Plug transplants for sweetpotato establishment

S.L. Lewthwaite and C.M. Triggs[1]

New Zealand Institute for Crop & Food Research Ltd, Pukekohe Research Centre, Cronin Road, RD1, Pukekohe, New Zealand
[1] Department of Statistics, University of Auckland, Private Bag 92 019, Auckland, New Zealand

Abstract

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is an important traditional crop in New Zealand. Commercial crops are established by transplanting unrooted sprouts. In recent years a plant selection program has developed in which new cultivars are evaluated. However, in the early stages of cultivar development the amount of plant material for propagation is limited. Sweetpotato plug transplants allow the production of robust and uniform plant stands from small amounts of plant material. Three experiments were conducted to evaluate the effect of plug transplants on subsequent plant growth, for both scientific and commercial purposes. The first experiment compared the effect of four propagation methods (unrooted sprouts, rooted sprouts and two plug sizes) throughout the growth period on the Japanese cultivar Beniazuma. Plug transplants and rooted sprouts produced equivalent yields of comparable quality at commercial harvest dates. As sweetpotato cultivars vary in the time required to initiate storage roots, the second experiment examined the effect of plug transplants on root yield and shape in four cultivars. When plug transplants were used the North American cultivar Jewel had a lower yield while the cultivar Owairaka Red, traditionally grown in New Zealand, produced a higher yield than when rooted sprouts were used. In the third experiment, in which transplants of various shoot/root ratios were compared, performance gains in cv. Owairaka Red were confirmed when propagated by plugs. Plug transplants appear useful for research purposes but are not recommended for general commercial use on the basis of these trials. However, they show some promise in cv. Owairaka Red and further evaluation is required.

Additional key words: *storage root, root shape, cultivar*

Introduction

Sweetpotato (*Ipomoea batatas* (L.) Lam.) is an important traditional crop in New Zealand where it is known as kumara (Lewthwaite, 1997). Sweetpotato was the main crop in early Polynesian New Zealand, and large areas were grown by planting sprouted root pieces directly into the field (Best, 1925). Following contact with Europe and America, new sweetpotato cultivars were introduced that allowed the development of propagation by vine cuttings or sprouts pulled from storage roots (Berridge, 1913). Outbreaks of various fungal diseases (Coleman, 1962) forced commercial sweetpotato producers to adopt improved crop hygiene practices. The present recommended practice is to use sprouts produced on storage roots, but cut above the soil line to reduce contact with the underlying roots and potential diseases. However, it is still common for sprouts to be pulled directly from the storage root as they have a fringe of roots already formed at their base. Sweetpotato transplant production contributes significant costs to the crop and it would be helpful to explore alternative methods of propagation. The early evaluation and commercialisation of new sweetpotato cultivars (Lewthwaite, 1991) are also limited by the multiplication rate of planting material, which could be solved by the use of plug transplants.

Plug transplants have been used in the commercial production of vegetable and floricultural crops for many years (Marr and Jirak, 1990), and the variables of plug size (cell volume), transplant age (Leskovar and Vavrina, 1999), nutrition (Bailey *et al.*, 1996) and lighting (Shaddick, 1996) have been studied to maximise individual crop performance. While root crops are not generally propagated in this way, sweetpotato plug transplants could reduce transplant shock and increase the potential for automatic transplanting (Suggs and Mohapatra, 1988). Sweetpotato plants produced from plugs are both morphologically and genetically more uniform than conventional sprouts. This is due to the cellular construction of the plug trays and also because the plants are propagated from pre-existing meristematic regions such as nodes, which are more genetically consistent than plants originating from adventitious sprouts (Villordon and LaBonte, 1996). New Zealand has a temperate climate, and the use of plugs could also allow plants to be produced well before the transplanting period and stored during periods of inclement weather, with little loss of condition. These three experiments were designed to explore the relationship between the initial transplant and storage root development and, in particular, to compare sweetpotato plug transplants with commercial transplants.

