and the anthocyanin expression was signalling the presence of excess assimilate due to a high level of plant vigour. Our assumption was based on the finding of (Kano and Mano 2002) who postulated that excess assimilate is converted to anthocyanin when the two main assimilate sinks, i.e. the tops and the roots, cannot accept anymore. Spence and Humphries (1971) however had a slightly different theory and found that when the sink potential of the roots is limited by over watering the leaves accumulated more of the purple pigment. This is thought to be due to an accumulation of anthocyanin in the leaf lamina suggesting anthocyanin is an assimilate sink only when other plant sinks cannot accept assimilate. However in our experiment the root sink was not limited. When the vine was cut non-pigmented and pigmented cuttings were taken off the same plants. The cause of the retardation must therefore be due to an inherent accumulation of some other growth altering substance in the pigmented vine cutting. Therefore our conclusion is that the pigmented vine is expressing a stress symptom that leads to reduced plant establishment when used as planting material. Cuttings off the same plant will behave differently depending on their inherent physiological state leading to uneven establishment and quality in the crop.

*Interaction*

There was an interaction evident for A ($P<0.001$) and T root numbers ($P<0.05$) where vine orientation root counts were altered depending on vine pigmentation. When planted flat there was no difference in A (Pigmented-7.06, Non-pigmented-5.25 LSD 2.25) or T root counts (Pigmented-16.88, Non-pigmented-17.94, LSD 4.59). However when planted in a vertical orientation the pigmented vine produced five less A roots per plant (Pigmented-4.94, Non-pigmented-9.94 LSD 2.25) and eight less roots in the T root category (Pigmented-14.62, Non-pigmented-22.52, LSD 4.59). This finding shows that vertical planting can cause some compounding of the negative effects of using pigmented vine.

### 68 DAYS AFTER PLANTING (DAP)

*Control*

Plants were sampled at 68 DAP to coincide with the rapid bulking phase of storage root development. Results in Table 6 show the control has lower T marketable numbers, T

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[8] Pigmentation is related to the level of a chemical compound called anthocyanin

marketable root weights, T root numbers, and T root weights. These differences suggest that the reduced vigour seen in the grower control plant material at 34 DAP has continued up to 68 DAP.

*Pigmentation*
T Marketable (P<0.01) and T root weight (P=0.090) remains lower for the pigmented vine regardless of orientation confirming the treatment effects observed at 34 DAP.

*Orientation*
There were slight differences for T marketable numbers (P=0.076), and none for T marketable weights. T root weights showed no differences although the flat orientation had a higher T root number than the vertical at 68 DAP. A difference between nodes was evident with node three of the vertical treatment producing half the number of marketable roots and only one fifth the weight of marketable roots compared to the flat orientation. T weight and T root number was also reduced at node three for the vertical orientation while the T weight at node one and two was higher for the vertical orientation. The T number of roots at node three was lower for the vertical treatment.

Node three of the vertical treatment is placed approximately 175 mm below the surface, temperature readings (Figure 1) at this depth while lower than the shallower readings do not appear to be low enough to reduce sugar conversion to starch (Spence and Humphries 1971). Therefore other factors must be inhibiting the development of the bulking marketable roots. Factors like overcrowding and possibly less movement in the soil at depth restrict the sweetpotatoes when they are expanding. Figure 2 shows the appearance of the experiment treatments at 68 DAP, with the flat treatments showing a more even size range across all nodes.

(a) (b) (c)

(d) (e)

**Figure 2.** Treatment effect 68 DAP replication 2 (a) Non-pigmented vertical (b) Pigmented vertical (c) Pigmented flat (d) Non-pigmented flat (e) Grower control.

208 DAYS AFTER PLANTING (DAP)

Significant differences for T root weight (P<0.05) and root count (P=0.062) at 208 DAP (Table 7) were apparent for the Control vs the mean of all other treatment. However no differences were found in the commercially important Small (S) and Medium (M) grades. No differences were found for pigmentation or planting orientation and this suggests that the early establishment differences measured at 34 and 68 DAP have not manifested themselves at 208 DAP. This is surprising and is thought to be due to the early advanced treatments being limited in some way e.g. due to environment, nutrition or water. Another issue that must be considered is virus disease status of the planting material. Planting material for treatments one to four were taken from material that had only been propagated once since coming out of virus free tissue culture. In contrast the grower control treatment had planting material that had been propagated many times from a commercial situation and would contain much higher incidence of viruses and possibly phytoplasmas.

## Conclusion

The substantial differences seen between the Grower control and the mean of all other treatments confirms the findings of a previous research project (Coleman et al 2005) that demonstrated large reductions in quality due to disease build up in plant material. The differences seen at 37 and 68 DAP for the grower control although reduced by the final sampling would definitely have reduced marketable yield in a 120 day maturity harvest.

There is a clear pattern of reduced establishment for pigmented vine vs. non-pigmented vine. This indicates that the pigmentation is a stress reaction and that this plant material should be avoided where possible.

Flat planting is reducing node to node variability in root weight. This planting technique must therefore be a key strategy for industry to adopt to improve final root shape and quality.

Establishment differences that were measurable at early establishment largely disappeared towards the end of the experiment. This has been a common theme in the project and supports the use of sampling in the early establishment phase.

## References

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# Experiment 6: Physiology of Sweetpotato vine type and herbicide application 17th March to 12th October 2004.

## Introduction

This was the 6th in a series of experiments conducted during 2003 and 2004. This experiment was planted in March to coincide with typical (high) summer soil temperatures experienced in Australia's sweetpotato production areas. The research team was particularly interested in assessing the effect of summer planting temperatures on flat vine orientation. Experiment 1 in 2003 had suggested that a flat planting had the potential to greatly improve final sweetpotato shape and hence quality. However the research team was concerned that using a flat orientation in summer may expose the early adventitious roots to high soil temperatures resulting in reduction of adventitious roots and or permanent damage. This experiment was standardised to all flat planted material and three possible physiological influences were tested across it. Firstly two herbicides were tested as very little recent research has been conducted in Australia assessing the likely impact of herbicides on early plant establishment. These herbicides are used in the United States and were tested as a preliminary investigation of possible effects they may have on root formation and root shape to ascertain whether a further project may be warranted in this area. Secondly three common vine types were also planted to assess what if any impact inherent vine physiology may have on early plant establishment. Thirdly at the co-operators request a foliar phosphoric acid treatment was tested on this site as the soil type was one known to tie up phosphorous.

## Methodology

### Fertiliser

Nutrients (kg/ha) added and dates applied are shown in Table 1. All nutrients were applied via trickle irrigation. A soil test was performed and it showed that no basal fertiliser application was required.

**Table 1. Fertiliser additions**

| Fertiliser | Date applied | N | P | K | S | Ca | Mg | Zn | Cu | B | Mo |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
| KNO3 | 27/4/04 | 16 | | 44 | | | | | | | |
| | | | | | | | | | | | |
| KNO3 | 23/05/04 | 11 | | 30 | | | | | | | |
| | | | | | | | | | | | |
| Agribor | 28/2/05 | | | | | | | | | 0.2 | |
| | | | | | | | | | | | |
| Microfine Gypsum | | | | | 3 | | 4 | | | | |
| Total | | 27 | | 77 | 3 | | 4 | | | 0.2 | |

### Treatments

The experimental design was a randomized block design with four replicates and six treatments. Planting material for the experimental treatments was standardised to a length of

450 mm with three nodes in the first 200 mm from the cut end. All treatments (Table 2) were planted flat at 50 mm depth with three nodes underground

Each plot consisted of two rows 2.7 m long by 1.9 metres wide, this is equivalent to 34 188 plants/Ha. Treatments ran down the row with each row (rep) separated by two guard rows that resulted in a 1.9 metre buffer between datum rows as shown in Diagram 1.

**Diagram 1. Trial plan layout**

| Guard rows | Datum Rep1(row 1,2) | Guard rows | Datum Rep 2 (row 3,4) | Guard rows | Datum Rep 3 (row 5,6) | Guard rows | Datum Rep 4 (row 7,8) | Guard rows |
|---|---|---|---|---|---|---|---|---|
| | 6 | | 3 | | 4 | | 1 | |
| | 5 | | 2 | | 3 | | 5 | |
| | 2 | | 1 | | 6 | | 2 | |
| | 3 | | 4 | | 1 | | 6 | |
| | 4 | | 5 | | 2 | | 3 | |
| | 1 | | 6 | | 5 | | 4 | |

**Table 2. Treatment descriptions**

| **Treatment No.** | ***Treatment applied*** |
|---|---|
| 1. | Pigmented |
| 2. | Non-pigmented (control) |
| 3. | Thin |
| 4. | Phosphoric acid |
| 5. | Simazine |
| 6 | Stomp |

Simazine (T5) was applied 5 DAP (Days After Planting) at a rate of 1.5litres/hectare, Stomp (T6) was applied at 0 DAP at a rate of 2 litres/hectare as these treatments needed to be watered in, all plots were hand watered at their respective times of application. Phosphoric acid treatment (T4 85%Phosphoric acid) was applied 14 DAP at 3.6 litres/hectare as a foliar spray. Pigmented planting material was selected from plants grown on widely spaced rows to allow runners to grow in the open and develop pigmentation.
Thin vine (T3) was selected out of the total vine pool, Figure 1 in Experiment 3 shows the type of vine selected.

**Planting**
The experiment was planted 17/03/2004.

The plant spacing for all treatments was 30 cm. In guard rows cuttings were vertically planted with a stick.

All planting material was generated at Gatton research station using a seedbed derived from pathogen tested plants taken out of tissue culture in 2003.

Immediately following planting the experimental block was trickle irrigated. Irrigation was monitored using tensiometers with soil water content held at or near field capacity.

**Sampling**

Treatment plots were sampled at 34, 130 and 208 DAP. A four plant sub sample was taken from each plot running from west to east. At each sampling time, two plants in the plot were left as buffers for the next four plant sub sample. For the 34 DAP sampling the roots at each of the first three nodes were sorted, counted and weighed as shown in Table 3. At 34 DAP fresh weight of tops was also recorded.

**Table 3. Description of root evaluation method for 34 DAP**

| Root type* | Number | Weight |
|---|---|---|
| Adventitious (A) | x | |
| Initiated (I) | x | |
| Setting (S) | x | |
| Bulking (B) | x | x |

*Adventitious roots: thick white lateral roots that develop from the nodes after planting
Initiated roots: adventitious roots that had started to develop pigmentation
Setting roots: roots that had developed full pigmentation and had not started to bulk ie < 5 mm diameter
Bulking roots: roots that had started to bulk ie >5 mm diameter

For the 130 and 208 DAP samplings roots at each of the three nodes were sorted into, Undersize, Small, Medium, Large, Second and Reject grades, counted and then weighed as shown in Table 4. Undersize, Small, Medium, Large, Second and Reject grades were defined as per commercially available product specifications. The primary evaluation used a grading system based on dimensions i.e. length and diameter. If an individual sweetpotato could not be distinguished from its nearest grade a secondary parameter i.e. weight was used.

**Table 4. Description of root evaluation method for 130 and 208 DAP**

| Grade |
|---|
| Small (S): Length 130-180 mm, Diameter 50-60 mm, weight 170-310 g |
| Medium (M): Length 180-250 mm, Diameter 60-75 mm, weight 310-620 g |
| Large (L): Length greater than 250 mm long and/or diameter greater than 75 mm, weight 620-860) g |
| Undersize: Length shorter than 130 mm diameter less than 50 mm, weight 63-170 g |
| Second Grade: S+M+L(shape does not meet first grade specification) |
| Reject Grade |

## Statistical Analysis

Results for the three samplings (34 DAP, 130 DAP and 208 DAP) were analysed for treatment effects by analysis of variance (ANOVA). The analysis results are shown in Tables 6 to 10. Comparisons of treatment means used an unprotected LSD (Least Significant Difference) test.

**Table 5. 34 DAP Treatment effects per plant square root transformed with back transformed data represented in brackets**

| Trt No. | Treatment | A | | I | | S | | AIS | | B | | | | Total roots | | Plant top weight(g) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Count | | Count | | Count | | Count | | Count | | Weight(g) | | Count | | | |
| 1 | Pigmented | 1.951 | (3.806) | 0.962 | (0.925) | 0.945 | (0.893) | 2.593 | (6.724) | 2.380 | (5.664) | 6.42 | (41.22) | 3.410 | (11.628) | 17.31 | (299.64) |
| 2 | Non-pigmented | 2.008 | (4.032) | 0.883 | (0.780) | 0.990 | (0.980) | 2.541 | (6.457) | 2.722 | (7.409) | 7.25 | (52.56) | 3.739 | (13.980) | 13.71 | (187.96) |
| 3 | Thin | 2.164 | (4.683) | 1.010 | (1.020) | 0.675 | (0.456) | 2.692 | (7.247) | 2.542 | (6.462) | 6.81 | (46.38) | 3.589 | (12.881) | 12.46 | (155.25) |
| 4 | Phosphoric acid | 2.245 | (5.040) | 1.105 | (1.221) | 0.976 | (0.953) | 2.859 | (8.174) | 2.623 | (6.880) | 7.70 | (59.29) | 3.739 | (13.980) | 13.73 | (188.51) |
| 5 | Simazine | 2.355 | (5.546) | 0.746 | (0.557) | 0.649 | (0.421) | 2.768 | (7.662) | 0.971 | (0.943) | 1.71 | (2.92) | 3.014 | (9.084) | 7.48 | (55.95) |
| 6 | Stomp | 1.852 | (3.430) | 0.962 | (0.925) | 0.939 | (0.882) | 2.462 | (6.061) | 2.924 | (8.550) | 9.10 | (82.81) | 3.727 | (13.891) | 15.24 | (232.26) |
| | F test | p=0.051 | | n.s. | | n.s. | | n.s. | | *** | | *** | | * | | *** | |
| | LSD (P=0.05) | 0.339 | | 0.466 | | 0.570 | | 0.354 | | 0.497 | | 1.47 | | 0.430 | | 2.97 | |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Table 6. 130 DAP root counts per plant square root transformed with back transformed data represented in brackets

| Trt No. | Treatment | Undersize | | Small | | Medium | | Large | | Seconds | | Rejects | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Counts | | Counts | | Counts | | Counts | | Counts | | Counts | | Counts | |
| 1 | Pigmented | 0.062 | (0.004) | 0.588 | (0.346) | 0.437 | (0.191) | 0.088 | (0.008) | 0.813 | (0.661) | 2.010 | (4.040) | 2.608 | (6.802) |
| 2 | Non-pigmented | 0.000 | (0.000) | 1.173 | (1.376) | 0.500 | (0.250) | 0.000 | (0.000) | 1.115 | (1.243) | 2.192 | (4.805) | 2.996 | (8.976) |
| 3 | Thin | 0.000 | (0.000) | 0.811 | (0.658) | 0.338 | (0.114) | 0.000 | (0.000) | 1.072 | (1.149) | 1.576 | (2.484) | 2.408 | (5.798) |
| 4 | Phosphoric acid | 0.000 | (0.000) | 0.899 | (0.808) | 0.774 | (0.599) | 0.062 | (0.004) | 1.224 | (1.498) | 2.066 | (4.268) | 2.957 | (8.744) |
| 5 | Simazine | 0.000 | (0.000) | 0.427 | (0.182) | 0.427 | (0.182) | 0.125 | (0.016) | 1.138 | (1.295) | 2.131 | (4.541) | 2.744 | (7.530) |
| 6 | Stomp | 0.000 | (0.000) | 0.578 | (0.334) | 0.942 | (0.887) | 0.000 | (0.000) | 1.309 | (1.713) | 2.194 | (4.814) | 3.037 | (9.223) |
| | F test | n.s. | | n.s. | | * | | n.s. | | n.s. | | n.s. | | n.s. | |
| | LSD (P=0.05) | 0.077 | | 0.571 | | 0.383 | | 0.163 | | 0.421 | | 0.713 | | 0.640 | |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Table 7. 130 DAP root weights per plant square root transformed with back transformed data represented in brackets (weights are in grams)

| Trt No. | Treatment | Undersize | | Small | | Medium | | Large | | Seconds | | Rejects | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Weights | | Weights | | Weights | | Weights | | Weights | | Weights | | Weights | |
| 1 | Pigmented | 0.58 | (0.34) | 7.62 | (58.06) | 7.40 | (54.76) | 2.14 | (4.58) | 11.40 | (129.96) | 23.29 | (542.42) | 34.84 | (1213.83) |
| 2 | Non-pigmented | 0.00 | (0.00) | 16.82 | (282.91) | 9.40 | (88.36) | 0.00 | (0.00) | 15.70 | (246.49) | 19.71 | (388.48) | 36.75 | (1350.56) |
| 3 | Thin | 0.00 | (0.00) | 11.34 | (128.60) | 6.80 | (46.24) | 0.00 | (0.00) | 14.70 | (216.09) | 15.16 | (229.83) | 30.70 | (942.49) |
| 4 | Phosphoric acid | 0.00 | (0.00) | 12.24 | (149.82) | 14.90 | (222.01) | 1.42 | (2.02) | 16.60 | (275.56) | 16.65 | (277.22) | 36.38 | (1323.50) |
| 5 | Simazine | 0.00 | (0.00) | 5.77 | (33.29) | 7.70 | (59.29) | 2.57 | (6.60) | 14.40 | (207.36) | 20.21 | (408.44) | 31.88 | (1016.33) |
| 6 | Stomp | 0.00 | (0.00) | 9.04 | (81.72) | 18.30 | (334.89) | 0.00 | (0.00) | 18.00 | (324.00) | 19.92 | (396.81) | 38.31 | (1467.66) |
| | F test | n.s. | | P=0.074 | | * | | n.s. | | n.s. | | n.s. | | P=0.074 | |
| | LSD (P=0.05) | 0.71 | | 7.40 | | 6.82 | | 3.55 | | 5.79 | | 6.58 | | 5.60 | |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

### Table 8. 208 DAP counts per plant square root transformed with back transformed data represented in brackets

| Trt No. | Treatment | Undersize | | Small | | Medium | | Large | | Seconds | | Rejects | | Totals | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Counts | | Counts | | Counts | | Counts | | Counts | | Counts | | Counts | |
| 1 | Pigmented | 0.483 | (0.233) | 0.453 | (0.205) | 0.463 | (0.214) | 0.151 | (0.023) | 0.869 | (0.755) | 1.975 | (3.901) | 2.685 | (7.209) |
| 2 | Non-pigmented | 0.623 | (0.388) | 0.606 | (0.367) | 0.660 | (0.436) | 0.188 | (0.035) | 1.303 | (1.698) | 2.021 | (4.084) | 3.006 | (9.036) |
| 3 | Thin | 0.748 | (0.560) | 0.651 | (0.424) | 0.623 | (0.388) | 0.188 | (0.035) | 1.350 | (1.823) | 1.734 | (3.007) | 2.839 | (8.060) |
| 4 | Phosphoric acid | 1.096 | (1.201) | 0.765 | (0.585) | 0.739 | (0.546) | 0.063 | (0.004) | 1.375 | (1.891) | 1.683 | (2.832) | 2.919 | (8.521) |
| 5 | Simazine | 0.276 | (0.076) | 0.535 | (0.286) | 0.578 | (0.334) | 0.188 | (0.035) | 1.139 | (1.297) | 2.256 | (5.090) | 2.905 | (8.439) |
| 6 | Stomp | 0.587 | (0.345) | 0.535 | (0.286) | 0.826 | (0.682) | 0.188 | (0.035) | 1.200 | (1.440) | 1.730 | (2.993) | 2.747 | (7.546) |
| | F test | P=0.064 | | n.s. | | n.s. | | n.s. | | * | | n.s. | | n.s. | |
| | LSD (P=0.05) | 0.508 | | 0.602 | | 0.483 | | 0.322 | | 0.307 | | 0.507 | | 0.485 | |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

**Table 9: 208 DAP weights per plant square root transformed with back transformed data represented in brackets (weights are in grams)**

| Trt No. | Treatment | Undersize |  | Small |  | Medium |  | Large |  | Seconds |  | Rejects |  | Totals |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Weight |  | Weight |  | Weight |  | Weight |  | Weight |  | Weight |  | Weight |  |
| 1 | Pigmented | 5.52 | (30.47) | 7.40 | (54.76) | 9.60 | (92.16) | 4.27 | (18.23) | 16.80 | (282.24) | 27.21 | (740.38) | 43.08 | (1855.89) |
| 2 | Non-pigmented | 6.65 | (44.22) | 9.46 | (89.49) | 14.10 | (198.81) | 4.99 | (24.90) | 21.00 | (441.00) | 21.51 | (462.68) | 42.57 | (1812.20) |
| 3 | Thin | 8.70 | (75.69) | 9.97 | (99.40) | 12.90 | (166.41) | 4.70 | (22.09) | 23.60 | (556.96) | 20.74 | (430.15) | 43.62 | (1902.70) |
| 4 | Phosphoric acid | 11.41 | (130.19) | 12.37 | (153.02) | 15.10 | (228.01) | 1.71 | (2.92) | 24.10 | (580.81) | 17.79 | (316.48) | 42.94 | (1843.84) |
| 5 | Simazine | 3.20 | (10.24) | 7.72 | (59.60) | 11.90 | (141.61) | 4.98 | (24.80) | 19.40 | (376.36) | 25.23 | (636.55) | 40.75 | (1660.56) |
| 6 | Stomp | 6.11 | (37.33) | 8.70 | (75.69) | 17.00 | (289.00) | 4.99 | (24.90) | 22.60 | (510.76) | 19.21 | (369.02) | 42.96 | (1845.56) |
|  | F test | n.s. |  | n.s. |  | n.s. |  | n.s. |  | P=0.094 |  | * |  | n.s. |  |
|  | LSD (P=0.05) | 5.68 |  | 9.25 |  | 9.59 |  | 8.50 |  | 5.56 |  | 5.67 |  | 7.43 |  |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Results and Discussion

### 34 DAYS AFTER PLANTING (DAP)

Plants were sampled at 34 DAP to coincide with storage root initiation and bulking root formation i.e. the stage when early adventitious roots initiate and then begin bulking to form sweetpotato storage roots (Wilson 1982).

Results in Table 5 show that plant top weight for T5 (Treatment 5 Simazine) is lower than all other treatments. T1 (Treatment 1 Pigmented) had a higher top weight than all other treatments other than T6 (Treatment 6 Stomp). This suggests that T5, is showing phytotoxicity effects on vegetative growth whereas pigmented vine selected from plants allowed to grow in the open is showing superior vegetative growth.

For Adventitious roots T6 has a lower root count than T4 and T5.

For Bulking root counts T5 is lower than all other treatments with the only other difference being T1 lower than T6. For Bulking root weights T5 is again lower than all other treatments with T6 higher than all treatments other than T4 (phosphoric acid).

For Total root counts T5 is showing a lower total count than all other treatments apart from T1.

These results suggest that early establishment as measured by vegetative and root growth is retarded by the herbicide Simazine (T5). For the important Bulking root category there appears (at this early growth stage) to be a positive response to the herbicide Stomp (T6). There is also some suggestion of a positive response to phosphoric acid addition (T4).

### 130 DAYS AFTER PLANTING (DAP)

Plants were sampled at 130 DAP to coincide with late bulking and to gain an understanding of the treatment effects when the plants were dormant in winter in case the winter dormancy period eliminated the early establishment gains by the time of final harvest.

Table 6 (root counts per plant) shows that the only treatment response is in the Medium category. T6 is higher in Medium root counts than all other treatments other than T4.

Table 7 (root weight per plant) show for Medium weights results are similar to counts where T6 is higher than all treatments other than T4. T4 is also showing higher Medium weights than T1, T3 and T5. For Total root weights T6 is higher than T3 and T5.

Results suggest that the apparent positive root growth response found at 30 DAP for T6 has carried through to 130 DAP. Again, as for 30 DAP there is the suggestion of a positive response to phosphoric acid addition (T4). T5 appears to be overcoming some of the early growth retardation shown at 30 DAP. T3 (Treatment 3 Thin) has now produced a lower Total root weight than T2 (Control), T4 and T6 pointing to some drop in the Thin treatments ability to bulk roots as fast as the control and the two higher performing treatments of Stomp and Phosphoric acid.

208 DAYS AFTER PLANTING (DAP)

By 208 DAP few commercially relevant differences were evident between treatments. Of interest is reject weights where T1 had more rejects than all other treatments apart from T5. For Seconds counts this result was reversed with T1 having fewer seconds than all other treatments apart form T5. These results suggest that T1 and T5 are producing more commercially unacceptable roots than other treatments.

## Conclusion

The purpose of testing the two herbicides was to ascertain their impact if any on root shape. Simazine while not producing any final yield penalty obviously set the plants back in the early establishment phase. It is expected that in a shorter maturing crop of e.g. 120 days there would be a substantial yield reduction from this product. The apparent improvement in yields seen at the earlier samplings for Stomp is not thought due to weed suppression as all plots were subject to similar weed control practises. It is suggested that the improvement in yields is due to a hormonal effect. There does seem to be a strong case to investigate the effects of Stomp further.

There was suggestion of a positive response to foliar phosphoric acid with little penalty found for using thin vine. There was some indication of a negative effect from using pigmented vine, corroborating the findings of Experiment 5 where there was a large negative impact due to pigmented vine.

Establishment differences that were measurable at early establishment once again were not all found at the final sampling. This has been a common theme in the project and suggests the use of sampling in the early establishment phase is a sound experimental technique. Previous research where data was only recorded at final commercial harvests does not reflect what we now understand as optimal maturity for the cv. Beauregard i.e. 120 days. Hence limiting this cultivar due to season, location, leaf area competition, moisture etc has restricted our understanding of the yield capacity of the cultivar to date. It is our belief that rapidly establishing treatments are being limited by the production system we were using. Experiment 7 conducted in a non-limiting environment provides a true indication of yield potential of the cv. Beauregard.

## References

Spence J A and Humphries E C (1971) Effect of moisture supply root temperature and growth regulators on photosynthesis of isolated rooted leaves of sweet potato. Journal of American Botany (36), 115-121.

Wilson LA (1982) Tuberization in sweet potato (Ipomoea batatas (L.) Lam). Sweet potato: proceedings of the first international symposium (Ed: Villareal RL and Griggs, TD). Asian Vegetable Research and Development Centre, Shanhua, Taiwan. pp.79-94.

## Experiment 7. Physiology of Sweetpotato plant establishment and irrigation Bundaberg Research Station 1st December 2004 to 7th April 2005

### Introduction

This was the 7th experiment in a series of experiments conducted in 2003 and 2004. This experiment was planted in December to coincide with typical (high) summer soil temperatures experienced in Australia's sweetpotato production areas. The research team was interested in assessing the effect various irrigation techniques may have on soil temperatures and plant establishment. Earlier experiments had indicated that a flat cutting had the potential to produce the highest yield of smooth skin sweet potatoes. These experiments had also indicated that high temperatures in the root zone may be reducing adventitious roots particularly in the first 14 days after planting. Growers on the project management committee were interested in comparing trickle and overhead irrigation techniques for establishment. The irrigation treatments were designed to take into account issues raised after two years of experimentation.

### Methodology

**Fertiliser**
Nutrients (kg/ha) added and dates applied are shown in Table 1.

**Table 1. Nutrients applied**

| Fertiliser | Date applied | N | P | K | S | Mg | Zn | Cu | B | Mo |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |
| Fertica | 26/8/04 | 84 | 22 | 44 | 57 | 2.6 | 1.64 | 1.16 | 0.71 | |
| | | | | | | | | | | |
| DM3 | 17/1/05 | 32 | 17 | 72 | | | 0.05 | | 0.08 | 0.01 |
| | | | | | | | | | | |
| KNO3 | 28/2/05 | 12 | | 34 | | | | | | |
| Total | | 84 | 39 | 150 | 57 | 2.6 | 1.7 | 1.16 | 0.79 | 0.01 |

**Treatments**
The experimental design was a six treatment randomized block with three replications. Plot size was 12 m long with 3 m buffer between treatments. Treatments ran down the row with each row (rep) separated by guard rows as show in Diagram 1

**Diagram1 Trial plan layout**

| Guard row | Datum row 1 | Guard row | Guard row | Datum row 2 | Guard row | Guard row | Datum row 3 | Guard row |
|---|---|---|---|---|---|---|---|---|
| | 6 | | | 3 | | | 4 | |
| | 5 | | | 2 | | | 3 | |
| | 2 | | | 1 | | | 6 | |
| | 3 | | | 4 | | | 1 | |
| | 4 | | | 5 | | | 2 | |
| | 1 | | | 6 | | | 5 | |

The planned treatment applications are shown in Table 2. At 21 DAP (Days After Planting) all treatments were terminated and all plots reverted to the same trickle irrigation program. Treatments were selected to reflect sprinkler (overhead) and trickle applications singularly, in combination, best practise and commercial usage based on grower input. Amount of water applied per irrigation event is shown in Table 5

**Table 2. Planned Treatments**

| Treatment Number | Treatment applied |
|---|---|
| 1 | Wet Overhead: overhead irrigation DAP 0 to 10, 12,13, 16 |
| 2 | Overhead + trickle: overhead DAP 0, 2, 4 + Trickle irrigation DAP 6, 9, 13, 17 |
| 3 | Best Practise: trickle irrigation DAP 0, 2, 4, 6, 9, 13, 17 |
| 4 | Wet Trickle: trickle irritated DAP 0 to 10, 12, 13, 16, 19 |
| 5 | Dry trickle: trickle irrigated DAP 5, 8, 15, 19 |
| 6 | Commercial Trickle: trickle irrigated DAP 0, 5, 10, 12, 16 |

Irrigation layout is depicted in the following photo for treatment 2 (trickle irrigation + wet overhead)

**Planting**
Trial planted 1/12/2004.

In datum rows, 45 cm long cuttings were flat planted by hand to a depth of 50 mm ensuring three nodes were underground. Plant spacing was 30 cm. In guard rows cuttings were V planted using poles.

As datum row plants were from three sources (Rockhampton Seedbed, Rockhampton field and Gatton seedbed) each datum row was planted from one source. Rep 1 datum row 1 planted with Rockhampton field cuttings, Rep 2 datum row 2 Rockhampton seedbed, Rep 3 datum row 3 Gatton seedbed.

Immediately following planting the overhead irrigation treatments were watered for 1 hour 30 minutes. Trickle irrigation treatments were then watered until the wetting front from each emitter joined (see photo below).

After trickle irrigating the overhead irrigation was turned on again as the wetting front had not penetrated as far as trickle treatments. Overall a total 4 cubic meters ($m^3$) of water (4000L) was added to overhead irrigation plots and 1.3 $m^3$ (1300L) of water to trickle irrigation plots. Digging showed the water front from both irrigation methods had moved to minimum 20 cm. The difference in amounts of water added between overhead and trickle irrigation highlights the efficiency of trickle irrigation watering a small band of soil compared to overhead irrigation spreading water over a large area.

**Chemical Application**

Nemacur was applied at bed preparation on the 26/8/04 as a preventative measure for root-knot nematode.

Weed control was performed twice in December 2004 with the contact herbicide gramoxone and applied by back pack sprayer to minimise damage to plants.

Confidor was applied through the trickle irrigation system for whitefly control 21/1/05.

Talstar was applied by boomspray for hawkmoth and sweetpotato weevil control on 18/2/05.

**Sampling**

Treatment plots were sampled three times; 6/5/2005 (37 DAP), 16/2/2005 (78 DAP) and 7/4/2005 (128 DAP). At each sampling the first two plants in the plot were left untouched and the next six plants taken. For the first two samplings the roots at each of the first three nodes were sorted counted and weighed as shown in Table 3. In the 37 DAP sampling fresh weight of tops was also recorded.

**Table 3. Measurements recorded for 37 DAP and 78 DAP sampling**

| Root type* | Number | Weight |
|---|---|---|
| Adventitious (A) | x | |
| Initiated (I) | x | |
| Setting (S) | x | |
| Bulking G1 (5 -10 mm) | x | x |
| Bulking G2 (10 - 30 mm) | x | x |
| Bulking G3 (>30 mm) | x | x |

*Adventitious roots: thick white roots that develop from the nodes after planting
Initiated roots: adventitious roots that had started to develop pigmentation
Setting roots: roots that had developed full pigmentation and had not started to bulk ie < 5 mm diameter
Bulking roots: roots that had started to bulk ie >5 mm

For the 128 DAP sampling roots at each of the three nodes were sorted into Undersize, Small, Medium, Large, Second and Reject grades, counted and then weighed as shown in Table 4. Small, Medium, Large, Second and Reject grades were defined as per commercially available product specifications.

**Table 4. Grade definitions**

| **Grade** |
|---|
| Small (S): Length 130-180 mm, Diameter 50-60 mm, weight 170-310 g |
| Medium (M): Length 180-250 mm, Diameter 60-75 mm, weight 310-620 g |
| Large (L): Length greater than 250 mm long and/or diameter greater than 75 mm, weight 620-860g |
| Undersize (U): Length shorter than 130 mm diameter less than 50 mm, weight 63-170 g |
| Second Grade: S+M+L(shape does not meet first grade specification) |
| Reject Grade |

## Irrigation

For overhead irrigation treatments (T1 and T2) the amount of water to add per irrigation was defined as 60% of the Pan Evaporation measured for the previous day. The amount of water added to achieve 60% PE was measured by rain gauges (ml) and with a water meter ($m^3$). To ensure treatments T1 and T2 received the same total amounts of water additional water was added to T2 at DAP 2 and 4 to compensate for the daily overhead watering in T1 (see Table 5).

For trickle irrigation treatments the amount of water added per irrigation was defined as the amount required for the surface wetting fronts to join in T4 (Treatment 4 wet trickle). To ensure all trickle treatments received the same total amounts of water additional water was added to T3, T5 and T6 to compensate for the daily watering of T4 (see table 5). Amounts added to each treatment were measured with a water meter with this measurement being used to calculate the additional water to add to a treatment.

At 21 DAP treatments were discontinued and all plots were watered by trickle irrigation on a commercial schedule where irrigation was applied to maintain tensiometers in a range of 10-35kpa until harvest.

The total amount of water added per treatment at each irrigation event ($m^3$ of water) up to 21 DAP is shown in Table 5.

## Rainfall

Rain started to fall at 4 DAP and rainfall figures up to 21 DAP are shown in Table 6. Due to rainfall events the original treatment schedule (Table 2) had to be modified (Table 5).

**Table 5. Comparison of Planned and Actual irrigation events**

| | Days After Planting (DAP) | | | | | | | | | | | | | | | | | | | | | Total ($m^3$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | |
| 1 | o | o | o | o | o | o | o | o | o | o | | o | o | | | o | | | o | | o | |
| | 2* | 2.1 | 1.4 | 0.4 | 1.6 | 1.4 | | | | | | 1.1 | 1.1 | | | 2.8 | | | 1.3 | 2.1 | 2.5 | 19.8 |
| 2 | | o | | o | | x | | | x | | | | x | | | | x | | | | x | |
| | | 4.2 | | 1.8 | | 0.47 | | | | | | | 1.75 | | | | 1.1 | | | | 1.3 | 10.62 |
| 3 | | x | | x | | x | | | x | | | | x | | | | x | | | | x | |
| | | 1.85 | | 1.3 | | 0.47 | | | | | | | 2.15 | | | | 2 | | | | 1.3 | 9.07 |
| 4 | x | x | x | x | x | x | x | x | x | x | | x | x | | | x | | | x | | x | 0 |
| | 0.9 | 0.95 | 0.9 | 0.4 | 0.4 | | 0.4 | | | | | 0.8 | 0.8 | | | 1.05 | | | 1.3 | | 1.3 | 9.2 |
| 5 | | | | | | | | x | | | | | | | x | | | | x | | x | |
| | | | | | | | | | | | | | | | | | | | 2.5 | | 1.3 | 3.8 |
| 6 | | | | | x | | | | | x | | x | | | | x | | | | | x | |
| | | | | | 3.2 | 0.47 | | | | | | 0.8 | | | | 2.25 | | | | 1.1 | 1.3 | 9.12 |

o planned overhead irrigation events, x planned trickle irrigation events, * actual irrigation events in $m^3$ of water

**Table 6. Rainfall up to 21 DAP**

| | Days After Planting (DAP) | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | Total |
| Rainfall (mm) | | | | 3.75 | 3.5 | 17.8 | 13.3 | 4.5 | 15.3 | | 9.25 | | 2 | | | | | | | 7 | 1.38 | 77.78 |

**Temperature measurement**

Tiny tag temperature probes were placed in treatments 1 to 6 of Datum row 2 at 25 and 100 mm depth. Temperature readings were automatically recorded every 15 minutes. Unfortunately recording problems were encountered at the 25 mm depth and data for T4, T5 and T6 only could be retrieved (Figure 1). At the 100 mm depth temperature recordings for all treatments were retrieved (Figure 2).

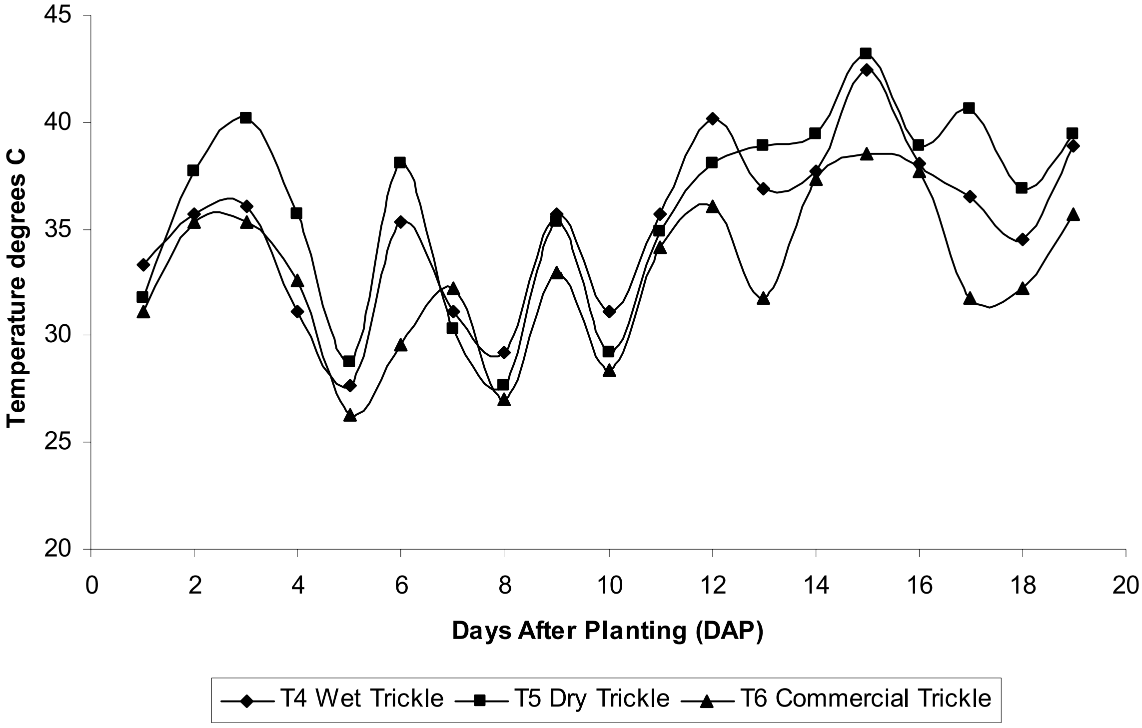

**Figure 1.** Maximum Daily Soil Temperature 25 mm depth T4, T5, T6 for DAP 1 to 19.

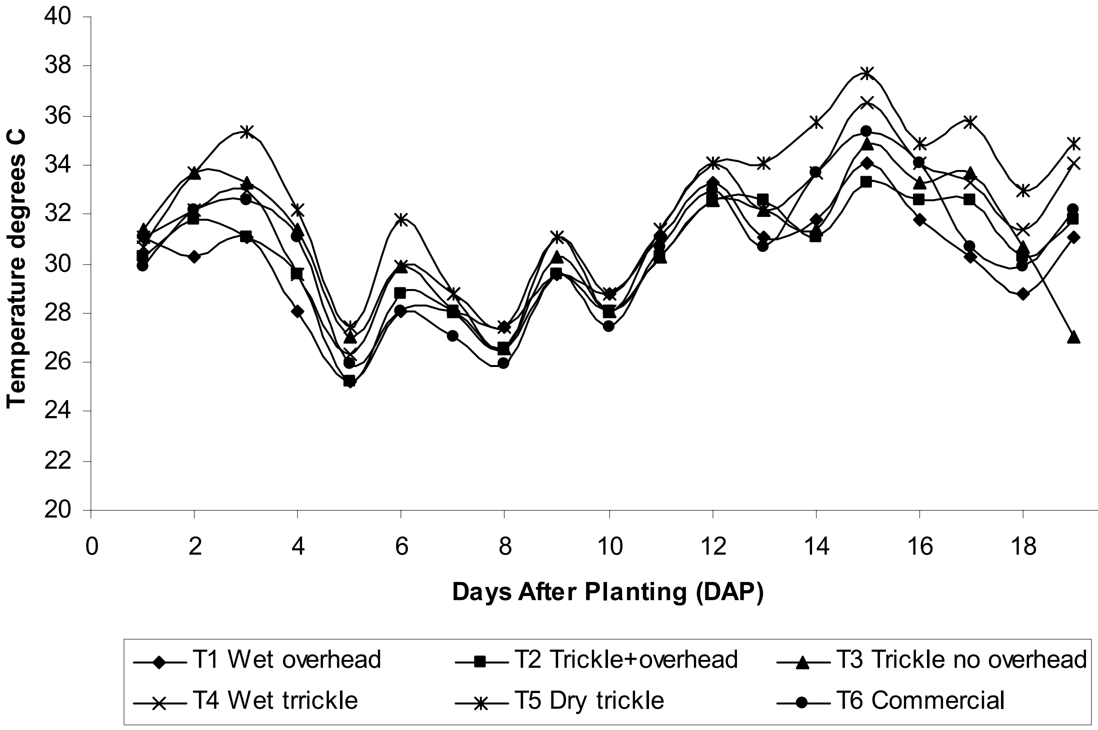

**Figure 2.** Maximum Daily Soil Temperature 100 mm depth T1 to T6 for DAP 1 to 19.

Even though each temperature recording is from one probe only the influence of irrigation in modulating temperature is highlighted in T5 (see Figures 1 and 2). T5 (Dry trickle) is consistently higher than all other treatments. The influence of rainfall in modulating temperature is also vividly expressed in T5 with the decline in maximum temperatures occurring at each significant rainfall event. Interestingly T4 showed higher than expected maximum temperatures compared with other irrigated treatments and at the 25 mm depth was on average only 0.9°C different in temperature to T5 compared with 3.1°C for T6 (Commercial trickle) It is surmised this was due to the frequent daily "light" irrigation quickly drying out and not reducing the maximum temperature as much as less frequent heavier irrigation as in T6. In fact heavy irrigations act as a sink or reservoir of water to modulate temperature. In Figure 2 the overhead irrigation treatments (1 and 2) consistently had the lowest maximum temperatures particularly in the critical first 7 DAP.

The difference in temperature between the 25 mm and 100 mm depth for T4 is shown Figure 3. These results highlight the inherent danger in planting close to the surface in summer with soil temperatures approaching critical levels for root growth.