Materials and Methods

All three experiments were planted in the same field at Pukekohe (Lat. 36°57'S), New Zealand, in Patumahoe clay loam soil. A base fertiliser of 30% potassic superphosphate was broadcast at 1 t/ha prior to moulding. All experimental material was transplanted into the field on 30 November 1994 and was well watered in. Rainfall was supplemented by overhead irrigation throughout the growing season. Weeds were controlled by hand weeding and herbicide application (alachlor).

The first experiment compared the yield and shape of sweetpotato roots produced from propagules with various degrees of root restriction. Three harvest dates were included in this experiment to capture any early or transient changes to root yield and shape. The Japanese cultivar Beniazuma (Lewthwaite *et al.*, 1997) was used in experiment 1 because it produces relatively low yields of sweet, high dry matter roots, which could be used for flour production. Dry matter yield is important in flour production while root shape is not critical. Experiment 1 was a factorial experiment planted in a split plot design with three replicates. Each plot was four rows wide, but only the middle two rows were harvested. The harvested portion of each plot was 3.5 m long by 1.5 m wide and contained 20 plants, arranged in two rows. The sub plot factor was propagation method: 1) unrooted commercial sprouts (30 cm long with 6 nodes), 2) rooted sprouts (30 cm long with 6 nodes, rooted prior to transplanting), 3) large plugs (sprouts with 3 nodes, rooted in plugs of 45 ml volume) and 4) small plugs (sprouts with 3 nodes, rooted in plugs of 16 ml volume). The rooted sprouts and plug treatments were cut and placed in a commercial peat/pumice bedding mix on 27 October 1994, 35 days before being transplanted into the field, while the unrooted control was cut and transplanted into the field on the same day. Rooted sprouts and plug transplants were prepared for transplanting over the same growing period, under the same conditions, except plugs were restricted in root shape and volume while rooted sprouts were prepared in large non-restrictive trays. All treatments were initially maintained in an unheated glasshouse, apart from one week of hardening immediately prior to transplanting into the field. The main plot treatment factor was harvest date (15 March, 28 March and 13 April 1995), when a two row potato digger was used to lift the plots. Harvested roots were sorted into marketable and unmarketable (distorted and/or < 2.5 cm diameter) grades and weighed. Percentage dry matter content was calculated for each plot by drying samples at 80°C for 5 days.

The second experiment examined the effect of transplant root restriction on a range of sweetpotato cultivars. Some cultivars may produce distorted storage roots as a result of secondary thickening of roots formed within the plug itself rather than from new roots extending from the plug following field establishment. In four cultivars, cuttings rooted under restrictive conditions as large plugs were compared with commercial cuttings rooted in large spacious trays. This experiment was factorial and planted in a modified alpha design (Williams and John, 1989) with three replicates. The plots were 3.5 m long by 1.5 m wide and contained 20 plants, arranged in two rows. The four cultivars used were: (1) Owairaka Red from New Zealand, (2) Jewel from the USA, (3) 93N9/2 from Taiwan and (4) Beniazuma from Japan (Lewthwaite *et al.*, 1997). The transplants for each cultivar were prepared in two ways: (1) rooted sprouts (30 cm long with 6 nodes, rooted prior to transplanting) and (2) sprouts rooted in large plugs (sprouts with 3 nodes, rooted in plugs of 45 ml volume). This experiment was harvested on 18 April 1995 and the roots were processed in the same manner as experiment 1.

The third experiment was used to evaluate transplants of various shoot to root ratios. Under current commercial practice, a contact herbicide (paraquat dichloride) is used to remove seedling weeds shortly after transplant establishment, but sweetpotato transplants are also defoliated to various degrees. Some commercial growers consider that some transplant defoliation is beneficial and increases final root yields. Experiment 3 was planted in a Latin square design of 25 plots with five treatments each replicated five times. The plots were 1.5 m long by 1.5 m wide and contained 10 plants, arranged in two rows. The New Zealand cultivar Owairaka Red was used for all of the treatments: (1) rooted sprouts (30 cm long with 6 nodes, rooted prior to transplanting), (2) large plugs (sprouts with 3 nodes, rooted in plugs of 45 ml volume), (3) trimmed sprouts (rooted sprouts as in treatment one, but with the apical tip including the top node removed just prior to transplanting), (4) pulled sprouts (30 cm long with 6 nodes, pulled directly from the storage root) and (5) defoliated sprouts (rooted sprouts as in treatment one, but with the apical tip including the top two nodes and all leaves removed, just prior to transplanting). This experiment was harvested by hand on 18 April 1995. The roots were sorted into marketable and unmarketable grades and weighed.