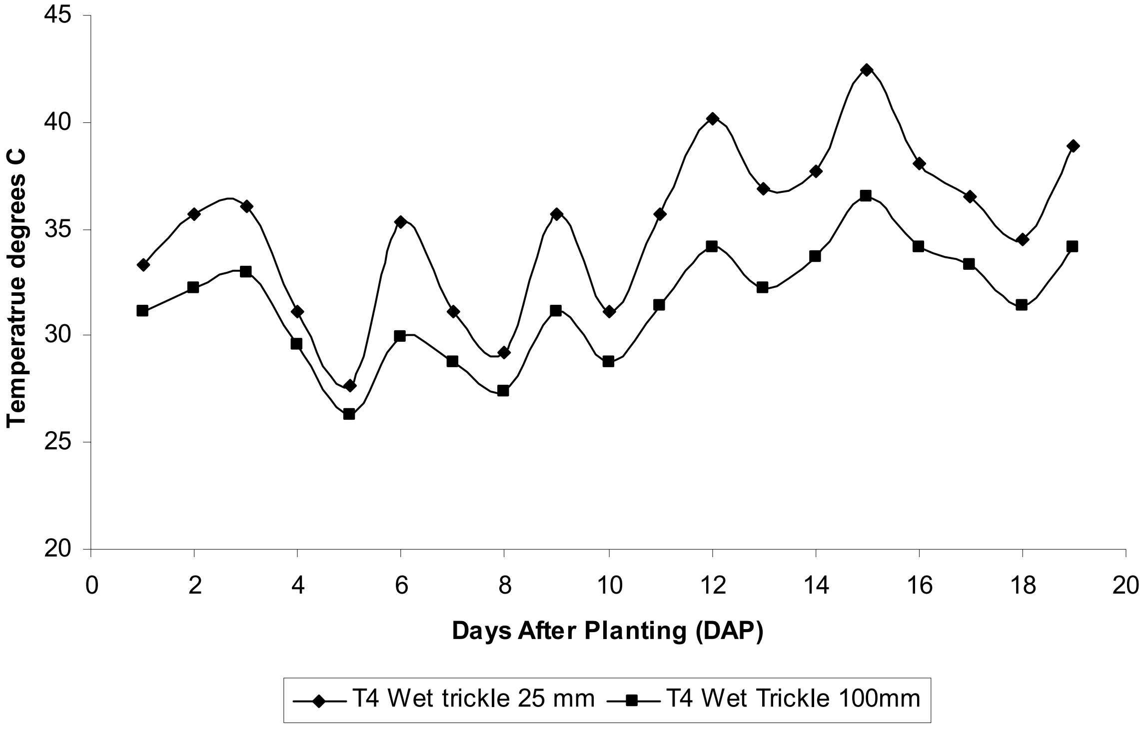

**Figure 3.** Maximum Daily Soil Temperature 25 mm and 100 mm depth T4 for DAP 1 to 19.

Atmospheric and soil temperatures are potentially the most underestimated cause of transplant shock and poor storage root development in the sweetpotato industry. High atmospheric temperatures without adequate cooling from irrigation can cause leaf loss and has a dramatic impact on adventitious root development (Coleman et al 2003). Pardales et al 1999 has shown that root zone temperatures of 40 ºC or higher can result in overall reduced length and development in adventitious roots and any development that does occur tend to be greater at deeper nodes (lower soil temp). At root zone temperatures of 25 ºC, more roots are initiated and elongated from nodes closer to the soil surface. Results for this trial suggest temperature could have been influencing root development.

**Statistical Analysis**

Results for the three samplings (37 DAP, 79 DAP and 128 DAP) were analysed for treatment and nodal effects by analysis of variance (ANOVA). The analysis results are shown in Tables 6 to 10. Comparisons of treatment means used an unprotected LSD (Least Significant Difference) test.

**Table 6. 37 DAP Treatment effects per plant (weights are in grams)**

| Treatment | A | I | S | AIS | G1 | | G2 | | G3 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Count | Count | Count | Count | Count | Weight | Count | Weight | Count | Weight |
| 1.Overhead | 0.48 | 0.50 | 0.94 | 1.93 | 2.26 | 13.30 | 0.96 | 28.70 | 0.06 | 3.98 |
| 2.Trickle + overhead | 0.37 | 0.59 | 0.61 | 1.57 | 2.30 | 14.57 | 0.94 | 28.20 | 0.04 | 2.83 |
| 3.Trickle | 0.22 | 0.54 | 1.00 | 1.76 | 2.39 | 14.35 | 0.74 | 21.10 | 0.02 | 1.17 |
| 4.Wet Trickle | 0.59 | 0.59 | 1.08 | 2.20 | 2.24 | 12.65 | 0.35 | 9.70 | 0.09 | 5.39 |
| 5.Dry Trickle | 0.28 | 0.54 | 1.20 | 2.02 | 2.02 | 15.93 | 0.41 | 14.20 | 0.00 | 0.00 |
| 6.Commercial trickle | 0.28 | 0.43 | 0.72 | 1.43 | 1.89 | 14.70 | 0.54 | 15.10 | 0.02 | 0.80 |
| F test | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | P=0.066 | n.s. | n.s. | n.s. |
| LSD (P=0.05) | 0.32 | 0.35 | 0.58 | 0.69 | 0.62 | 5.40 | 0.48 | 16.25 | 0.08 | 5.05 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

**Table 7. 37 DAP Nodal effects per plant (weights are in grams)**

| Node | A | I | S | AIS | G1 | | G2 | | G3 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Count | Count | Count | Count | Count | Weight | Count | Weight | Count | Weight |
| 1 | 0.26 | 0.41 | 0.59 | 1.26 | 1.69 | 12.73 | 0.75 | 25.00 | 0.07 | 4.40 |
| 2 | 0.42 | 0.55 | 0.93 | 1.89 | 2.07 | 12.89 | 0.60 | 17.30 | 0.04 | 2.00 |
| 3 | 0.44 | 0.64 | 1.23 | 2.31 | 2.79 | 17.13 | 0.62 | 16.20 | 0.01 | 0.69 |
| F test | P=0.085 | P=0.055 | *** | *** | *** | ** | n.s. | * | n.s. | n.s. |
| LSD (P=0.05) | 0.17 | 0.19 | 0.31 | 0.44 | 0.37 | 2.83 | 0.19 | 6.23 | 0.06 | 3.58 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Table 8. 79 DAP Treatment effects per plant (weights are in grams)

| Treatment | AIS | G1 | | G2 | | G3 | |
|---|---|---|---|---|---|---|---|
| | Count | Count | Weight | Count | Weight | Count | Weight |
| 1.Overhead | 0.93 | 1.59 | 17.80 | 1.59 | 120.30 | 1.20 | 253.00 |
| 2.Trickle + overhead | 0.46 | 1.22 | 17.90 | 1.41 | 111.10 | 0.89 | 207.00 |
| 3.Trickle | 0.46 | 1.00 | 11.40 | 1.32 | 100.70 | 0.83 | 212.00 |
| 4.Wet Trickle | 0.50 | 1.20 | 16.40 | 1.19 | 91.40 | 0.94 | 214.00 |
| 5.Dry Trickle | 0.54 | 0.85 | 11.10 | 1.15 | 77.80 | 1.13 | 230.00 |
| 6.Commercial trickle | 0.39 | 0.63 | 7.00 | 1.15 | 80.10 | 1.17 | 237.00 |
| F test | n.s. | n.s. | * | n.s. | n.s. | n.s. | n.s. |
| LSD (P=0.05) | 0.67 | 0.37 | 7.31 | 0.44 | 34.83 | 0.39 | 94.90 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Table 9. 79 DAP Nodal effects per plant (weights are in grams)

| Node | AIS | G1 | | G2 | | G3 | |
|---|---|---|---|---|---|---|---|
| | Count | Count | Weight | Count | Weight | Count | Weight |
| 1 | 0.44 | 0.62 | 8.80 | 0.98 | 80.70 | 1.07 | 270.00 |
| 2 | 0.42 | 1.12 | 13.50 | 1.41 | 104.90 | 0.94 | 221.00 |
| 3 | 0.78 | 1.51 | 18.40 | 1.51 | 105.10 | 0.98 | 185.00 |
| F test | * | *** | ** | *** | n.s. | n.s. | * |
| LSD (P=0.05) | 0.30 | 0.37 | 5.89 | 0.28 | 26.76 | 0.24 | 59.60 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

**Table 10. 128 DAP Treatment effects per plant (weights are in grams)**

| Treatment | Small | | Medium | | Large | | Undersize | | Seconds | | Rejects | | Pencil | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | Weight | Count | Weight | Count | Weight | Count | Weight | Count | Weight | Count | Weight | Count | Count | Weight |
| 1.Overhead | 0.52 | 135.10 | 0.93 | 468.00 | 0.28 | 278.00 | 0.63 | 66.00 | 0.19 | 74.00 | 0.44 | 28.80 | 0.19 | 2.98 | 1050.00 |
| 2.Trickle + overhead | 0.52 | 134.70 | 0.93 | 479.00 | 0.24 | 203.00 | 0.44 | 50.50 | 0.24 | 90.00 | 0.70 | 34.70 | 0.35 | 3.07 | 992.00 |
| 3.Trickle | 0.32 | 82.40 | 0.50 | 265.00 | 0.30 | 308.00 | 0.32 | 37.40 | 0.44 | 192.00 | 0.72 | 40.00 | 0.37 | 2.59 | 925.00 |
| 4.Wet Trickle | 0.37 | 87.70 | 0.63 | 347.00 | 0.26 | 273.00 | 0.61 | 55.90 | 0.22 | 90.00 | 0.50 | 38.90 | 0.26 | 2.59 | 892.00 |
| 5.Dry Trickle | 0.39 | 100.70 | 0.48 | 233.00 | 0.30 | 307.00 | 0.32 | 37.10 | 0.39 | 139.00 | 0.57 | 83.30 | 0.24 | 2.44 | 903.00 |
| 6.Commercial trickle | 0.56 | 150.40 | 0.41 | 208.00 | 0.41 | 381.00 | 0.33 | 36.80 | 0.19 | 87.00 | 0.70 | 61.20 | 0.17 | 2.59 | 926.00 |
| F test | n.s. | n.s. | * | ** | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | n.s. | P=0.080 | n.s. | * | n.s. |
| LSD (P=0.05) | 0.29 | 76.42 | 0.30 | 151.20 | 0.25 | 278.30 | 0.38 | 33.07 | 0.26 | 122.20 | 0.26 | 38.91 | 0.32 | 0.42 | 195.70 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

**Table 11. 128 DAP Nodal Analysis per plant (weights are in grams)**

| Node | Small | | Medium | | Large | | Undersize | | Seconds | | Rejects | | Pencil | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Count | Weight | Count | Weight | Count | Weight | Count | Weight | Count | Weight | Count | Weight | Count | Count | Weight |
| 1 | 0.25 | 60.90 | 0.67 | 340.00 | 0.37 | 369.00 | 0.36 | 39.20 | 0.24 | 106.00 | 0.41 | 39.20 | 0.19 | 2.30 | 954.00 |
| 2 | 0.46 | 123.30 | 0.57 | 306.00 | 0.28 | 282.00 | 0.38 | 42.00 | 0.22 | 86.00 | 0.75 | 39.70 | 0.26 | 2.67 | 880.00 |
| 3 | 0.62 | 161.40 | 0.69 | 354.00 | 0.24 | 224.00 | 0.58 | 59.80 | 0.37 | 145.00 | 0.67 | 64.60 | 0.33 | 3.18 | 1010.00 |
| F test | *** | *** | n.s. | n.s. | n.s. | n.s. | P=0.090 | n.s. | n.s. | n.s. | * | n.s. | n.s. | *** | n.s. |
| LSD (P=0.05) | 0.18 | 47.54 | 0.22 | 120.10 | 0.15 | 148.50 | 0.22 | 22.67 | 0.16 | 68.40 | 0.24 | 39.66 | 0.18 | 0.43 | 199.90 |

n.s.-not significant at P>0.10, * -P<0.05, ** -P<0.01, *** -P<0.001

## Results and Discussion

### 37 DAYS AFTER PLANTING (DAP)

Plants were sampled at 37 DAP to coincide with storage root initiation i.e. the stage when early adventitious roots initiate and start to form sweetpotato storage roots (Wilson 1982). Results in Table 6 show a difference (P=0.066) in the count for G2 roots (Bulking roots 10-30 mm diameter) with T1 and T2 different from T4 and T5 This is an important difference as the size of the bulking roots early in the plants development gives a strong indication of the improvement in plant establishment that the irrigation regimes for T1 and T2 provide. The temperature measurements (Figure 2) show improved cooling in the root zone of T1 and T2. Temperature measurements also suggest the frequent watering of T4 was not of a long enough period to ensure maximum growth (whether this was temperature or water related is unknown). Results for T5 are not unexpected and also could be explained as temperature and or water effect.

The 37 DAP nodal effects are shown in Table 7. Results show a strong nodal effect for counts of Adventitious (A), Initiated (I), Setting (S) and a sum of all these roots (AIS or potential marketable roots). Node three was significantly different to node one (i.e. dominated) for A and I roots. Nodes two and three were significantly different to node one for S and AIS. This was unexpected compared with field experience with V planting where generally node one dominates and suggests that flat planting should lead to more uniform root set across the nodes.

The results for A, I and S roots were not carried through to the bulking roots (G1, G2, and G3) with only G1 roots (5-10 mm) showing a significant result for count and weight. There was very strong node three domination for count and weight over nodes one and two. For G2 roots only the weight of roots was significantly different with nodes two and three dominant over node one.

### 79 DAYS AFTER PLANTING (DAP)

Plants were sampled at 79 DAP to coincide with the rapid bulking phase of storage root development. Results in Table 8 show a significant difference in the weight of G1 roots (bulking roots 5-10 mm in diameter) only with T1 and T2 significantly different to T6. It is suggested not too much should be read into this result however it does reflect the results for 37 DAP where T1 and T2 are showing significant differences compared with some other treatments.

The 79 DAP nodal effects are shown in Table 9. Results reflect the strong nodal effects found at 37 DAP for counts of AIS. As for 37 DAP node 3 AIS is dominant to nodes one and two.

Different to 37 DAP however was the effect on bulking roots with all bulking roots showing a nodal effect. For the smaller G1 roots node three was dominant to node one in both root weight and count. For the intermediate size G2 roots nodes 2 and 3 were dominant to node one in count only. The dominance of node 3 changed for larger G3 roots where node one was dominant to node three in weight. The results suggest that as the roots increase in size (G3 are bulking roots greater than 30 mm) the dominance of node 3 diminishes as node one takes over.

128 DAYS AFTER PLANTING (DAP)

Results in Table 10 show a significant response in count and weight for Medium grade roots and weight only for Reject grade. In Medium grade T1 and T2 have significantly more roots and weight per node compared with T3, T5 and T6. In Reject grade T5 has more weight of roots compared with all other treatments other than T6 (P=0.080). In Table 11, nodal analysis shows that only Smalls, Undersize and Rejects showed any dominance of node, two and three over node one(P=0.090). Nodal analysis suggests that the flat planting technique results in uniforms set across the three nodes for the commercially important Medium grade.

## Conclusion

The large difference in the Medium grade yield for T1 and T2 demonstrates increases in the premium Medium grade are achievable using more frequent irrigation in the first five days after planting. This has major implications for Industry. Coleman et al (2003) suggests that until a root system is established the provision of moisture is critical for the developing roots. A pot experiment (Pardales et al 2000) showed that holding sweetpotato plants at field capacity or higher for the early establishment phase resulted in significantly increased top growth, adventitious root growth and elongation compared to deficient moisture regimes. Pardales et al (1999) found that a reduction in adventitious roots will have a major influence on the plants ability to forage for nutrients and water and make the plant more susceptible to environmental stresses like drought.

It is suggested that the response to irrigation for T1 and T2 occurred in the first five days prior to rainfall. This is based on the findings of Pardales (1999), the influence of rain (over 70 mm of rain fell after 5 DAP) and the fact that all treatments reverted to identical irrigation regimes at 21 DAP. Since few major differences were found for bulking weight at 37 and 79 DAP the influence of T1 and T2 did not manifest itself until late bulking. The high level of rejects in the driest treatment (T5) and the high temperatures recoded (1 to 5 DAP) (Figure 2) supports this finding and suggests that there was irreversible damage done to the adventitious roots possibly at a cellular level in the early establishment phase. This irreversible damage does not appear to be consistent with the well documented root lignification process that often occurs at the root initiation stage (Wilson 1982). However it is suggesting that the cultivar Beauregard does not necessarily respond to heat by producing [9]pencil roots but produces bulking roots that are deformed and bent. There have been many reports by growers of this cultivar (Beauregard) producing poorly shaped veined roots when planted in hot conditions and this research supports these grower experiences. The major implication for the Australian industry is that the first five DAP are a crucial period in the crop cycle for ensuring the highest possible yields of smooth skin easy to peel sweetpotatoes are produced at final harvest.

Nodal analysis suggests that the flat planting technique results in uniform root set across the three nodes for the commercially important Medium grade. This also has important implications for industry.

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[9] Pencil roots were described by Wilson in 1982 as roots that had initiated but did not form bulking roots.

Pardales Jose R Jr, Dionisio M.Banoc, Akira Yamauchi, Morio Iijima and Yasuhiro Kono (1999) Root system development of cassava and sweetpotato during early growth stage as affected by high root zone temperature. Plant production science 2 (4), 134-139.

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# Project Technology Transfer

## Summary

A suite of technology transfer methods including on farm experiments, information sessions, media news releases, newsletters and farm visits were utilised during the course of the project.

## Introduction

The design of the project process was based on adult learning principles of Action, Evaluation, Review (with additional information) and Plan followed again by action. The first two experiments in 2003 were the initial action phase of looking at a large number of interest areas followed by evaluation, then review with the management committee to plan the next phase of experiments (five) for years 2004 and 2005. For grower clients a suite of methodologies were used to provide them with information for review and planning prior to trialling in their farming systems.

## Methodology for information transfer

Methods used were:

1. Field experiments
2. Information sessions
3. Media news releases
4. Newsletter
5. Farm visits
6. Australian Sweetpotato Growers Association
7. Field demonstrations

### 1. Field Experiments

Of the seven experiments, six were carried out on cooperating grower properties. Apart from the obvious advantage of assessing a number of soil types and climatic regimes the cooperating grower became personally involved in the experiment. The grower then became part of the information transfer process. Field walks were held on properties at harvest time so growers could see first hand experimental results. The seventh and final experiment was carried out at the Department of Primary Industry and Fisheries Bundaberg Research Station. This final experiment looked at six irrigation treatments requiring a level of control that was not available under commercial irrigation systems.

**Experiment 1**: Impact of different cutting and planting techniques on plant establishment and sweetpotato marketability. April to December 2003
Place: Bundaberg (Qld), Grower: Dean Akers

**Experiment 2**: Physiology of sweetpotato planting treatments in winter. May - Dec 2003
Place: Rockhampton (Qld), Grower: Rodney and Col Wolfenden

**Experiment 3**: Physiology of sweetpotato vine type and orientation. Jan - Aug 2004
Place: Bundaberg (Qld), Grower: Dean Akers

**Experiment 4**: Physiology of sweetpotato planting technique and depth. Jan - Oct 2004
Place: Cudgen (NSW), Grower: Kerry and Matthew Pritchard

**Experiment 5**: Physiology of Sweetpotato vine type and planting orientation. Feb - Sept 2004
Place: Bundaberg (Qld), Grower: Brendan Peterson

**Experiment 6**: Physiology of Sweetpotato vine type and herbicide application. Jan - Aug 2004
Place: Rockhampton (Qld), Grower: Rodney and Col Wolfenden

**Experiment 7**: Physiology of Sweetpotato plant establishment and Irrigation Dec - Apr 2005
Place: Bundaberg (Qld), Grower: DPI&F Bundaberg Research Station.

### 2. 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). At all information sessions written handouts were produced for growers to take home

| Date | Venue | Content Presented |
|---|---|---|
| November 2003 | Bundaberg DPI meeting room | Experiment 1 results and Experiment 2 interim results. Project review also carried out with grower management committee. |
| December 2003 | Cudgen Leagues club | Experiment 1 and 2 interim results |
| May 2004 | Bundaberg Research Station | Development of Australian Sweetpotato Industry Group |
| October 2004 | Cudgen leagues club | Experiment 2, 3 results, interim results Experiment 4, 5, 6 |
| December 2004 | Bundaberg DPI Research Station | Experiment 2, 3 results, interim results Experiment 4, 5, 6 |
| July 2005 | Bundaberg DPI Research Station | Results Experiments 1 to 7 |
| August 2005 | Cudgen leagues club | Results Experiments 1 to 7 |
| November 2005 | Mareeba | Results Experiments 1 to 7 |

### 3. 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)
- Vegetables Australia (Ausveg magazine)

### 4. Newsletter

Trial results have appeared in five editions of the “Sweetpotato Newsletter”: April 2003, January 2004, January 2005, October 2005 and February 2006. The newsletter is distributed to all Australian states with a distribution list of 149 growers and 32 Market merchants, Retailers and Agribusiness.

### 5. Farm Visits

A structured part of the information review process was for project staff to visit key growers in the major sweetpotato growing regions for one on one discussion of project results. During the course of the project 75 farm visits specifically related to the project were carried out in the following sweetpotato growing areas: Mareeba, Rockhampton, Bundaberg and Cudgen.

### 6. Australian Sweetpotato Growers Association

One of the key activities of the project was the formation of a management committee with grower representation from the key sweetpotato production areas of Mareeba, Rockhampton, Bundaberg and Cudgen. The management committee met twice per year to review project results and plan further experimentation. A positive outcome from the committee meetings was the formation of the Australian Sweetpotato Growers Association with members from all over Australia representing over 80% of the production area. Project members facilitated the group’s development with one of the projects grower management committee members becoming the inaugural group chairman.

### 8. Field Demonstrations

Two field demonstrations were held in 2006 to reinforce the outcomes of the project for the industry and give new growers an opportunity to view first hand the project outcomes. The project team planted demonstration plots at DPI&F’s Bundaberg Research Station and at a grower collaborators farm in Cudgen. Treatments highlighted vine orientation, planting depth, vine length, number of nodes, node damage, defoliation, plant spacing and irrigation. These treatments were hand excavated and in conjunction with an audio-visual presentation provided a summary of the project outcomes.

### 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. During 2005 a separate HAL funded sweetpotato project (VG 01010) carried out a survey of sweetpotato growers on adoption of project outcomes. Team members of the project reported here were also the principal project officers involved in the VG 01010 project. Included in the survey were questions relating to the current project on planting technique, spacing and irrigation. Pertinent survey results relating to this project are summarised below. The reader is directed to the project report (VG01010) for the complete survey results

VG01010 Survey report selected questions:

*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

*Question: Plant spacing*

When asked if they had changed their plant spacing in the last 4 years 80% of growers in Bundaberg and Cudgen indicated they had

*Question: Irrigation Method*

In 2005, all growers in Cudgen and Mareeba used sprinkler irrigation at planting whereas in Bundaberg this had dropped to 60% with the remainder planting into moisture using trickle irrigation

*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.

As of May 2006 it is estimated that approximately 80% of the Australian crop is planted horizontally

Due to the strong industry linkages and the ownership created by testing many grower nominated treatments adoption of findings occurred as the project evolved.

## Conclusions and Recommendations

The main outcomes from the project were the use of a flat cutting orientation and the importance of soil moisture in the first 5 days after planting.

It is recommended that growers utilise flat cuttings planted 50mm below the surface and maintain small amounts of daily irrigation at least until five days after planting especially in warm conditions. Ambient temperatures over 27 ºC are considered to produce soil temperatures that retard early adventitious root growth and this can be managed with daily irrigation.

For cv. Beauregard it is recommended that cuttings shorter than 30 cm not be used. Seedlings are not recommended at this stage unless they can be produced in a manner that does not constrict early adventitious roots before planting.

The development of leaf area at or just after planting is an important indicator of plant establishment and any agronomic practice that cause leaf loss will either reduce yield, and or delay maturity.

To maximise grower learning it is strongly recommended that wherever possible close contact is maintained with key industry players to enhance the adoption of research outcomes.

For all future sweetpotato experimentation it is recommended that plant material is standardised on the following:
- Pathogen tested material only is used
- If plant material is from different sources then it is blocked by source (especially if seedbed and vegetative vine are used in the same experiment)
- Planting material is cut to a specified length
- The same number of nodes are buried for each plant in a treatment
- Flat planting is used with daily irrigation in the first 5 days after planting.
- Sampling should occur over the life of the plant with at least the critical growth stages being sampled. For cv. Beauregard 30 DAP (root initiation) 60 DAP (early bulking) 120 DAP (optimum maturity).

## Acknowledgements

We gratefully acknowledge the interest of the sweetpotato growers and industry members who have supported this project. In particular, Kerry Pritchard, Doug Padden, Henry Pritchard, Sam Rasso, Brendan Peterson, Rodney and Col Wolfenden, Mathew Pritchard, Duane Joyce, Dean Akers, Troy Prichard, Dave Fisher, directly helped in allowing us to conduct trials on their properties.

The industry members who service the sweetpotato industry deserve special mention. In particular at Cudgen Henry Pritchard (Primac Elders Ltd) has been a great supporter of the project activities and has given freely of his knowledge. The support of the Tweed Valley Growers Association and, John Demiano and John Maughan (Elders - Bundaberg), Richard Ross and Matt Dent (Growcom) is also gratefully acknowledged.

The input of the project management committee that went on to become the Australian sweetpotato growers association (ASPG) has been crucial to the success of the project and maintaining it's industry relevance. The members of the committee that helped to drive the project were Rodney Wolfenden (Chair), Dean Akers, Dave Fisher and Sam Rasso.

We thank DPI&F research station staff particularly Gavin Berry and Warren Flor (Bundaberg Research Station), Bill Pumpa (Rockhampton), Sandra Dennien and Peter Case (Gatton Research Station), and Christina Playford (Biometry Rockhampton).

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## Appendix 1

# Production of marketable sweetpotato

Russell Alan McCrystal

A report submitted as required for the degree of Bachelor Agricultural Science

(Rural Technology) in the University of Queensland

School of Agronomy and Horticulture

Faculty of Natural Resources, Agriculture and Veterinary Science

The University of Queensland, Gatton

November, 2003

The work reported in this research project report has been carried out by the undersigned. Where reference has been made to the results of other workers, appropriate acknowledgement of the source of information has been made.

Author________________

This is to certify that the academic style and manner of presentation of the research project report are appropriate to the discipline, that all requirements of the University in relation to the deposition of records of research have been met and that the information contained in the report is a true representation of the data collected.

Project supervisor_________________

# Table of contents

# Summary

The sweetpotato (*Ipomoea batatas L.*) cultivar Beauregard was grown in the field from August 2003 to October 2004 to investigate the influence that planting technique has on sweetpotato yield (storage root weight and number) and shape. Experimental treatments consisted of variations of three planting orientations, vertical, flat and V shaped. The five vertical planting techniques included vertical shallow, medium, deep, back, and broken cuttings. The three horizontal techniques included flat, shallow, medium, and deep. The V shaped techniques included V shape 3 nodes, V shape 2 nodes, and long V shape three nodes. The flat medium planting technique produced significantly greater numbers of marketable sweetpotatoes, with no storage root weight or number penalties. The long V shape planting technique optimised plant establishment by 44 days after planting, increasing storage root weight and number. This early gain was lost at final harvest (169 days after planting) due to other limiting factors such as irrigation and nutrition. The results indicate that a sweetpotato cutting planted horizontally in the soil profile to a medium depth (7.5 cm) will optimise the number and weight of marketable storage roots. There is potential to increase yields through the use of longer cuttings if other limiting factors such as irrigation and nutrition can be quantified and their effects reduced.

# Introduction

The sweetpotato (*Ipomoea batatas L.*) is a dicotyledonous plant that belongs to the family Convolvulaceae. Amongst the approximate 50 genera and more than 1000 species of this family, only Ipomoea batatas is of major importance as a food (Woolfe 1992). There are a very large number of cultivars that differ in the colour of the root skin (white, cream, brown, yellow, red or purple), or flesh (white, cream, yellow, orange or reddish-purple), in size and maturity, the resistance to disease, and in the texture of the cooked roots (Woolfe 1992).

The sweetpotato originated in Central or South America, and remains of cultivated sweetpotato from Peru have been dated at approximately 2000 B.C. (Woolfe 1992). Sweetpotato has now spread to most of the world's tropical, sub-tropical and warmer temperate regions. It has become an extremely important crop, being cultivated in more than 100 countries (Woolfe 1992). Developing countries produce and consume nearly all of the world's sweetpotatoes. Approximately 90% are grown in Asia, just under 5% in Africa and only 5% in the rest of the world. Only about 2% of the world's sweetpotatoes are grown in industrialised countries, mainly in the United States and Japan (Woolfe 1992).

Sweetpotato was introduced into Australia primarily as a stock feed. In many cases they were only considered as a substitute for Irish potatoes when prices of that vegetable were high (Loader et al. 2000).

Sweetpotato production in Australia is very small on a global scale, approximately 16 000 tonnes per year (Coleman 2002 *pers comm*). By comparison, Irish potato production is approximately 1.2 million tonnes per year (Harper 2003 *pers comm*). Major sweetpotato production areas are situated along the east coast of Australia including Mareeba, Rockhampton and Bundaberg in Queensland, and Cudgen on the Tweed coast, Northern NSW. The most prominent growing area is Bundaberg, producing approximately 7000 tonnes per year of sweetpotato.

A grower survey undertaken by DPI in 2002 of the Mareeba, Bundaberg and Cudgen areas indicated that of the 866 acres planted, approximately 95% were of Beauregard. The other 5% planted were mostly of the cultivar Northern Star.

Beauregard is described as a dessert type sweetpotato, as it was developed in the USA for their sweet style of cooking. The cultivar was introduced into Australia from the USA about 10 years ago (Coleman 2002 *pers comm*). Beauregard is a gold cultivar, preferred for its smooth, pink with orange skin, elongate shape, and good orange flesh quality (Loader et al. 2000). Northern star is described as a staple type sweetpotato and has smooth, clear, waxy, intermediate purple outer skin and a deep purple inner skin with a small white spot around the eyes, and pale cream flesh (Loader et al. 2000).

Sweetpotato is predominately grown for the fresh market, although a small quantity of sweetpotato is supplied to the processing industry, commonly for baby food. Sweetpotato is available on the Australian domestic market for 12 months of the year, and most are sold in the Brisbane, Sydney and Melbourne wholesale markets through agents or merchants. Smaller markets are Adelaide, Newcastle, Perth, Townsville, and direct selling to retail outlets.

Variability of sweetpotato shape is the main issue facing the sweetpotato industry in Australia. Smooth even-shaped roots are in high market demand while ribbed, elongate and bent roots are of little value. Globally few markets are as discerning with regard to shape as Australia. Other major markets where shape is particularly important, such as the United States of America, have a short annual production window. Australian producers must produce sweetpotato year round and this leads to a common set of planting and plant establishment methods being applied across a range of environmental conditions.

# Materials & Methods

## Plant material

On the 31 February and 1 April 2003, 2244 Beauregard cuttings were prepared for planting on the 3 April 2003. Cuttings were taken from first generation virus-checked material provided by the DPI low disease seed program, led by Bill O'Donnell and Eric Coleman. Cuttings were prepared by cutting a length of vine and removing leaves from the nodes at the base end of the cutting. The leaves are removed from those nodes at the bottom end of the cutting, as they are the nodes placed under the soil profile for storage root production.  Cuttings were prepared of different lengths, different numbers of nodes, different type and from different sources. Cutting lengths compared were 45cm and 60cm. The number of nodes compared were two, three and four nodes under the soil profile. Cutting types included tip, back and broken. A tip cutting is the length of vine taken starting from the apical meristem to where the vine is cut. A back cutting has its apical meristem removed and the broken cutting was purposely broken along the vine at a point between those nodes placed below the soil surface. Plant material was classed into two groups, that with purple pigmentation and that without purple pigmentation. Once cuttings were prepared they were stored for three days at ambient temperature in the shade, with the nodes that were to be placed into the soils profile wrapped in moistened hessian bags.

## Planting site

The experiment was conducted on a forest red soil (ferressol), on a commercial property near Bundaberg. The experimental area had previously been cropped with sugar cane for several years.

## Planting methods

*Planting* - On the 3 April 2003 all cuttings were planted 30 cm apart in hills 1.5m wide by 0.5m high for both the buffer and experimental hills. The different cutting materials were blocked with purple pigmentation material in block one and material without purple pigmentation in blocks two and three. Immediately after planting, property staff irrigated the experiment with 25mm of water using solid-set sprinklers.

*Treatments* - The experimental planting techniques (treatments) consist of eleven variations of three planting orientations. The three orientations are vertical, flat and V shaped (Figure 2).

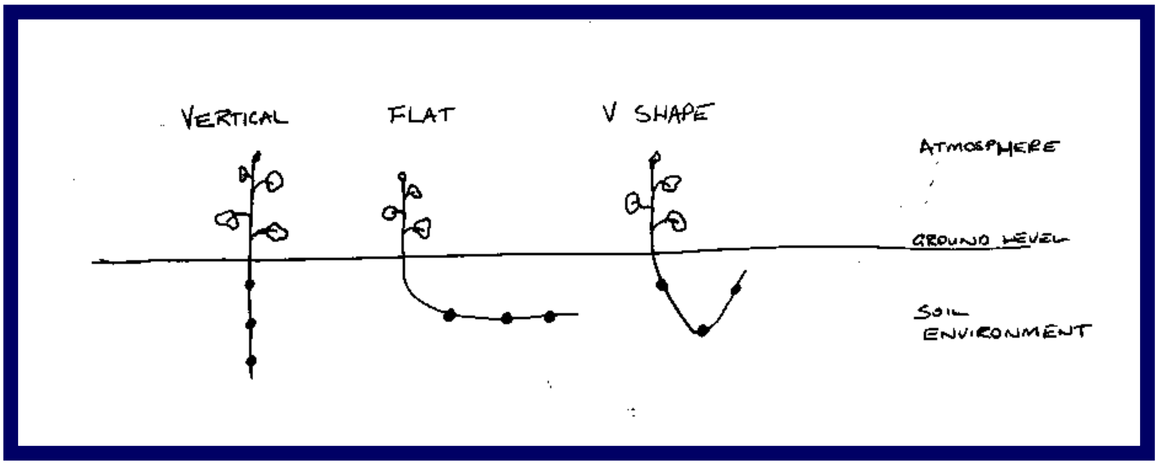

**Figure 2:** Three cutting orientations under the soil surface, vertical, flat and V shape.

Vertical Orientations

- Back cutting with 3 nodes planted to 15 cm
- Broken cutting with 3 nodes planted to 15 cm
- Vertical shallow cutting with 2 nodes planted to 10 cm
- Vertical medium cutting with 3 nodes planted to 15 cm *(control)*
- Vertical deep cutting with 4 nodes in soil planted to 20 cm

Flat Orientations

- Flat shallow cutting with 3 nodes in soil planted at 2.5 cm
- Flat medium cutting with 3 nodes in soil planted at 7.5 cm
- Flat deep cutting with 4 nodes in soil planted at 12.5 cm

V shape orientations

- Long V shape cutting (2 ends out of soil, 2 nodes in soil) planted to 15 cm
- V shaped with 3 nodes in soil planted to 15 cm
- V shaped with 2 nodes in soil planted to 10 cm

## Crop management

The crop was managed by the property manager. Crop management practices include weed control, insect control, nutrition application, and irrigation.

## Experimental measurements

At 44 DAP the first three plants of the first experimental hill for all planting treatments were harvested. Vine weight, storage root weight and storage root number were recorded. Sweetpotato vine was removed by cutting the main vine or vines from just above the soil surface.

At 69, 121, and 169 DAP the next three plants of the first experimental hill for all planting treatments were harvested. Vine weight, storage root weight and storage root number were recorded as at 44 DAP. The number of marketable roots was also recorded. Storage roots that were smooth and elliptical in shape were classed as marketable. Roots that were deformed, bent or lumpy were unmarketable. This was determined using the Woolworth’s specification guide for marketable sweetpotatoes.

At final harvest (215 DAP) all plants (17) of the second experimental hill for all planting treatments were harvested. Storage root weight and number were recorded for undersized, small, medium and large marketable storage roots and unmarketable storage roots according to the Woolworth's specification guide for marketable sweetpotatoes.

| | |
|---|---|
| Undersized | Length <130mm |
| | Diameter <50mm |
| Small | Length 130 – 180mm |
| | Diameter 50 – 60mm |
| Medium | Length 180 – 250mm |
| | Diameter 60 – 75mm |
| Large | Length >250mm |
| | Diameter >75mm |

At final harvest a further two planting techniques were harvested from outside of the initial experimental zone. These included

1) DPI&F sweetpotato material planted using growers method (DPI)
2) Growers material planted using growers method (Dean's)

These plots were harvested to gain an idea of how the growers method influences marketable storage root weight and number.

## Experimental design and analysis

The design was a randomised complete block, comprising eleven planting treatments as main plots, replicated in three blocks. The treatments were randomly assigned within each block and each treatment plot. Experimental main plots consisted of four hills, each being 1.5 m wide, 0.5 m high by 5.4 m long. Only the central 2 hills of the plot were used for experimental purposes. The outer, non-experimental hills were used as buffer zones between the blocks. Experimental plots were also buffered by a white skinned, purple flesh sweetpotato cultivar at each end of the experimental zone, which consisted of 17 plants per hill.

Genstat version 6 was used to run standard analysis of variance procedures for sweetpotato yields and yield components. Standard F-tests at the 5 % probability level were used to determine significant differences between treatments, and protected LSDs were used for examining differences between individual treatments. The correlation of storage root weight and storage root number to vine weight was also analysed using simple linear regression and simple linear regression with groups.

# Results

At 44 DAP the first sample harvest was undertaken. The long V-shape planting technique produced the greatest average weight of storage roots at 288.3 g (Figure3). This is significantly greater than all other planting techniques ($P < 0.05$, lsd = 87), except for the vertical medium technique (209 g) and the V-shaped 2 node technique (205 g). The planting techniques recording the lowest total storage root weight were the three variations of the flat technique. Storage roots from the flat shallow technique had a mean weight of 142.4 g, the flat medium 96 g and the flat deep 122 g. These values were all significantly less then those for the long V shape planting technique (Figure 3).

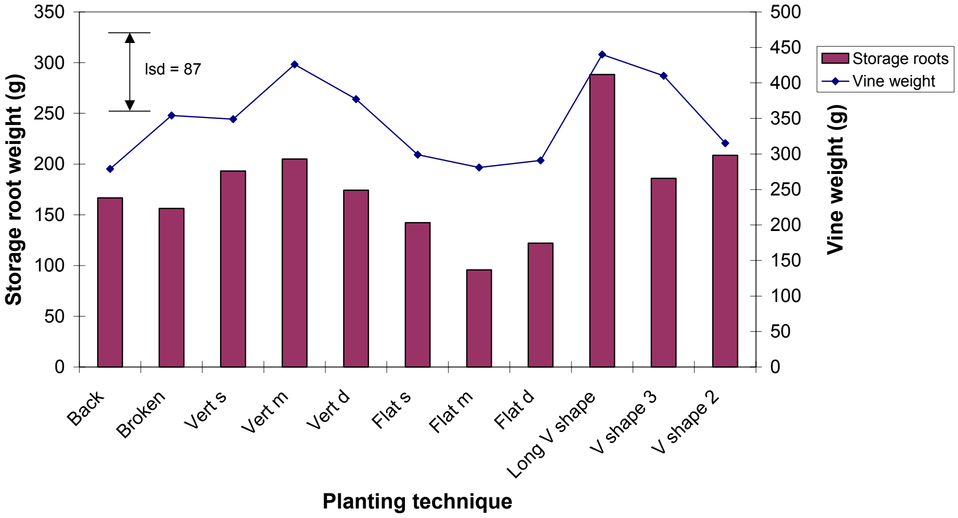

**Figure 3:** Vine weight and storage root weight per sample (3 plants) ($P<0.05$, lsd=87) response to planting technique at 44 DAP.

The long V shape planting technique also produced the greatest average number of storage roots (23) (Figure 4). This number is significantly greater than from all other planting techniques ($P < 0.05$, lsd 5.6), except for the V shape 3 node (21), flat medium (19) and the flat shallow (18) (Figure 4).

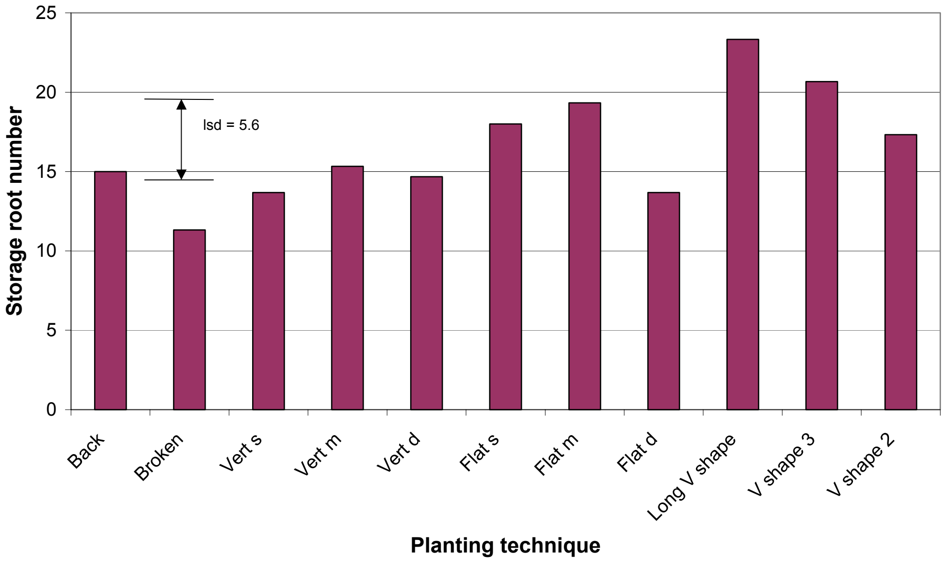

**Figure 4:** Storage root number per sample (3 plants) in response to planting technique at 44DAP (P<0.05, lsd 5.6).

A significant blocking effect occurred for both storage root number (P<0.05, lsd = 3) and storage root weight (P<0.05, lsd = 46) (Figure 5). Block three recorded the greatest storage root weight (204g) and storage root number (19). This was significantly greater than for block one for both storage root weight (136g) and storage root number (14), but was not significantly greater than for block two for storage root weight (189g) and storage root number (16) (Figure 5).

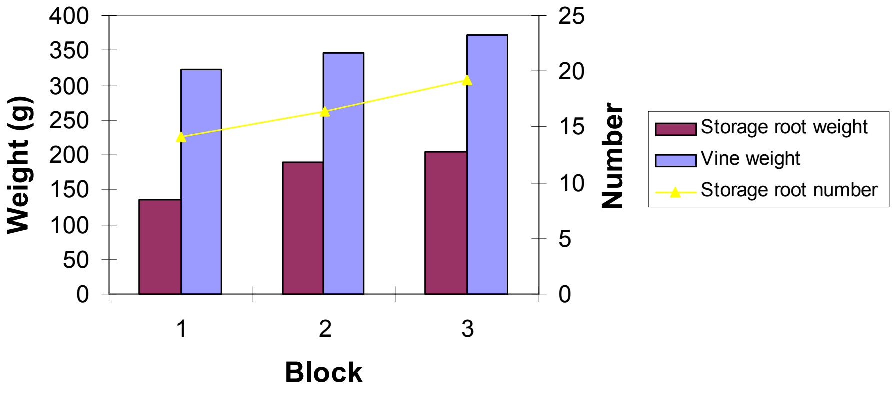

**Figure 5:** Vine weight (g), storage root weight (g) and storage root number per sample (3 plants) in response to blocking.

Vine weight was correlated to the storage root weight (Figure 6), but storage root number was not (data not shown). Correlation was low when vine and root weight data were analysed using simple linear regression ($r^2 = 0.475$). When analysed using simple linear regression with groups (purple or non-purple planting material) the correlation between vine weight and storage root weight increased. The coefficient of determination for the purple group and the non-purple groups were both 0.542 (Figure 6). For the blocked data the coefficient of determination was no different (0.53).