Results and Discussion

In experiment 1 none of the propagation treatments produced total yields significantly larger than that of the unrooted commercial standard, at any harvest (Table 1). The small plugs tended to lag in yield for both of the early harvests, but recovered to equal the control by the third harvest. None of the marketable yields differed significantly from the control, demonstrating the absence of significant root shape distortion. Root dry matter content did not differ significantly across propagation treatments or harvests. These results showed that over a full growing season the final root yield and quality of plug transplants of cv. Beniazuma were comparable to commercial cuttings. Following commercial practice, the unrooted sprouts were transplanted entirely without roots and had to re-establish a shoot to root ratio. Thus, plants in this treatment had to form an entirely new set of roots, but it was expected that root shape distortion would be minimal. The other three propagation treatments, while allowing the plants to develop roots prior to transplanting, imposed increasing degrees of restriction on the root ball volume, yet there was no measurable distortion to final root shape.

In experiment 2 cv. 93N9/2 and cv. Beniazuma showed no significant differences in total or marketable yield between the two propagation methods (Table 2). However, cv. Jewel showed a 33% reduction in marketable yield when plug transplants were used ($P = 0.002$) while the traditional New Zealand cultivar, Owairaka Red, showed an increase of 16% in marketable yield ($P = 0.094$) with this propagation method. The increase in marketable yield of cv. Owairaka Red when using plug transplants is in contrast to the reductions shown by the other three cultivars ($P = 0.012$). The proportion of marketable roots and root dry matter content did not vary significantly between the propagation treatments, indicating that root shape and general quality were comparable.

In the third experiment although the totally defoliated sprouts survived and grew they produced a significantly lower total and marketable yield than any other treatment ($P = 0.005$, $P = 0.003$ respectively) (Table 3). The plug transplants produced the highest marketable yield, significantly higher ($P = 0.003$) than the trimmed, pulled

Table 2. Mean total and marketable yields (t/ha) produced by various sweetpotato cultivars, under two propagation treatments.

Cultivar	Yield	Propagation method: Rooted sprouts	Propagation method: Large plugs
Owairaka Red	Total	42	51
	Marketable	29	33
Beniazuma	Total	51	45
	Marketable	33	30
93N9/2	Total	36	30
	Marketable	22	21
Jewel	Total	44	31
	Marketable	29	19
LSD $_{(P < 0.05)}$	Total	12.8	
	Marketable	6.0	

Table 1. Mean total and marketable yields (t/ha) produced by the Japanese sweetpotato cultivar Beniazuma , at three harvest dates with four propagation treatments.

Propagation method	Harvest 1 Total	Harvest 1 Marketable	Harvest 2 Total	Harvest 2 Marketable	Harvest 3 Total	Harvest 3 Marketable
Rooted sprouts	22	16	22	16	28	26
Unrooted sprouts	18	15	23	17	25	22
Large plugs	20	15	25	20	27	24
Small plugs	15	10	16	12	28	24
LSD $_{(p < 0.05)}$	Total	7.5				
	Marketable	8.1				

Table 3. Mean total yields (t/ha), marketable yields (t/ha) and marketable percent of total yields produced by the sweetpotato cultivar Owairaka Red, under five propagation treatments.