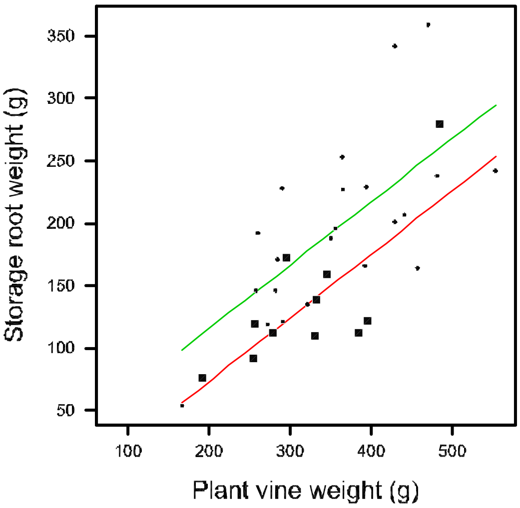

**Figure 6:** Relationship between vine weight (g) and storage root weight (g) at 44 DAP when grouped into purple (|) or non-purple pigmented (●) planting materials ($R^2$ for both lines is 0.542).

At 69 DAP the second sample harvest was undertaken. Significant differences occurred between planting techniques for the average storage root weight (P<0.05, lsd=150) (Figure 7). No significant differences occurred for the average storage root number (average of 21) (figure 8), marketable storage root number (average of 6) (figure 8) or vine weight (average of 525 g). No significant correlation was found at 69 DAP between storage root weight/number and vine weight ($r^2 = 0.15$).

The long V shaped planting technique had a significantly greater storage root weight (613 g) (figure 7) than all flat techniques, the vertical techniques, and the other V shaped techniques except for the vertical deep planting technique (479 g). Storage root weight showed similar trends to those noted between planting techniques at 44 DAP, and flat planting techniques recording lowest storage root weights (figure 7).

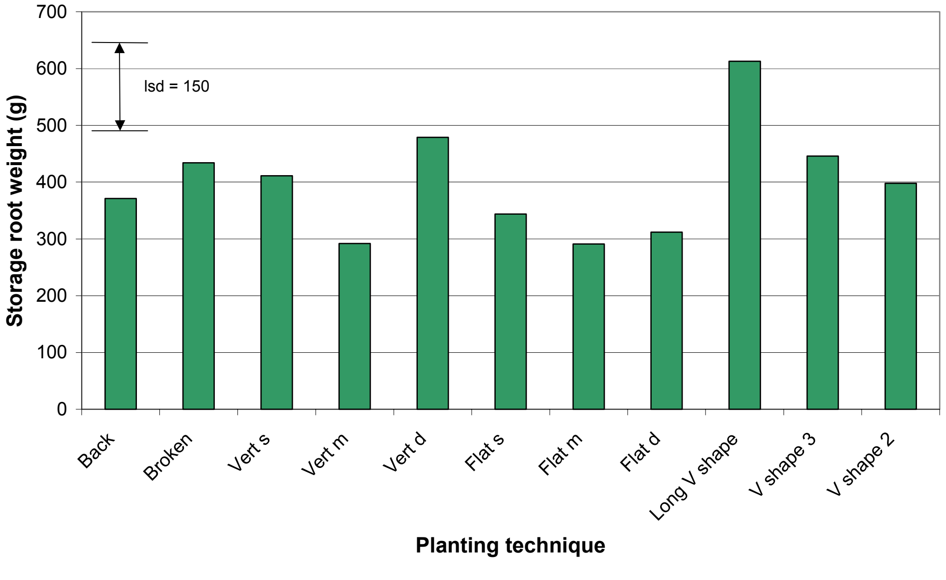

**Figure 7:** Storage root weight per sample (3 plants) (P<0.05, lsd=87) response to planting technique at 69 DAP.

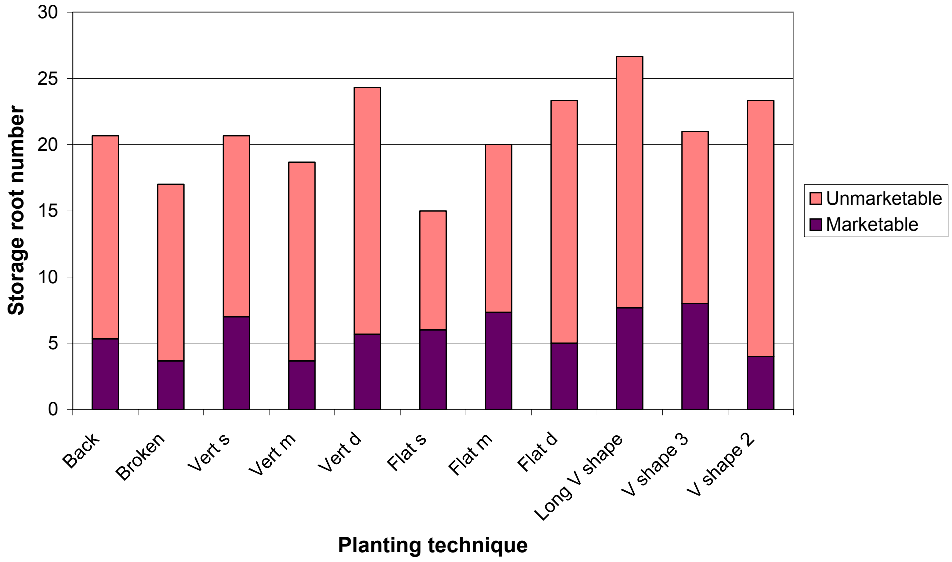

**Figure 8:** Storage root number per sample (3 plants) of three plants (divided into both marketable and unmarketable storage roots) in response to planting technique at 69 DAP.

At 121 DAP there were no significant differences in average storage root weight (average of 1559 g) (figure 9), vine weight (average of 886 g) or marketable root numbers (average of 9) between planting techniques (figure10). Significant differences did occur between planting techniques for the average number of storage roots set (P<0.05 & lsd = 7) (figure10). Storage root number was significantly greater for the flat deep planting technique, recording an average of 30 storage roots per sample of three plants. This was significantly greater than all vertical techniques and the long V shape technique. The flat deep technique did not produce significantly greater numbers of storage roots than the V shape 3, V shape 2 or other flat techniques. The flat shallow technique produced 27 storage roots and the flat medium 24 storage roots.

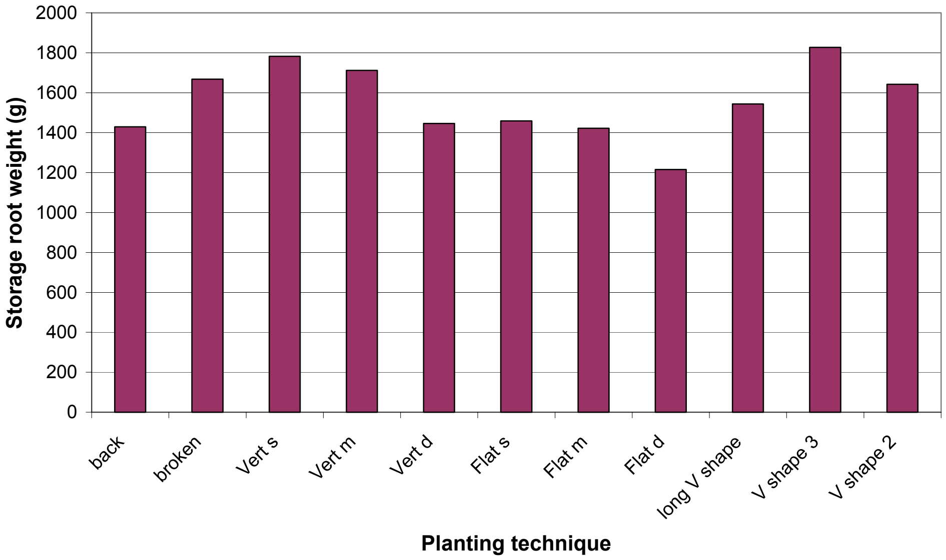

**Figure 9:** Storage root weight per sample (3 plants) in response to planting technique at 121 DAP.

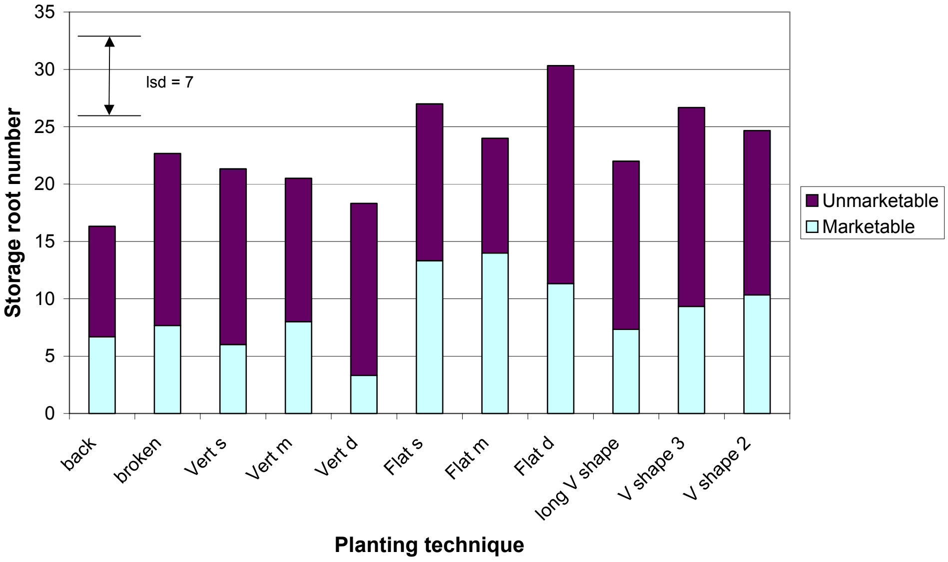

**Figure 10:** Storage root number per sample (3 plants) (divided into both marketable and unmarketable storage roots) in response to planting technique at 121 DAP. Significant (P<0.05, lsd = 7).

At 169 DAP there were no significant differences between planting techniques for storage root weight (average of 3179 g) (figure 11), storage root number (average of 26) (figure 12) or vine weight (average of 1126 g), but there was a significant difference in the number of marketable storage roots ($P<0.05$, lsd = 6) between planting techniques (figure 13). The flat medium planting technique produced a significantly greater number of marketable roots (averaging 20) then did all vertical and V shaped techniques. Within the flat techniques the flat deep produced significantly fewer marketable roots (average of 13) then did the flat medium (20), but the flat shallow (average of 15.67) did not produce significantly more or less marketable roots than the flat deep or medium planting techniques.

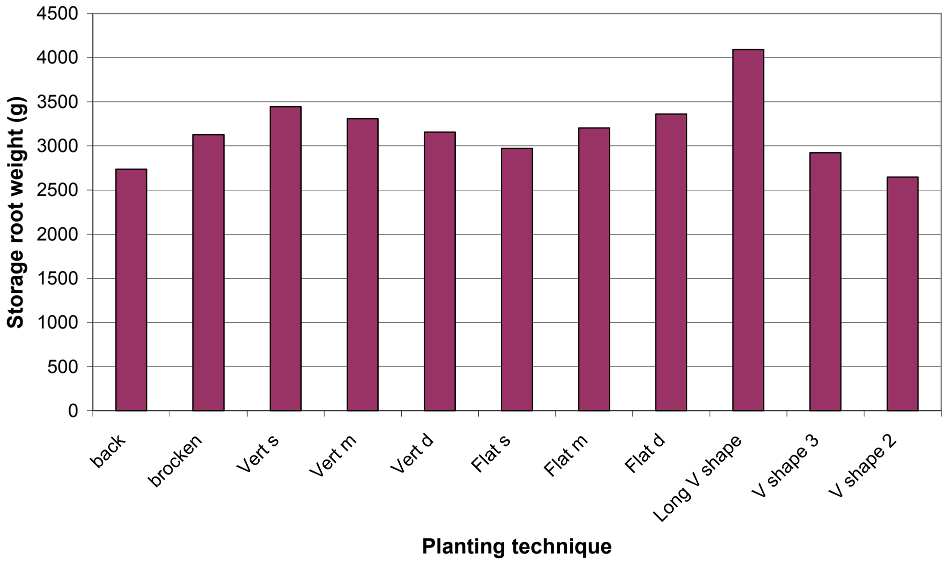

**Figure 11:** Storage root weight per sample (3 plants) in response to planting technique at 169 DAP.

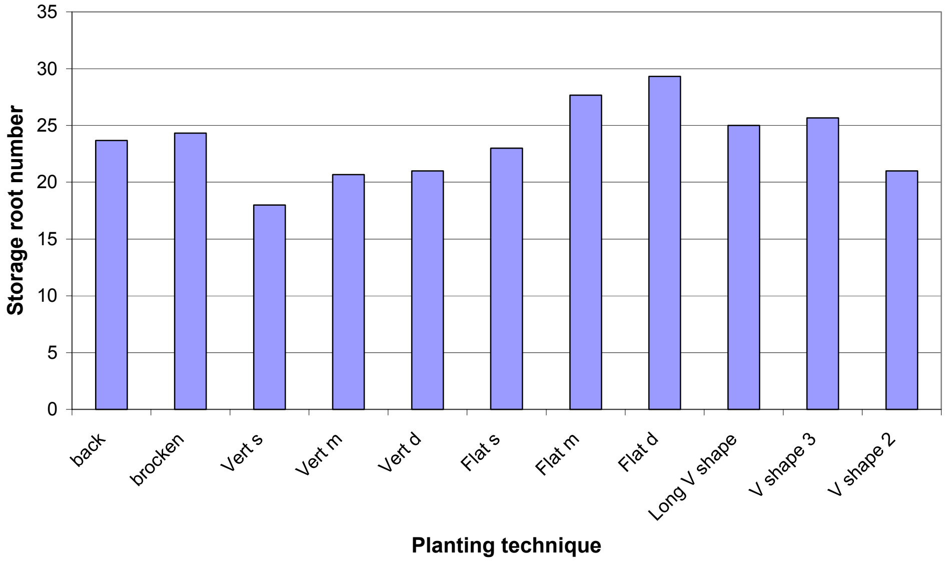

**Figure 12:** Storage root number per sample (3 plants) in response to planting technique at 169 DAP.

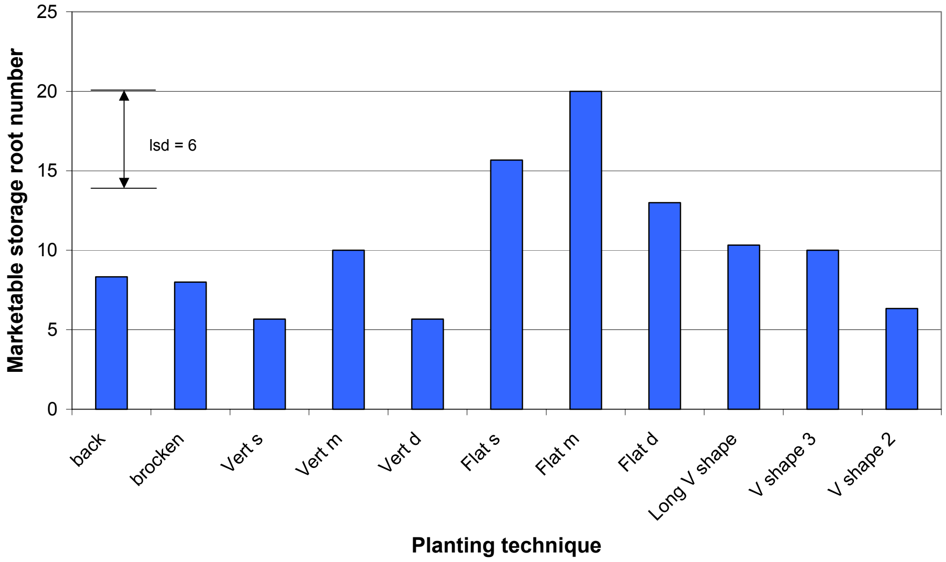

**Figure 13:** Marketable shape storage root number per sample (3 plants) in response to planting technique at 169 DAP, Significant ($P<0.05$, lsd=6).

At final harvest (215 DAP) the flat deep and medium planting techniques recorded the greatest number of storage roots, at 81 and 80 respectively. This is significantly ($P < 0.05$, lsd = 17) greater than all planting techniques, except for the vertical deep planting technique that set 65 storage roots (figure 14). The flat medium planting technique recorded the greatest storage root weight at 25 kg. This is significantly ($P < 0.10$, lsd = 5) greater than all planting techniques, except the V shape with 2 nodes (22.8 kg), flat shallow (22.3 kg), flat deep (21.8 kg), vertical deep (21) and the long V shape (20.4 kg) planting techniques (figure 15).

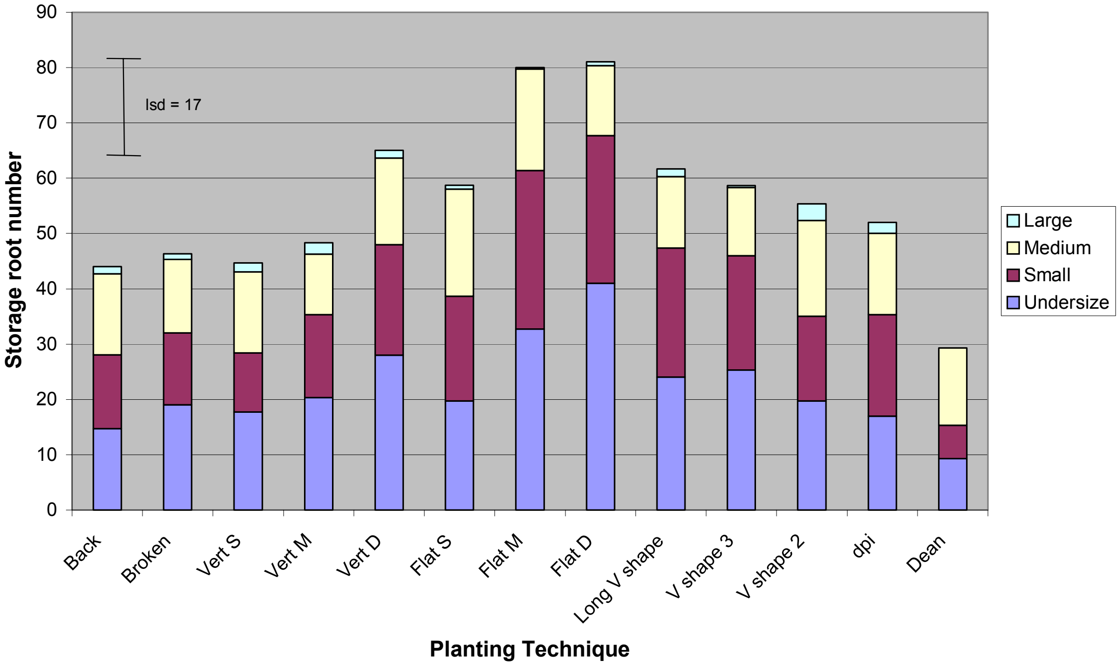

**Figure 14:** Marketable storage root number, per sample (17 plants), in response to planting technique at final harvest (215 DAP). Significant ($P < 0.05$, lsd = 17). Note: The different colours within the bars represent the different size categories of marketable storage roots.

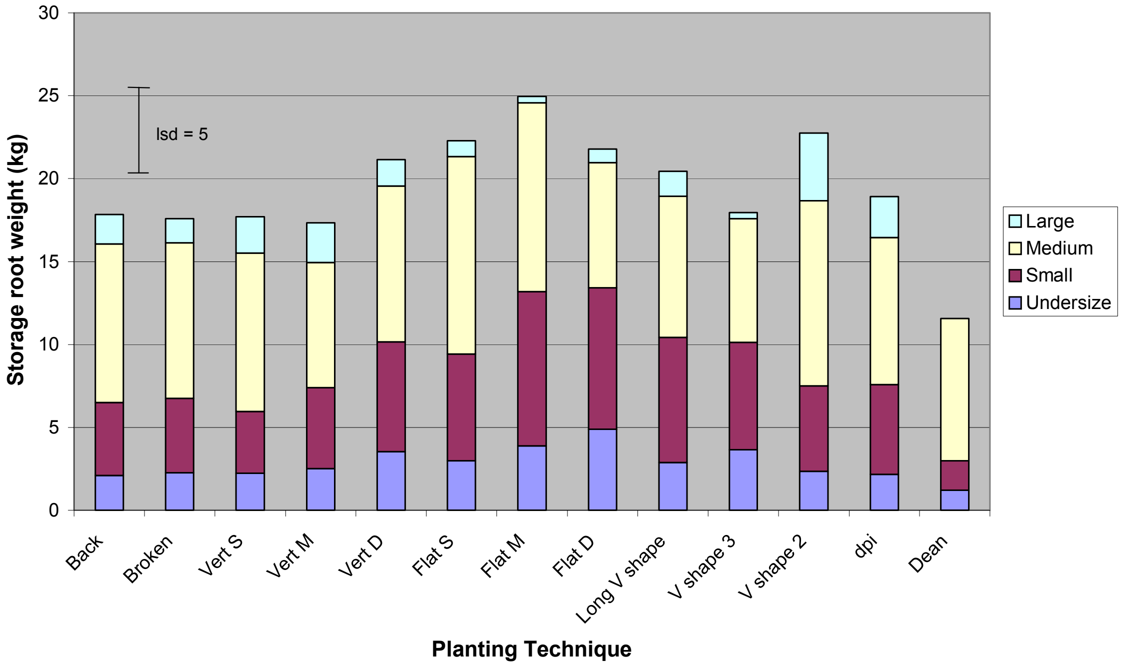

**Figure 15:** Marketable storage root weight, per sample (17 plants), in response to planting technique at final harvest (215 DAP). Significant ($P < 0.10$, lsd = 5). Note: The different colours within the bars represent the different size categories of marketable storage roots.

These yield parameters were further divided into size categories (undersize, small, medium, large and unmarketable) and analysed. Within the small category the flat medium planting technique set 29 storage roots. This is significantly ($P < 0.05$, lsd = 6) greater than all planting techniques, except for the flat deep (27) and long V shape (23) planting techniques (figure 16). The flat medium planting technique also recorded the greatest storage root weight, for the small size category, at 9.3 kg. This is significantly ($P < 0.05$, lsd = 2.1 kg) greater than all planting techniques, except the flat deep (8.5 kg) and the long V shape (7.5 kg) planting techniques (figure 17).

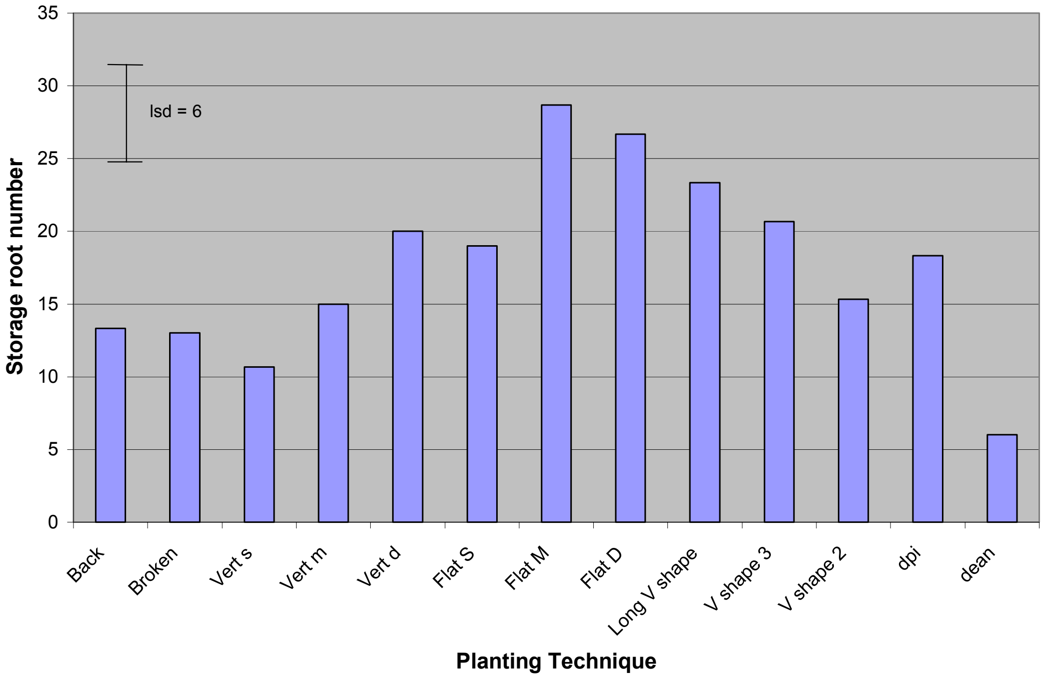

**Figure 16:** Small storage root number, per sampling (17 plants), in response to planting technique. Significant (P < 0.05, lsd = 6).

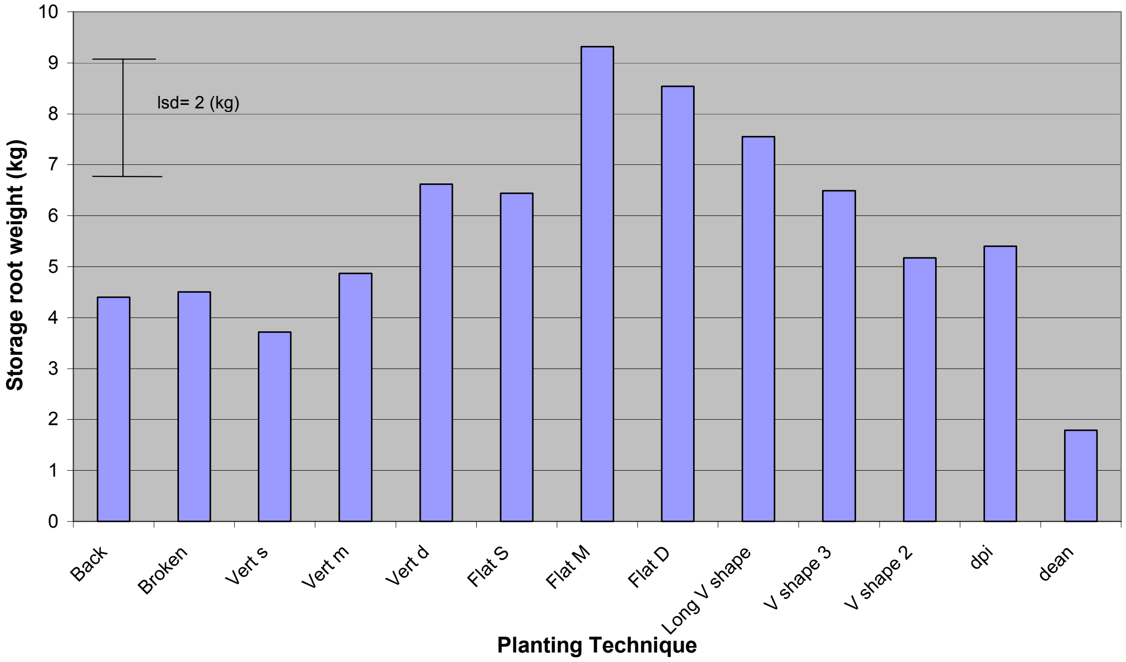

**Figure 17:** Small storage root weight (kg), per sampling (17 plants), in response to planting technique. Significant (P < 0.05, lsd = 2).

Within the undersize category the flat deep planting technique set 41 storage roots. This is significantly (P < 0.05, lsd = 12) greater than all planting techniques, except the flat medium planting technique, which set 33 undersized storage roots (figure 18). The flat deep planting technique also recorded the greatest storage root weight, for the undersize category, at 4.9 kg. This is significantly (P < 0.05, lsd = 1.4) greater than all planting techniques, except the flat medium (3.9 kg) and V shape 3 node (3.7 kg) planting techniques (figure 19).

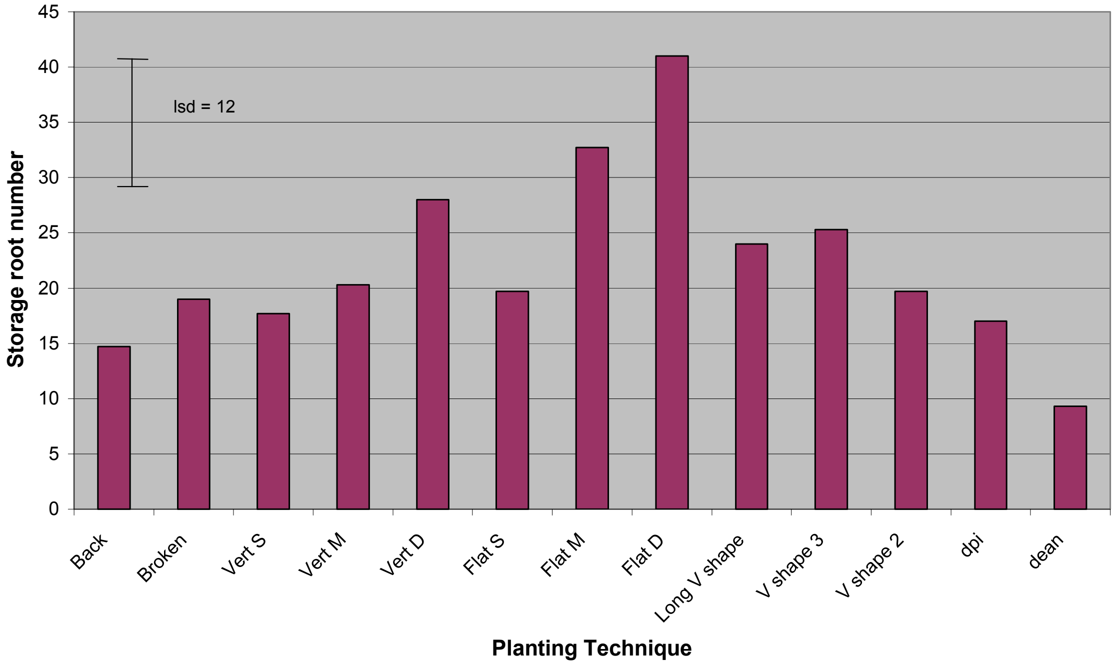

**Figure 18:** Undersize storage root numbers, per sampling (17 plants), in response to planting technique. Significant (P < 0.05, lsd = 12).

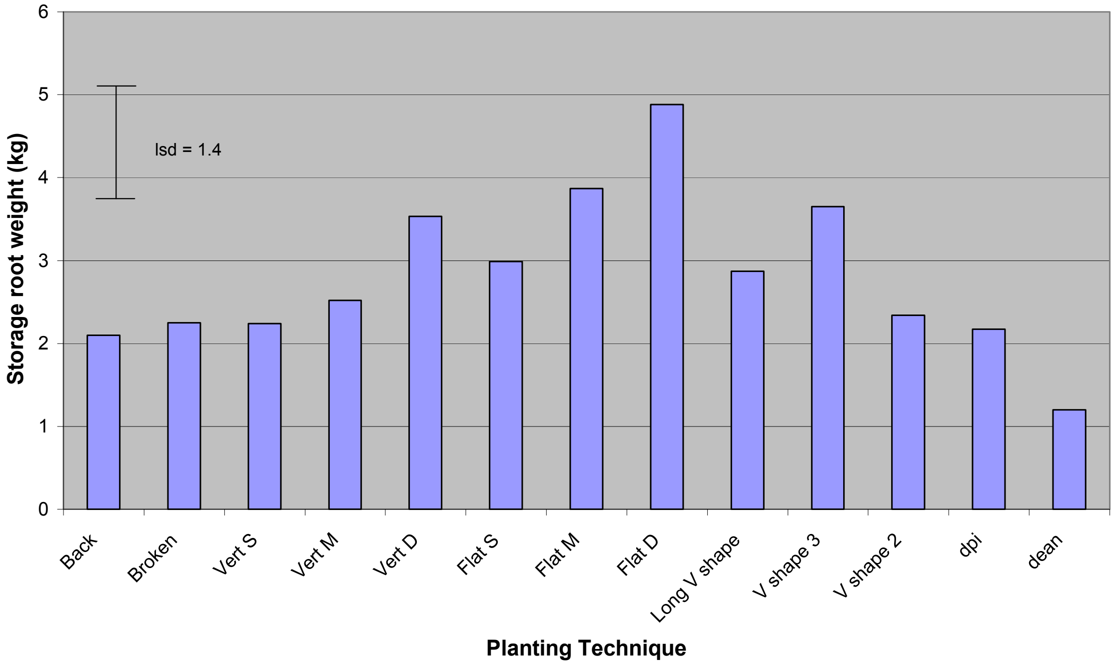

**Figure 19:** Undersize storage root weight (kg), per sampling (17 plants), in response to planting technique. Significant ($P < 0.05$, lsd = 1.4).

No significant differences occurred between planting techniques for storage root weight and number in the large, medium and unmarketable storage root categories. The average storage root weight and number for the large size category recorded was 1.5 kg and 1 respectively. The average storage root weight was 9.3 kg and the average storage root number was 15 for the medium size category. For the unmarketable category of storage roots the average weight was 17 kg and the average number was 68.

## Discussion

Planting technique influences storage root shape and plant establishment for an autumn planting of the sweetpotato cultivar Beauregard in the Bundaberg region on a red ferrosol, hard setting soil. A tip cutting of 45 cm with three nodes planted horizontally in the soil profile to a depth of 7.5 or 12.5 cm optimises the number of marketable storage roots at 215 DAP (figure 14). Early crop establishment can also be optimised (44 DAP), but these initial gains are lost at 215 DAP due to other determining factors. A 60 cm cutting planted with three nodes in a V-shaped orientation to a depth of 15 cm optimised plant establishment resulting in the greatest weight of storage roots (figure 3), which was correlated to vine weight (figure 6), and the greatest numbers of storage roots set (figure 4).

At 169 DAP the 45 cm long tip cutting planted horizontally in the soil profile with three nodes at a depth of 7.5 cm (flat medium technique) yielded an average of 20 marketable shaped storage roots (figure 13). This result was significantly greater than all V-shaped and vertical planting techniques (figure 13). Within the flat planting techniques (shallow, medium, and deep) the flat shallow planting technique averaged 16 marketable storage roots, which was similar to the flat medium technique, but the flat deep planting technique did produce significantly fewer marketable storage roots.

At 215 DAP the 45 cm long tip cutting planted horizontally in the soil profile with three nodes at a depth of 7.5 cm (flat medium technique) and 12.5 cm (flat deep technique) yielded an average of 80 and 81 marketable shaped storage roots respectively (figure 14). These numbers are significantly greater than from all other planting techniques other than the vertical deep technique, planted to 20 cm (figure 14).

The flat planting technique was able to minimise the crowding of storage roots in comparison to the vertical and V-shaped planting techniques. Adventitious roots produced in the first 20 days from root primordia (typically found at nodes) were the first sweetpotatoes or storage roots to develop under favourable environmental conditions (Woolfe 1992). These adventitious roots perceive gravity, in the root cap, which directs growth of these roots downward (Taiz & Zeiger 2002). This means that as these roots move downwards in the soil profile, soil structure effects the proliferation of these adventitious roots throughout the soil profile. Physical restriction due to overcrowding in the root zone is more likely to occur depending on the orientation of the cutting. The overcrowding in the root zone manifests itself as poor storage root shape from 169 DAP to final harvest (215 DAP). The orientation of the vertical and V-shaped planting techniques combined with the soil structure in which the cuttings were planted resulted in the adventitious roots proliferating close to one another in the soil profile. Once these roots were initiated as storage roots and bulking began, their shape was influenced by the size and shape of the surrounding storage roots. The flat planting techniques were able to ensure that adventitious root proliferation from one node was sufficiently spaced from other nodes and thus minimising storage root crowding.

Results obtained from samplings 44 DAP to 169 DAP were based on two storage root categories, marketable and unmarketable. At final harvest (215 DAP) the larger collection of plants enabled the marketable storage root data to be further categorised into undersize, small, medium and large marketable storage roots. Analysing this data revealed that the flat medium and flat deep planting techniques set significantly greater numbers of marketable storage roots. These results were similar to those found at the 169 DAP sampling. The difference between the 215 DAP and the 169 DAP results is that the significantly greater numbers of marketable storage roots set by the flat medium planting technique is due to significantly greater numbers of undersized and small storage roots (figure 14, 16 & 18). No significant differences were achieved between planting techniques for the medium and large storage root categories.

Early storage root formation can be enhanced by modifying common planting techniques. However any benefit gained by this early storage root development is lost later in the crops development due to other yield limiting factors such as irrigation and nutrition. At 44 DAP the long V shape planting technique, with three nodes planted to 15 cm deep produced the greatest storage root weight (figure 3) and storage root number (figure 4). Early plant establishment was indicated by an increased storage root weight, increased storage root numbers, and increased vine weight. Vine weight was correlated to storage root weight at 44 DAP (figure 6). The increased ability of the longer cutting to establish itself before other treatments may be associated with cutting length, but more directly, it is associated to an increased number of new leaves. According to Salisbury and Ross (1992) new leaves produce more IAA than older leaves and IAA initiates adventitious roots at the root primordia. This is supported in this experiment by the use of a back cutting i.e. a cutting which has the apical meristem removed. The back cutting technique set significantly lower numbers of storage roots and with less weight than the long V shaped planting technique (apical meristem intact) (figures 4 and 5). The 60 cm tip cutting maximised storage root weight at 44 DAP as it inevitably increased the number of leaves in comparison to a 45 cm tip cutting at planting. These extra leaves give the establishing plant the ability to partition more assimilates into root sink development soon after planting.

At 121 DAP the flat deep planting technique had significantly greater numbers of storage roots then all vertical and long V planting techniques. This unexpected result may be due to favourable conditions at the nodes of the flat deep technique setting more storage roots between 69 DAP and 121 DAP. The node sites for other techniques may not had favourable conditions. The increased depth may have produced optimum soil temperatures for storage root initiation (25ºC) whereas at other depths, the soil temperatures (less then 25ºC) may have inhibited further storage root initiation. At this stage the crop was trying to develop in the coldest part of the growing season and the depth of this planting may have acted as a buffer against decreasing surface soil temperatures and allowing the conversion of carbohydrates to starch (Kano and Mano 2002).

At planting, the crop-experienced ideal, non-limiting conditions for plant establishment, as plants were initially irrigated directly after planting by overhead sprinklers and then further watered by a rainstorm that evening. These conditions ensured that the only factor limiting plant establishment was planting technique. The timing of this experiment in autumn in the Bundaberg region, meant that the growth and development of the sweetpotato crop was over the winter period. Though the winter period in the Bundaberg region is mild, crop development is reduced as root zone temperatures do drop below those needed for starch accumulation Beauregard. The use of an overhead travelling irrigator and different vine materials (purple or no purple pigmentation) in this experiment also added variation (figure 5). Travelling irrigators can reasonably be expected to only deliver 70% distribution uniformity (Wallace 2003 *pers comm*). Future work should be performed using trickle irrigation to reduce this variability.

# Conclusion

Shape is the main factor affecting the quality of fresh sweetpotatoes in Australia. The ability to influence shape and hence marketability early in the crop production phase, presents a major shift in current agronomic practices for the majority of Australian sweetpotato producers. A flat planting technique can reduce crowding and optimise marketable storage root numbers in hard setting soils. Longer cuttings with increased numbers of new leaves optimises plant establishment, storage root number and weight, but this early gain is lost later during crop development due to other limiting factors, such irrigation and/or nutrition. Further research needs to test the same planting techniques under different environmental conditions such as summer planting on a lighter textured soil. The effects of irrigation and nutrition should also be investigated in relation to inhibiting yield potential. A cutting planted horizontally in the soil profile will optimise the number of marketable storage roots. This increase in storage root numbers does not result in the increase of the premium medium grade of marketable storage roots but in the increase of undersized and small storage roots. There is potential to increase saleable yields through the use of different length cuttings and cutting types but other factors need to be investigated so as to continue this early potential through to final harvest. The challenge is to ensure that the increase in marketable storage root numbers are in the medium category and not in the small and undersized categories.

# Acknowledgements

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Appendix 2

# HAL Project VG02114 Development of Smooth skinned easy to peel sweetpotato-Literature review

*Eric Coleman, Russell McCrystal, John Maltby, William O'donnell, DPI Gatton Research Station September 2003*

# HAL Project Report

## Development of smooth skinned easy to peel sweetpotato using smart state technology

## Acknowledgements

Funding for operating expenses for this project has been provided by QFVG. Horticulture Australia Limited (HAL) has then matched this funding. The Department of Primary Industries (Queensland) has provided the input of permanent Agency for Food and Fibre Sciences (AFFS) Horticulture staff to manage and carry out the project work.

Craig Henderson from AFFS-Horticulture Gatton is thanked for supplying a literature review he performed as part of a Rural Water Use Efficiency project. References and parts of Craig’s review have been used in developing this review. Craig’s full review is attached as Appendix 1

# HAL Project Report

## Development of smooth skinned easy to peel sweetpotato using smart state technology

## Summary

To consistently produce the quality sweetpotato desired by the Australian market requires use of production techniques that allow the sweetpotato plant to initiate and develop sweetpotatoes over a range of environmental conditions.

For sweetpotato storage roots to develop consistently involves careful consideration of factors that will influence the three major stages of storage root development:

***(i) adventitious root development***

***(ii) storage root initiation***

***(iii) storage root thickening (bulking)***

Adventitious root development occurs in the first 30 days after planting (DAP) and these adventitious roots later become the first storage root the sweetpotato plant develops. The development of adventitious roots is influenced well before planting of the cutting with the physiological state of the plant material selected being of major importance. After planting, adventitious growth can be easily checked by management practices that do not adequately consider the vulnerability of this plant while it is establishing.

The storage root initiation phase is governed by plant hormones in response to a range of environmental and genetic cues, all of which are not yet fully understood.

The root thickening process that leads to production of marketable storage roots is then controlled by environmental and management practices that influence the production of photosynthetic assimilate (sugars) in the leaves and their subsequent transport and storage in the roots. Understanding this source sink relationship is necessary for developing new management strategies to develop smooth skinned easy to peel sweetpotato.

## Main Findings

- ***There are major differences between cultivars and how they establish***
- ***Soil temperature impacts on initiation and bulking***
- ***Irrigation is a major plant establishment management issue***
- ***Leaf development after transplanting is critical***
- ***Gains in early establishment can often be lost later in the crop by other limiting factors***
- ***Stress at strategic times may improve bulking***
- ***There may be strategic times to take cuttings***
- ***In general hills are better for sweetpotato production***

# HAL Project Report

## Development of smooth skinned easy to peel sweetpotato using smart state technology

## Introduction

Variability of sweetpotato shape is the number one issue facing the sweetpotato industry in Australia. Smooth even shaped roots are in high market demand while ribbed, elongate and bent roots are of little value. Globally few markets are as discerning with regard to shape as Australia. Other major markets where shape is particularly important such as the U.S have a short annual production window. Australian producers must produce sweetpotato year round and this leads to a common set of planting and plant establishment methods being applied across a range of environmental conditions.

Nowhere in the world have multiple strategies been developed for overcoming plant establishment challenges under varying environmental conditions. A management strategy to overcome this will therefore require a combination of early plant establishment techniques that can be changed to suit the changing planting environments throughout the year.

This will most likely include

- use of different methods of producing plant material
- a better understanding of plant material selection in relation to it's vigour.
- adjusting planting methods depending on the environmental conditions at the time of planting
- developing management strategies for plant establishment at crucial stages to minimize adverse environmental impacts.

The aim of this review is to identify international research that can be applied to the Australian production system to help us develop new strategies for our unique production and marketing chain.

*A comment on terminology*
There is conjecture in the literature on whether a sweetpotato is a tuber or a root. So as to not confuse the issue I have referred to the sweetpotato as a storage root not a tuber.