Propagation method	Total yield	Marketable yield	% Marketable
Large plugs	37	33	88
Rooted sprouts	36	28	78
Trimmed sprouts	32	24	75
Pulled sprouts	30	24	81
Defoliated sprouts	19	16	81
LSD $_{(P<0.05)}$	8.3	6.9	8.3

and defoliated sprouts. The plug transplants also produced the highest proportion (88%) of marketable roots, which was higher than the 81% proportion produced by the pulled or defoliated sprouts, ($P = 0.044$) and very much higher than that produced by the other two treatments ($P = 0.004$). The non-marketable roots in this trial tended to be small rather than distorted. This experiment demonstrated that while sweetpotato transplants were generally robust, transplant survival alone is not a guarantee of optimum yields. Some transplants were more efficient than others in producing storage roots, influencing the final yields. There was no evidence that defoliation increased yields, as trimmed sprouts produced the same marketable yield as pulled sprouts, while defoliated sprouts produced significantly lower ($P = 0.003$) marketable yields. The rooted sprouts produced a significantly ($P < 0.05$) lower marketable proportion than the plug transplants, suggesting that the plug transplants had developed a more efficient shoot to root ratio capable of enlarging most of the initiated storage roots.

Conclusion

In these trials, no evidence was seen of root distortion caused by using plug transplants. In general, root yields from plug transplants were comparable to yields using commercial transplants. Plug transplants could not be recommended for general commercial use on the basis of these trials as there was no consistent gain in yield or quality. However, as these trials were of limited size, further evaluation of the potential for plug transplants to increase the marketable yield of cv. Owairaka Red is required. Reducing the transplant's shoot to root ratio by partial or total defoliation did not increase storage root yields, but the characteristics of the initial transplant did influence final yield. Plug transplants appear useful for research purposes as they reliably produce robust and uniform plant stands from limited amounts of plant material.

References

Bailey, D.A., Nelson, P.V., Fonteno, W.C., Lee, J. and Huang, J. 1996. Breakthrough plug research: pH, fertilization and nutrition. *FloraCulture International 6(1)*, 18-19.

Berridge, W.C. 1913. Kumeras, or sweet potatoes. *New Zealand Journal of Agriculture 7*, 415-419.

Best, E. 1925. Maori agriculture. 1976 edition, Dominion Museum Bulletin No. 9. Wellington, New Zealand, A.R. Shearer, Government Printer. 315 p.

Coleman, B.P. 1962. Vegetable production: hygienic methods essential for propagating kumara plants. *New Zealand Journal of Agriculture 105*, 431, 433, 435.

Leskovar, D.I. and Vavrina, C.S. 1999. Onion growth and yield are influenced by transplant tray cell size and age. *Scientia Horticulturae 80*, 133-143.

Lewthwaite, S.L. 1991. Potential for introduced sweet potato cultivars in New Zealand. *Proceedings Agronomy Society of New Zealand 21*, 1-5.

Lewthwaite, S.L. 1997. Commercial sweetpotato production in New Zealand: foundations for the future. *In* Proceedings of the International Workshop on Sweetpotato Production System toward the 21st Century, Miyakonojo, Miyazaki, Japan, (eds., D.R. LaBonte, M. Yamashita and H. Mochida), pp. 33-50. Kyushu National Agricultural Experiment Station, Japan.

Lewthwaite, S.L., Sutton, K. and Triggs, C.M. 1997. Free sugar composition of sweetpotato cultivars after storage. *New Zealand Journal of Crop and Horticultural Science 25(1)*, 33-41.

Marr, C.W. and Jirak, M. 1990. Holding tomato transplants in plug trays. *HortScience 25(2)*, 173-176.

Shaddick, C. 1996. Prospects for programmed plugs. *Grower 125(13)*, 32-33.

Suggs, C.W. and Mohapatra, S.C. 1988. Tobacco transplants 2. Effects of bare-root versus intact-root plants on yield, value, growth rate, and chemistry. *Tobacco International 190(1)*, 40-45.

Villordon, A.Q. and LaBonte, D.R. 1996. Genetic variation among sweetpotatoes propagated through nodal and adventitious sprouts. *Journal of the American Society for Horticultural Science 121*, 170-174.

Williams, E.R. and John, J.A. 1989. Construction of row and column designs with contiguous replicates. *Applied Statistics 38*, 149-154.