Also for ease of reading I have substituted the use of the word assimilate (that is the product of photosynthesis) for sugars.

# HAL Project Report

## Development of smooth skinned easy to peel sweetpotato using smart state technology

## Plant material and planting techniques

### Introduction

The use of vegetative plant material has the potential to produce major variations in the way a crop like sweetpotato establishes and grows. These variations may be due to planting material size, amount of nutrient, energy reserves, the number of growing points (nodes) and the conditions experienced when it is first planted. Further to this the way in which this material was growing before being cut for planting is also likely to contribute to it's performance once it is planted.

### Physiology and Environment

*Physiology of plant material*

Plant material selected may be from a plant that is actively producing top, just initiating storage roots, or rapidly thickening storage roots. Similarly levels of various nutrients needed for early growth may not be at optimum levels for fast healthy early establishment. Although no definitive evidence exists in the literature that might help decide what is optimum plant material, some evidence suggests that the physiology of the plant material has a major impact on early adventitious root development.

When one node pieces were propagated in seedling trays for 2 weeks, (Saiful Islam et al 2002) then transplanted either whole or with roots removed, the intact transplant had the highest yield of top weight and storage roots, while the transplant with the roots removed had the second highest yield of top and storage roots. When the two transplant treatments were compared to a standard un-rooted cutting both had higher top and root weights. There are a number of possible physiological reasons why a transplant with the roots removed produced more top and root wt than a standard cutting. Saiful Islam et al (2002) suggests that the transplant had a higher photosynthetic rate with sugars already being channelled into root production so new root production occurred more rapidly when the one node piece was planted after having it's roots removed. Whatever the reason this clearly demonstrates an early establishment difference between two cutting types that did not have roots, due to physiology of plant material.

Using plant material off crops that are stressed from lack of water, cold or heat may also reduce yields. Stressed plants can have higher levels of the plant hormone abscisic acid (ABA) which is an inhibitory hormone often associated with triggering dormancy/senescence (Salsbury and Ross 1992).

Young/new leaves are known to have higher levels of the auxin indole acetic acid (IAA). IAA has a known role in activating adventitious root growth on many plant cuttings and it is found in higher levels in young and newly developed leaves (Salsbury and Ross 1992). It is suggested this is a major contributing factor to the experience growers often have with faster establishment when they use tip cuttings instead of back cuttings. This also highlights the importance of healthy early leaf development and minimising leaf loss after transplanting.

*Temperature*
Atmospheric and soil temperatures are potentially the most underestimated cause of transplant shock and poor storage root development in the sweetpotato industry. High atmospheric temperatures without adequate cooling from irrigation can cause leaf loss and as described in the previous section this has a dramatic impact on adventitious root development. Root zone temperatures of 40 deg C or higher can result in overall reduced length and development in adventitious roots and any development that does occur tends to be greater at deeper nodes (lower soil temp). At root zone temperatures of 25 deg C, more roots are initiated and elongated from nodes closer to the soil surface (Pardales et al 1999).

Pardales et al (1999) also suggests that a reduction in adventitious roots will have a major influence on the plants ability to forage for nutrients and water and make the plant more susceptible to environmental stresses like drought.

## Management Strategies

*Cuttings/transplants and planting technique*
The size of cuttings being used has been shown (Hall 1986) to have an impact on the marketable yield of a given cultivar. These yield responses however are variable between cultivars. Hall (1986) found that the cultivar Red Jewel had higher yield of marketable (US number one grade) when a 40-45cm cutting was used compared to a 20-25 cm cutting, and there was no yield difference with varying the number of nodes under the ground or with a flat versus a vertical orientation. However for the cultivar Georgia Jet there was no difference between the 2 lengths of planting material or orientation but 2-3 nodes under the ground resulted in higher marketable yields than 5-6 under the ground. Similarly other research has shown significant increases in yield by using 46 and 61 cm long cuttings instead of 23 and 31 cm lengths (Godfrey 1973). The extra vine at planting was also shown to reduce the vine/tuber weight ratio suggesting that there was a positive influence in favour of storage root development by having extra vine early.

Another factor that may influence management techniques is that soil temperature changes as a result of depth in the soil profile over time. The soil surface is most sensitive to variations in solar radiation and atmospheric temperature and hence temperature fluctuations are most pronounced closer to the surface. The deeper in the soil profile the less pronounced temperature fluctuations will become.

There may be some scope, through the use of soil temperature probes at planting, to place the cuttings at the optimum depth and orientation as to ensure that the maximum number of nodes are placed in the optimum temperature zone for storage root initiation. In the cooler months of the year a shallow horizontal cutting orientation may be best to take advantage of soil temperature increases near the surface. Plooy and Du-Plooy (1990) stated that prolific storage root differentiation as well as more rapid development on the first subterranean nodes, compared with those of storage roots on the deeper nodes, was a general phenomenon and hence suggested that cultivars with long internodes could be profitably planted horizontally in the soil profile. During the warmer months, cuttings orientated vertically may place the nodes at soil depths that escape the warmer soil temperatures.

Lewthwaite (1999) has found sprouts held in air for six days and rooted seedlings from plug trays (transplants) to have significantly better plant establishment and higher yield at 53 days than sprouts treated with nutrient solution, held for 6 days, held for 9 or treated with anti-transpirant. . This research suggests that plant material that is planted with the ability to absorb nutrient and water (via small roots) is an improvement over a conventional cutting.

Use of transplants has also been shown by Saiful Islam et al (2002) to produce higher storage root to top yield and improved length and diameter of storage roots compared to a conventional cutting. While use of transplants may improve establishment and yield, other work has shown that the method of transplant production can markedly reduce quality. Ching (2000) demonstrated a strong relationship between storage root shape and transplant cell type. Round cells produced long bent storage roots and inverted pyramids produce shorter straighter storage roots. As the adventitious roots are the first to grow and they later become the storage roots the amount of time the transplant spends in the cell will also impact on the final storage root shape.

In another interesting study, Levett (1993) changed the number of nodes buried and significantly changed the size distribution, but once again it was highly cultivar dependant.

Table 1. Summary of critical plant material and planting technique issues

| *Positive Responses* | *Negative Responses* |
|---|---|
| Plant material that is actively producing adventitious roots (eg transplants) | Plant material losing leaves, off late bulking plants or from stressed crops |
| Cuttings longer than 40cm | Cuttings shorter than 40cm |
| Root zone temperatures below 35 deg C | Root zone temperatures above 35 deg C |
| Transplants | Transplants with constricted roots |
| Cuttings with small roots | Cuttings with long roots |

# HAL Project Report

## Development of smooth skinned easy to peel sweetpotato using smart state technology

## Early Plant establishment(planting to 20DAP)

### Introduction

When sweetpotato cuttings are planted there is always an episode of transplant shock. The amount of transplant shock is governed by a number of factors and anything that is done to minimise that shock will lead to less wilting, faster establishment and higher yields of shoot and root mass. The first adventitious roots produced are the primary absorbers of water and minerals and become the first sweetpotatoes to form (Pardales et al 1999).

### Physiology and Environment

*Root development*
Saiful Islam et al (2002) produced one node plug transplants in two different volume plugs. He then planted some with roots i.e. plug intact (transplant) some with roots removed and a conventional tip cutting. Under a non- irrigated planting (although in a high rainfall area) he found the transplants with roots intact not only had the highest shoot and root yield during growth but also the greatest mass of non-storage roots. These non-storage roots are thought to greatly enhance the ability of the plant to take up nutrients leading to greater storage root yield. The greater quantity of these non-storage roots was maintained through to final harvest. This suggests that anything that inhibits early root establishment will have a marked impact on final storage root yield.

In an experiment conducted by Lewthwaite (1999) cuttings that were held until some roots developed and transplants, had much greater yields of leaf and root material then a range of other treatments with varying numbers of nodes underground. The held cuttings may be further enhanced by holding them in darkness (*perscomm* Lewthwaite 2003) Sprouts held for 9 days were not as good as those held for 6 days as many of the roots are easily broken at planting and excess time exposed to air induces root lignification (hardening) of the early adventitious roots stopping them progressing to storage roots later. It is postulated that this result could also be due to physiological aging of the plant material i.e. respiration and use of the energy reserves of the cutting before planting although no evidence could be found in the literature.

*Top development*
Not only do Young/new leaves produce the plant auxin indole acetic acid (IAA) that activates adventitious root growth on the cutting they are the

primary source of sugars that are needed to develop new growing points at the root and vine meristem (ends). After planting the cutting needs to generate sugars and partition them between the needs of the forming roots particularly the adventitious roots and the need to increase leaf area. Villagarcia et al (1998) has shown that high levels of N at 30 DAP reduces root initiation and diverts sugars to top growth. High levels of moisture (Henderson 2003) have also been shown to favour top growth. Little information has been found on the effect of high levels of N at planting when rapid vine growth would be useful. Villagarcia et al (1998) did find that switching from High N at 30 days to lower levels does stimulate storage root development.

## Management Strategies

### *Irrigation*

Until a root system is established the provision of moisture is critical for the developing roots. A pot experiment (Pardales et al 2000) showed that by holding sweetpotato plants at field capacity or higher for the early establishment phase significantly increased top growth, adventitious root growth and elongation compared to deficient moisture regimes.

### *Nutrition*

The application of N at plant establishment (particularly with trickle) may be an area needing further investigation as a tool to improve early plant/top growth and hence provide greater ability for the plant to produce sugars later for storage root development. High levels of N have been shown to favour top growth by a number of researchers (Villagarcia et al 1998, Acock and Garner 1984). Lewthwaite (1999) used 2 different nutrient starter treatments but found no significant effect. The risk with applying too much N early is that the plant will maintain top growth at the expense of storage root formation; this may lead to irreversible lignification. Villagarcia et al (1998) demonstrated a root bulking advantage by applying high N at 30DAP and later withdrawing the N resulting in diversion of sugars into greater root production.

### *Anti-transpirant*

Due to the fragile nature of sweetpotato cuttings some growers have suggested that coatings/anti-transpirant application may reduce moisture loss from the cutting while the roots are being established. Lewthwaite (1999) applied 2 anti-transpirant products designed to reduce the stress on the cuttings at planting but found no significant effect.

Table 2. Summary of positive and negative factors for early plant establishment

| *Positive factors for early cutting/plant establishment* | *Negative factors for early cutting/plant establishment* |
|---|---|
| Presence of roots at planting | No roots at planting |
| Transplant or small roots at planting | Long roots at planting |
| Early vigorous leaf growth | Wilting/leaf loss |
| High moisture levels up to 28DAP | Periods of moisture deficiency |
| Holding cuttings till small roots establish | Holding cuttings till roots over 15mm long develop |

## Storage root initiation(20DAP to 40DAP)

### Introduction

The actual production of sweetpotato storage roots for harvest, has been described by Wilson (1982) as a three stage process:

***Step 1. Development of potential sweetpotato bearing roots***

***Step 2. Sweetpotato initiation***

***Step 3. Sweetpotato development to maturity***

For this process to be successful of course we need as many healthy roots that have the potential to turn into storage roots as possible. Sweetpotato storage roots come from adventitious roots (adventitious roots are roots growing out of the stem). These adventitious roots are geotropic i.e. they tend to follow gravity and there are five distinct types (Wilson 1982)

- ***Thin***
- ***Thick***
- ***String***
- ***Pencil***
- ***Sweetpotato (tuber)***

Storage root initiation occurs in the cultivar Beauregard at 30-48 days after planting (DAP). These storage roots develop from the first adventitious roots sent out by the cutting planted in the first 1-2 weeks of growth. Factors that have a negative impact on the length, shape and vigour of these first adventitious roots are most likely to reduce yield of marketable quality storage roots.

### Physiology and Environment

*Storage root initiation*

Nakatani et al (1988) has shown that storage root initiation is the time at which top growth and stem elongation (the dominant sugar sinks) gives way to storage root development as the new sink (approx 7 weeks DAP). Chua and Kays (1981), Pardales et al (1999) have both linked the predominance of top growth to be the plants reaction to various environmental conditions such as drought, high root zone temperature and waterlogging. It is believed that these factors impact on the roots as the dominant sink causing excess sugars to be diverted to the tops encouraging their growth (Henderson 2003 , Nakatani et al 1988)

Two conditions have been shown to produce thick roots and thin roots without initiating storage roots, these are high root zone temperatures (Pardales et al 1999) and lack of aeration resulting from waterlogging (Chua and Kays 1981). The use of hills for planting has consistently proven superior for sweetpotato production around the world and this is thought to be linked to aeration (Chua and Kays 1981).

High root zone temperature (40 deg C) has also been shown to promote root lignification and thus retard sweetpotato development (Pardales et al 1999). High root zone temperature favours vegetative growth, this may be due to sugars being directed to the tops as the roots cannot develop or the high temps reduce the ability of the roots to convert sugars to starches resulting in sugars being directed to top growth.

*Storage root shape*
Experiments performed on different shaped transplant containers have shown a marked affect on shape of roots at harvest. Ching (2000) showed that sweetpotato transplants grown in round cells for the first 50 days produced 8 round coiled storage roots compared to none for plants grown in inverted pyramid cells. This early restriction of the adventitious roots must therefore be carefully considered in soils with poor structure. Likewise if early adventitious root development is too favourable i.e. in deep sands then it is possible that roots will become too elongate. It is suggested that duplex soils may produce shorter less elongate roots (*pers comm*. Canon 2002).

## Management

*Top growth*
As discussed previously the goal before initiation should be to develop as high a leaf area as possible. At root initiation management of potential root sink limiting factors must be carefully managed and then ideally a triggering of the plant hormones that start root swelling are needed. Possibly the best early plant establishment strategy to achieve this would be to induce some mild stress at approximately 30 DAP, possibly moisture or nutrient stress (particularly N) may be worthwhile.

*Irrigation and temperature*
Irrigation at the adventitious root development stage must be well managed. Low moisture levels may increase compaction reducing adventitious root ability to penetrate through the soil causing bending and shortening. Sajjapongse and Roan (1980) suggest that very loose soil favours top growth at the expense of storage root formation while hard ground restricts top growth and storage root formation/enlargement. The best bulk density for soil being 1.3-1.5 g/cc.

Irrigation stress at storage root initiation has been shown in a number of studies to limit both final yield and root set, this is probably best addressed by Henderson (2003). Henderson (2003) concludes that irrigation deficiency later in the storage root development process does not have the same impact on yield as it does in the early storage root formation stage.

### *Temperature Management*

As stated earlier soil temperature or root zone temperature has been shown to effect storage root initiation and subsequent bulking. Literature states that the optimum temperature zone for storage root initiation ranges from 20 to 30 deg C. Thus, the aim of the grower should be to provide a root zone temperature adequate for storage root initiation.

If water is readily available at the soil surface, most of the absorbed heat energy will be utilised to evaporate water. Brady and Weil (2002) state that water regulation seems to be a key to what little practical temperature control is possible for field soils. Soil temperature can be maintained below 30 deg C through irrigation or rain as long as the water is cooler than the soil it is penetrating. While in the cooler months, unnecessary soil moisture needs to be minimised so that energy is not wasted evaporating moisture instead of heating the soil profile.

Henderson (2003) proposed that different methods of irrigation may be more beneficial during certain environmental influences than others. For example, in the summer months at 40 – 50 DAP irrigation is essential for good crop establishment and storage root initiation. Henderson (2003) states that overhead irrigation should be used instead of trickle applications during this time to cool down the total soil surface and the surrounding atmosphere. Once the crop is established then trickle irrigation can be used.

Soil cover markedly influences the amount of solar radiation reaching the soil. According to Brady and Weil (2002) bare soils warm up more quickly and cool off more rapidly than those that are covered. Vegetation and mulches have the ability to buffer the amount of solar radiation reaching the soil surface. When atmospheric temperature and solar radiation are high it is important to establish a healthy crop canopy before storage root initiation occurs. This will provide buffering from sharp increases in soil temperature above 30 deg C.

When soil temperature drops below 20 deg C it is harder to establish an adequate crop canopy before storage root initiation (autumn plant). In this case the use of mulches, or wider plant spacings allowing more light to hit the soil surface may be useful warming techniques. This of course needs to be traded off with weed control, this also highlights the importance of weed control as weeds will provide unwanted cover and reduce soil temperatures in the cooler months.

### *Aspect*

The angle at which the suns rays strike the soil influence soil temperature (Brady and Weil 2002). If the sun is directly overhead, the incoming path of the rays are perpendicular to the soil surface and energy absorption is greatest. In the southern hemisphere during the summer the sun rises directly east to west, but during the winter months the sun moves further to the north, rising in the north east and setting in the north west. This seasonal change influences how the suns rays strike the soil surface.

The use of hills for sweetpotato production also influences the way in which the sun strikes the soil surface. Brady and Weil (2002) state that planting crops on ridges is one method of controlling the soil aspect on a micro scale and that ridges need only be 25 cm tall to have a marked effect. Planting sweetpotatoes on hills (minimum height of 25 cm) that are running east to west will encourage warming on the northern side of the hill in winter, Brady and Weil (2002) state that this can achieve an increase in temperature from one side to the other by 8 deg C. During the warmer months of the year hill direction may not influence soil temperatures as significantly as the sun is directly overhead.

Table 3 Summary of factors for root initiation

| *Positive factors for root initiation* | *Negative factors for root initiation* |
|---|---|
| Moist aerated conditions | Wet conditions with no aeration/oxygen |
| Healthy long adventitious roots | Short moisture stressed adventitious roots |
| Low N at 30DAP | High levels of N at 30DAP |
| High moisture levels up to 30DAP | Periods of moisture deficiency up to 30DAP |
| Root zone temperatures 20-30degC | High root zone temperature ie over 35deg c and low root zone temp below 15degC |
| Moisture stress at 30DAP | Heavy watering at 30DAP |

# HAL Project Report

## Development of smooth skinned easy to peel sweetpotato using smart state technology

## Relationship between top growth and root development(40DAP to harvest)

### Introduction

The relationship between top growth and root development is a complex process centred around the production of assimilates (sugars) from photosynthesis and their conversion to carbohydrates i.e. starches. These starches while stored in leaf blades and petioles are mainly stored in the roots as sweetpotatoes. The way the plant switches from sugar production for growth of top, to sugar storage in roots is a complex combination of how much sugars are being produced and a range of controlling plant growth regulators and environmental factors. When conditions favour the partitioning of sugars into top growth, growing roots are more prone to lignification an irreversible process that precludes root swelling.

Studies of sugar partitioning between the tops and the roots is made more difficult because the sweetpotato plant unlike other plants like potato (solanum tuberosum) does not have a distinct shift between vegetative growth and tuber/storage root development (Chua and Kays 1981). In short the sweetpotato is able to start loading sugars into the roots but can then change the sink back to vine or leaf growth depending on a number of environmental, nutritional and other factors.

### Physiology and Environment

*Source sink relationship*

The competition between the growing of vine and the development of storage roots (a source sink relationship) is the key to storage root development. The switching from early top development to storage root development is primarily governed by the genetic make up of the plant. The point of conjecture is whether the top or roots are dominant. Nakatani and Koda (1998) has shown the following:

- In the first 5-7 weeks after planting top growth and stem elongation is the dominant sink
- Storage roots become the dominant sink when they reach 10g/plant (about 8 weeks)
- After storage roots become dominant the main competitive sink is new leaf turnover

Contrary to this Bouwkamp and Hassam (1988) concluded that under the conditions of their experimental work vine effects were dominant in affects on root yield and root sink effects are not controlling. They go on to say that source sink relationships throughout a growing season vary among cultivars.

*Role of natural plant hormones*

The main focus of research in sweetpotato growth regulators has been to try and link levels of the various plant hormones such as gibberellins, auxins, cytokinins, abscisic acid and jasmonic acids to storage root initiation and storage root thickening.

**Gibberellins** act in most plants to promote extensive growth i.e. lengthening of stems and shoots. This has been confirmed in sweetpotato (Foda et al 1998) with gibberellins showing a strong inhibitory affect on sweetpotato storage root development (a thickening process).

**Auxins** and in particular indole acetic acid or IAA are the main plant hormones concerned with root growth and regulation. IAA is responsible for adventitious root development of stems of many vegetatively propagated plants. It is well recognised that young leaves and buds have a role in adventitious root development as they are a source of auxins at root primordia (potential sites for new roots) found at nodes (Salsbury and Ross 1992). While some researchers (Wilson 1982) consider IAA necessary for sweetpotato development others (Nakatani and Komeichi 1991) have shown that it is not a limiting factor in sweetpotato thickening.

**Cytokinins** promote cell division and cell expansion; they are naturally present in high levels in new shoot growth and can direct partitioning of nutrients to the new shoots where they are present. One of the main sweetpotato root development cytokinins is zeatin riboside (ZR). Zeatin riboside levels have been shown by a number of researchers to be elevated when thick roots appear particularly around week 4 to 7 (Nakatani and Komeichi 1991) (Matsuo et al 1983). As well as ZR riboside levels needing to be elevated for sweetpotato formation elevated levels of jasmonates are needed. Initial stimulation of ZR levels cannot always be linked to photosynthetic rate and there is a definite genetic role in the turning off and on, the production of this cytokinin (Nakatani and Komeichi 1991).

**Abscisic Acid ABA** is an inhibitory plant hormone that's levels are often elevated when a plant is undergoing stress. This stress can be in the form of, heat, cold, moisture deficit or salinity and in some plants it acts to trigger seed formation or dormancy (Salsbury and Ross 1992). Elevated levels of ABA have been reported in sweetpotato at root thickening (Nakatani and Komeichi 1991). While it appears that ZR acts to start root thickening, ABA takes over to keep the root bulking.

**Jasmonic acid** is also inhibitory and in many crops promotes dormancy, leaf senescence and differentiation of various organs and tissues. In sweetpotato elevated levels have been quantified at storage root initiation when root swelling and root colour change occurs (Nakatani and Kado 1998) (Koda 1997). However elevated levels do not promote storage root bulking past the initial thickening stage.

*Application of plant hormones/growth regulators*
As the exact mechanism for the production of storage roots from sugars is not fully understood there are no examples of any fieldwork showing significant benefits to root yield or quality due to the external application of plant growth regulators/hormones. Foda et al (1998) has used potassium bicarbonate as a growth regulator based on the assumption that luxury levels of CO2 would stimulate root development and had significant improvements in tuber weight. No other researchers have verified this work.

*Temperature*
Spence and Humphries (1971) found for the cultivar C9/9 that root zone temperatures between 20 and 30 deg C produced the highest rate of storage root development while temperatures below 15 and above 35 deg c retarded storage root development. This difference is most probably due to poor starch synthesis. Most cultivars have an ideal temperature range for the necessary enzyme to convert sugars to starches.

## Management

*Temperature*
The ability of the chemical pathways in the sweetpotato plant to convert sugars to starches and hence produce storage roots has been shown to be limited by temperature (Spence & Humphries 1971). The exact temperature range varies between varieties in Spence & Humphries (1971) experiments, 25 deg C was optimum and 30 deg C and 15 deg C were the limits for storage root development. Thus, the aim of the grower should be to provide a root zone temperature adequate for storage root bulking.

Generally, at storage root bulking a crop canopy has established buffering most solar radiation from reaching the soil. During the cooler months it may be beneficial to have wider plant spacings in order to maximise the amount of solar radiation hitting the soil surface. At this time, it is also important to ensure that any unnecessary soil moisture is minimised so that whatever energy reaches the soil surface is not wasted evaporating moisture instead of heating the soil profile. According to Henderson (2003) once the sweetpotato crop is established there are probably minimal effects from erring on the dry side of a soil moisture tension of 60 kPa.

Henderson (2003) also proposed that different methods of irrigation might be more beneficial during certain environmental influences than others. The use of trickle irrigation in the cooler months, instead of overhead, will enable wetting of a localised area, ensuring that any unnecessary soil moisture and heat loss is minimised.

For the same reasons discussed in the previous section '*Storage root inititiation (Temperature Management/Aspect)'* the sweetpotato crop should also be planted on hills running east to west, of a minimum height of 25 cm, during the cooler months. This will maximise the energy absorption of solar radiation into the soil surface.

During the warmer months the established crop canopy, present during storage root bulking, is necessary to buffer the extreme temperature fluctuations. Plant spacings should be closer than those used in the cooler months. When soil temperatures are increasing above the optimum temperature range during storage root bulking soil moisture can cool the soil environment back to within the optimum range. Applying irrigation will cool the soil profile suitably.

Aspect of the sweetpotato hills during the warmer months of the year may not influence soil temperatures as significantly as the sun is directly overhead.

*Irrigation*

Moisture stress has least impact during storage root development (Henderson 2003). However severe moisture stress (most commonly seen as mid day wilting) during storage root development that causes leaf stomata to close resulting in reduced transpiration and photosynthesis has been shown by Boukamp and Hassam (1988) to result in significant yield reductions. In a crop with a reduced leaf area the use of some extra irrigation to avoid mid-day wilting may be useful.

In an experiment by Lewthwaite (1999) well established seedlings and rooted cuttings had significantly higher root weight at 53 DAP but no significant differences at harvest, this is thought to be directly related to a lack of rainfall during bulking. This may explain some of the early success experienced by growers converting to trickle irrigation as well established crops are now reaching their full yield potential. Similarly full yield potential of over-wintered crops may not be reached unless irrigation regimes are increased going into spring.

*Top Growth*

Nakatani et al (1988) suggests that once the sweetpotato storage roots reach 10g/plant the roots become the dominant sink and a vigorous top will not limit yield. In most studies events that check top growth during storage root development will usually limit yield (Boukamp and Hasam 1988).

*Shape*

There was no evidence in the literature of the shape being affected by rate of starch production or the slowing or speeding up of growth during the root bulking stage. Levett (1993) changed the number of nodes buried and significantly changed the marketable and non-marketable distribution, but once again it was highly cultivar dependant. Although he did not comment in depth on the marketability criteria for shape there was a significant affect on the shape and size criteria he was measuring by changing the cutting orientation.

*Colour*

Spence and Humphries (1971) found that when the sink potential of the roots is limited by over watering the leaves are more purple and this is thought to be due to an accumulation of anthocyanin in the leaf lamina (blade), the anthocyanin is produced from the sugars that cannot be directed to the storage roots. Conversely this may also be seen during periods of moisture stress or cold when storage root development is inhibited. Kano and Mano (2002) found that the skin of sweetpotato roots was brilliant red in control (ambient temperature) and cool plots maintained at 20 deg C, where it was almost pink in the heat plots maintained at 30 deg C. Root sugar content was found to be higher in the heat plot than in the cool plot; where as starch content was found to be the inverse of that of sugars. Kano and Mano (2002) concluded that sugars transported into the root are converted to starch mainly at night as high day temperatures suppress the conversion of sugars to starch. Excess starch is then converted to root growth and/or metabolised into anthocyanin resulting in highly coloured red roots.

*Storage root development*

A number of researchers have been able to demonstrate large differences in sugar levels in the plant during different source sink activities. There is strong evidence to suggest that when photosynthetic rate is high and high levels of sugars are present in the plant levels of the enzyme that produces starch (AGPase ) is stimulated (Tsubone et al 1999). This means that at times of root development the level of sugars in the plant top may give a good indication of when the plant is going into a phase of rapid storage root development. The use of total soluble solids (sugars) for monitoring the changes in sugar levels during plant development has been used (Wilson et al 2001) as a means of understanding changes in source sink relationships. Measurement of soluble solids in the plant top may have some practical application for use in crop monitoring to understand what the plant is doing and how to adjust management practices such as nutrient and water application to optimise storage root development.

Storage root development has been shown to be adversely affected by water logged conditions i.e. a lack of oxygen in the root zone. (Chua and Kays 1981). This is also thought to be related to why hilling often provides more consistent yields than growing on the flat in some soils. High night temperatures may also interfere with starch synthesis Kano and Mano (2002) and hence the use of hills may well be justified in hot or tropical areas to aid in cooling the sweetpotato hill more rapidly after hot days

The efficiency of nitrogen use is often highest (depending on cultivar) when the amount of N available is limited. Similarly the amount of sugars i.e. soluble solids is highest in the leaf when N is limited. This is thought to be due to the fact that when excess nitrogen is available the plant tends to divert the product of photosynthesis i.e. sugars to new shoot growth and not into root formation. The exact timing of when to apply nitrogen to grow vine and when to limit it to divert assimilate to root fill is the big question. It is most likely different for different varieties. It is safe ????????

How to manage top growth later in root fill is not clear but is certainly different from variety to variety. Bouwkamp and Hassam (1988) found in some varieties the setting of high numbers of storage roots forms a powerful sink for sugars and can limit top growth too much resulting in a crop that will not reach it's full yield potential. There does seem however a direct relationship with keeping vine healthy and being able to achieve late fill. An example of when this is apparent under Australian conditions is when crops planted in May and grown over winter lose vine, this vine needs to be grown back to provide adequate sugar source to develop the storage roots. What this suggests is that you must constantly observe where the crop is at in relation to roots set and the potential demand for sugars to fill the roots. Then estimate the nutrient etc. needed to provide enough top to be able to fill the roots without promoting too much vigorous late top growth.

Table 4 Summary of factors for storage root development (bulking)

| *Positive factors for root development* | *Negative factors for root development* |
|---|---|
| Maintaining healthy vine cover | In high setting crops lack of canopy late can limit root fill |
| Root zone temperatures below 30degC | Root zone temperature over |
| Low Nitrogen application levels | High levels of N after initial vine growth stage ie approx 30DAP |
| Adequate irrigation to avoid mid day wilting | Mid day wilting in light canopy crop |

Table 5 Summary of natural growth regulator roles in root development

| Adventitious roots | Storage root initiation | Stroage root thickening |
|---|---|---|
| Elevated levels of indole acetic acid (IAA) in the plant | Zeatin Riboside enhances, levels are high in first 7 weeks | Zeatin riboside levels reduced |
| | Jasmonic acid thickens roots and changes colour | Abscisic acid improves root sink potential Possibly triggered by stress |

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# Literature review from Rural Water Use Efficiency Project 2003

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## Summary

Growing a high yield of marketable sweetpotatoes involves:

- Initiating a high number of storage roots per plant.
- Ensuring they continue to develop as storage roots.
- Filling them with photosynthesis-derived assimilates from the sweetpotato tops, so that the storage roots reach a premium size and quality.

Storage root initiation (2-8weeks after planting cuttings) is favoured by a well-aerated soil, with low nitrogen levels, and moderate-good moisture levels soil. It is probably better to err on the side of slightly dry than too wet. **For most sweetpotato cultivars, setting adequate numbers of storage roots is the critical determinate of yield.**

During bulking, sweetpotatoes can tolerate soils drying to 60-70kPa soil water suction between irrigations. The crop even appears able to cope with drier periods, and re-establish bulking rates once conditions improve, particularly on soils with reasonable silt or clay contents. Generally the crop will perform optimally where water supplies are equivalent to 70-80% of pan evaporation. Over watering will probably result in deterioration of harvested sweetpotato root quality, with poorer flesh colour, lower dry matter and simple sugar levels, poorer keeping attributes, and generally lower rating by taste panels.

## Yield development in sweetpotato

The number of storage roots initiated, the extent of their bulking, and their quality characteristics, determines marketable yields of sweetpotatoes. Plant physiological processes control initiation, bulking and inherent quality of storage roots, in response to genetically determined cultivar attributes, and external environmental conditions.

### Storage root initiation

The first storage root initiation takes place 2-8weeks after planting stem cuttings. This initiation occurs as localised, sub-apical, lateral swelling of the root. At this stage of development, the targeted root segregates into the distal stalk, (that part of the storage root closest to the stem), the actual marketable storage root, and the proximal end root, which finishes in the root tip (Wilson 1982). Storage root initiation is probably controlled by hormonal influences, particularly auxin levels (Wilson 1982). However, according to Chua and Kays (1981), the actual mechanisms driving the shift from simple adventitious root growth to storage root initiation have not been clearly enunciated.

Wilson (1982) detailed factors that promoted or inhibited storage root initiation (Table1).

Table 1. Factors determining the probability of initiating sweetpotato storage roots.

| Positive factors, enhancing storage root initiation | Negative factors, inhibiting storage root initiation |
|---|---|
| Dark, subterranean conditions | Exposure to light |
| Well aerated soil | Growth in $O_2$ deficient, waterlogged, or dry, compacted soil |
| Low soil nitrogen levels | High soil nitrogen levels |

Although the majority of marketable storage roots are formed during that first initiation period, some cultivars have the capacity to keep initiating and developing new storage roots during the whole of growing period.

### Storage root development

The process of developing a storage root is not completed once it is initiated. Wilson(1982) stated that, during the 8-12week period after planting (that is the period immediately following initiation), potential storage roots could lapse to pencil or string roots. These are thick roots that fail to expand to become a marketable product. This cessation of development and growth is thought to be due to lignification of secondary stellar tissues, preventing further lateral root expansion.

Wilson(1982) detailed several factors that affected the likelihood of initiated storage roots continuing to develop, or alternatively becoming pencil or string roots (Table2).

Table 2. Factors determining the development pathways of initiated sweetpotato storage roots.

| Positive factors, leading to ongoing storage root development | Negative factors, leading to conversion to pencil or string roots |
|---|---|
| Dark conditions | Waterlogging |
| Well aerated soil | Dry, compact soil |
| High soil potassium levels | High soil nitrogen levels |
| High kinetin levels and short days | High gibberellin levels and/or long days |
| Low temperatures | |

### Storage root bulking and maturation

During bulking, storage root length stabilises before lateral expansion is completed. As the stalk is basically structurally complete early in the bulking period, ongoing extension of storage root length takes place at the proximal (deeper) end of the storage root, toward the root tip (Wilson1982).

During storage root initiation and development, the numbers and sizes of cells that make up the storage root are primarily under hormonal influence. However, once this sink is established, increases in storage root size and weight are associated with photosynthate transfer from the sweetpotato plant tops (Wilson1982).

Once a potential sink is established, overall storage root yields are determined by rate and duration of bulking. Some genotypes grow shoots quickly and early, thus establishing photosynthetic capacity. However this diverts most of the early assimilates to top growth, slowing the initial growth of storage roots. However, once they start to fill the storage roots, this bulking occurs rapidly, with such genotypes being identified as 'late' bulkers (Wilson1982). Other genotypes have more storage root growth early, and gradually fill those roots over a long period.

## Factors determining sweetpotato yield

Bouwkamp (1989) suggested sweetpotato was a drought tolerant crop, having a deep rooting system, no critical requirements for pollination or fertilisation, and no specific physiological maturity. It was suggested that during stress conditions, storage root expansion could slow, but them resume maximum levels once conditions improved. The author did not discuss any implications for product quality in this scenario. In discussing sweetpotato root systems, Stanley and Maynard(1990) indicated sweetpotato roots extended beyond 121cm in the soil profile, however Jones (1961) suggested most root activity occurs in the top 60cm.

Studies have investigated whether sweetpotato yields are limited by sink capacity (i.e. the numbers and potential size of storage roots initiated and developed), or source limited (i.e. the net amounts and timing of assimilates provide by the vegetative tops via photosynthesis). Many irrigation studies indicate marketable yields are predominantly associated with sink development, rather than source related, i.e. yields limited by storage root number and potential for growth, rather than photosynthetic capacity of the above ground tops.

Enyi (1977) suggests establishment of storage roots first creates the necessary sink for assimilates, therefore early initiation sets pathways for desired assimilate flows early in crop life. Bouwkamp (1989) felt that low-yielding sweetpotato genotypes were probably sink limited (generating insufficient storage roots). However, that author also suggested that high-yielding sweetpotatoes may be source limited, and that improving the photosynthetic capacity of the tops may improve yields. Mechanisms such as resistance to midday wilting may increase photosynthate supply (where adverse weather causes plant shutdown, even with good soil moisture). Bouwkamp (1989) noted that where they improved resistance to wilting in low-yielding sweetpotato, it simply increased vine production, with no impact on yield, whereas in high yielding genotypes, resistance to midday wilting was highly correlated with increased yields.

## Influence of irrigation and soil water status on sweetpotato yield

### Storage root initiation

In a seminal study, Chua and Kays (1981) demonstrated that low $O_2$ absolutely suppressed storage root initiation, with <u>no</u> storage roots initiated in well-aerated water culture, or in a potting medium with $O_2$ concentrations held at 2.1%. Increasing the $O_2$ concentrations to ambient levels (21%) in the potting mix immediately enabled storage root initiation. Similarly, Suja and Nayar (1996) stated that excess watering reduced storage root numbers by reducing $O_2$ levels. Low root numbers reduced the partitioning of assimilates to roots, lowered yields and increased top growth.

In a glasshouse study, Acock and Garner (1984) found that constantly moist conditions, where aeration was adequate, did <u>not</u> suppress storage root initiation.

Moisture stress during storage root initiation has also been shown to reduce final storage root numbers and thus yields (Indira and Kabeerathumma 1988, Goswami *et al* 1995, Nair *e al.* 1996, Suja and Nayar 1996).

In their pot studies, Acock and Garner (1984) demonstrated that high levels of slow release fertiliser (with a 19:3:10 NPK analysis) inhibited storage root initiation.

However, whilst low fertiliser levels encouraged storage root initiation, it also limited yields because of subsequent poor vine growth. A sensible nutrition strategy would maintain minimum levels of nitrogen for initial growth, with the bulk of any supplementary nitrogen supplied in small amounts after storage root initiation and development.

Acock and Garner (1984) made the point that excessive vine growth may not cause poor storage root initiation and growth. They hypothesised that other factors may inhibit storage root initiation, which then reduces the below-ground sink available for using or storing assimilates. The sweetpotato thus partitions the excess assimilates to the tops, meaning that excessive top growth results from less storage root initiation and growth, and is not the cause of poor storage root production. Chua and Kays (1981) supported these ideas, in their experiments where they artificially suppressed storage roots by low $O_2$ concentrations. These plants grew more tops than sweetpotato plants that had normal storage root development.

### Storage root bulking

A few authors, such as Stanley and Maynard (1990), suggest sweetpotato yields are most sensitive to stress at root enlargement. Suja and Nayar (1996) indicated that severe moisture stress reduced $CO_2$ exchange though stomatal and non-stomatal pathways, decreasing leaf number, leaf area and vine length, and also storage root formation and growth. These conditions are analogous to the source limited findings of Bouwkamp (1989). In contrast, other studies such as Indira and Kabeerathumma (1988) did not find any impact of reducing soil water content to one third of field capacity during the bulking period had any impact on marketable root yields. It would seem that in most instances, moisture stress during bulking has to be relatively severe to adversely impact on yields.

## Influence of irrigation on sweetpotato quality

Several studies have investigated the impacts of soil water status and irrigation strategies on quality characteristics of sweetpotatoes (i.e. the harvested storage roots).

Many scientists have found that irrigation, or high soil water moisture levels, reduced the dry matter content of storage roots, compared to rain-fed, or infrequently irrigated crops (Constantin *et al.* 1974, Hammett *et al.* 1982, Suja and Nayar 1996, Crossman *etal.* 1998). However there are also studies that showed dry matter increasing with irrigation (Stanley and Maynard 1990, Thompson *et al.* 1992).

Thompson *et al.* (1992) showed complex sugar levels increased with irrigation whilst simple sugars fell. Suja and Nayar (1996) stated that moisture stress during maturation increased sugar levels.

Thompson *et al.* (1992) found the best flesh colour (due to carotenoid pigmentation) occurred when the sweetpotatoes were irrigated (including rain) to 75-100% of pan evaporation. Watering more than these amounts reduced flesh colour. Other studies similarly found reduced carotenoid contents and poorer overall flesh colour in high soil moisture conditions (Constantin *et al.* 1974, Hammett *et al.* 1982, Suja and Nayar 1996).
Taste panel tests indicated that general appearance, flavour and texture declined in crops irrigated beyond 110% of pan evaporation (Thompson *et al.* 1992) or following supplementary irrigation in high rainfall (circa 1350 mm p.a.) areas of Louisiana (Constantin *et al.* 1974).

Preventing soil cracking, by maintaining adequate soil moisture levels, reduced storage root damage by sweetpotato weevil (Crossman *et al.* 1998).

## Developing sweetpotato irrigation strategies

Stanley and Maynard (1990) state that sweetpotato requires around 450-600mm of water to produce a crop.

Sajjapongse and Roan (1982) suggested that when only a few irrigations were available, these were best done during bulking, to expand root size, and were least beneficial at initiation. This is in conflict with most other studies, which show that water stress at storage root initiation is critical. Given that in their work, there was no increase in storage root number when crops were irrigated at storage root initiation, it is probable that initiation was not restricted by insufficient soil water. Thus any benefits from irrigation would be associated with improving top growth and assimilate supply (a source-limited circumstance).

Many studies indicate that maintaining adequate soil moisture during storage root initiation is important, however it is better to err on the side of slightly dry than too moist, which markedly reduced yields (Suja and Nayar 1996). Supplying water in amounts equivalent to pan evaporation during 10-30 days after planting maximised storage root initiation, vine growth, bulking rate and consequent yields (Nair *et al.* 1996).

Goswami *et al.* (1995) found that ‘frequent’ irrigation (only every 20 days however), encouraged top growth compared to root growth, and resulted in shorter and thinner storage roots, compared to better performing strategies. Storage root number was maximised by single irrigations at initiation and early bulking, whilst three irrigations (at initiation, early bulking and late bulking) produced best yields. These studies were conducted in an environment where 200mm of rain during the first two months after planting, and 300mm overall during the growing period. Thus the frequent irrigation may have waterlogged the soil around initiation and storage root development.

In a very sandy soil, Peterson (1961) found no more than 25mm of irrigation per week was required to maximise sweetpotato yields, whilst 12mm per week resulted in lower production.

Thompson*etal.*(1992) demonstrated that supplying water at 75% of pan evaporation optimised sweetpotato yields. Marketable yields declined slightly when less water was applied, but much more markedly if more water was applied. Similarly in their experiment, Indira and Kabeerathumma(1990) measured best yields from sweetpotato crops watered at levels equivalent to pan evaporation, with slight yield reductions at half pan evaporation. However, when they supplied 50% more water than pan evaporation, yields were much more adversely affected.

A range of studies used soil water measurement devices as a method for determining irrigation strategies.

In sandy soils, Smittle*etal.*(1990) found that increasing the critical soil water tension for initiating irrigation from 25kPa to 100kPa, reduced water supply requirement for the life of the crop (from 281mm to 195mm respectively). Marketable yields similarly declined from 47t/ha to 35t/ha. However, marketable yields were maintained at high levels if soil moisture suction was kept below 25kPa during storage root initiation, even if soil suction was allowed to reach 100kPa during bulking. In contrast, adverse yield effects from major stress during storage root initiation could not be effectively ameliorated by frequent irrigation during bulking.

In a silt loam soil, Hammett *et al* (1982) did not find any yield advantage maintaining water levels above 25% of available moisture. Interestingly, they found a sandy soil more responsive to irrigation, requiring soil water to be held above 50% available moisture to maximise sweetpotato yields.

Jones (1961) found that it did not particularly matter what soil moisture level was used as the trigger for irrigation on a silt loam soil. All treatments, whether irrigated when soil water levels fell to 20, 40, 60 or 80%, used 380 mm of irrigation during the growing period, and achieved the same sweetpotato yield levels. The most frequently irrigated treatment received 21 irrigations at 6.2 day intervals, whilst the least frequently watered crop was irrigated every 22 days (6.5 irrigations).

Other tensiometer-based studies have shown best sweetpotato yields and water use efficiency when irrigating at 60kPa. Using a lower tensiometer value for irrigation (e.g. 20-35 kPa) reduced yields, whilst increasing to 70-90 kPa only had a small adverse affect on the quantity of marketable storage roots (Biswas *et al.* 1980, Biswas *et al* 1997, Crossman *et al.* 1998).

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