Field establishment of sweetpotato transplants

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Abstract

In New Zealand, commercial sweetpotato (*Ipomoea batatas* (L.) Lam.) crops are normally established in the field by transplanting unrooted sprouts. A range of treatments designed to reduce transplant shock (retarded early plant growth) and improve plant survival were field tested at Dargaville, New Zealand's main sweetpotato production area. The treatments included holding cut sprouts in air or sand for various periods before transplanting, applying anti-transpirants, or watering in transplants with fertiliser starter solutions. Further treatments examined the use of different sized transplants, rooting sprouts in plug trays, or modifying the field moulds in which the transplants were inserted. There were no significant differences among the plant survival rates of any of the treatments ($P = 0.461$). Two harvests were conducted, 53 days and 124 days after transplanting. In the first harvest, sprouts held in air or sand for six days, or rooted in plug trays, yielded a significantly higher total root weight and storage root weight than the commercial control ($P < 0.001$). By the second (commercial) harvest, the yield ($P = 0.003$) and number ($P < 0.001$) of storage roots was significantly reduced in treatments grown from small four node transplants, but was comparable with the control for other treatments. In conclusion, sweetpotato transplants held in air to allow root initiation suffered less transplant shock than those planted directly into the field, a technique which involved little additional effort.

Additional key words: *kumara, storage root, sprouts, holding period, plugs*

Introduction

New Zealand research into the field establishment of the sweetpotato (*Ipomoea batatas* (L.) Lam.) crop has been limited. The sweetpotato or kumara was first introduced into New Zealand by Polynesian voyagers, the Maori, who settled in New Zealand in the thirteenth century. Early propagation involved planting sprouted root pieces directly into the field (Best, 1925). However, the introduction of cultivars such as Waina by early American whalers allowed the most significant development in field establishment, propagation by vine cuttings or sprouts pulled from storage roots (Berridge, 1913). At present about 80% of the crop consists of the cultivar Owairaka Red, a mutant selected from cv.Waina and released commercially in 1954 (Lewthwaite, 1997). Improved hygiene practices were adopted following outbreaks of various fungal diseases such as black rot (*Ceratosystis fimbriata*) (Coleman, 1962). The current recommended practice is to transplant sprouts produced on storage roots, but cut above the soil level. In New Zealand's temperate climate sweetpotato is cultivated as an annual crop, with most of the crop planted during November. Dargaville (Lat. 35° 55' S), New Zealand's main sweetpotato production area has a mean air temperature of 15.4°C in November (50-year mean). Cool winds may occur during transplanting (Anon., 1999).

This experiment examined ways of improving plant survival and minimising the growth check caused by transplanting. Previous work (Lewthwaite and Triggs, 1999) demonstrated that transplant quality may affect final yield. In the present trial we modified the transplant itself and the environment in which it was placed in order to maximise growth. The results of earlier trials, which suggested that plug transplants may produce a yield increase in cv. Owairaka Red without loss of root quality, were further investigated (Lewthwaite and Triggs, 1999), as were reports that when sweetpotato sprouts were cut and held for several

days prior to transplanting root yields could increase (Hammett, 1981; Nakatani, 1993). It has been observed that smaller transplants may cope better than those of standard size when transplanted into cool, windy conditions and that sheltering the young plant within a hollow on the top of the mould may encourage early growth; these management options were also examined. Finally, the application of anti-transpirants to reduce water loss or the use of fertiliser starter solutions to supply readily absorbed nutrients (McKee, 1981) were also investigated.

Materials and Methods

Establishment

A total of 16 plant establishment treatments were used applied in this study (Table 1). Sprouts were produced by bedding storage roots of the cultivar Owairaka Red in trays of commercial potting mix in an unheated glasshouse. All the treatments were prepared so the entire trial could be transplanted into the field within a single day. The mean ambient air temperature during treatment preparation (November 1997) was 14.1°C.

Table 1. Sweetpotato (*Ipomoea batatas* (L.) Lam.) plant establishment treatments.

Treatment	Description
Control	Sprouts of commercial size (30 cm long, with 6 nodes), transplanted with 4 nodes inserted into the soil the day following cutting.
Held-1	As for the control, but held for 3 days under moist conditions at ambient temperature prior to transplanting.
Held-2	As for the control, but held for 6 days under moist conditions at ambient temperature prior to transplanting.
Held-3	As for the control, but held for 9 days under moist conditions at ambient temperature prior to transplanting.
Sand-1	As for the control, but held for 3 days with 4 nodes inserted into river sand prior to transplanting.
Sand-2	As for the control, but held for 6 days with 4 nodes inserted into river sand prior to transplanting.
Sand-3	As for the control, but held for 9 days with 4 nodes inserted into river sand prior to transplanting.
Anti-1	As for the control, but with leaves dipped in an anti-transpirant solution (Vaporgard® at 2% v/v) just prior to transplanting.
Anti-2	As for the control, but with leaves dipped in an anti-transpirant solution (commercial fish oil (NPK 5-1-1) at 1% v/v) just prior to transplanting.
Start-1	As for the control, but watered in with 200 ml per sprout of monopotassium phosphate (NPK 0-52-34) in a 1% w/v solution.
Start-2	As for the control, but watered in with 200 ml per sprout of monoammonium phosphate (NPK 12-61-0) in a 1% w/v solution.
Mould	As for the control, but transplanted into a protective groove formed along the top of the soil ridge, to reduce exposure.
Size-1	Small sprouts (4 nodes) with 1 node inserted into the soil the day following cutting.
Size-2	Small sprouts (4 nodes) with 2 nodes inserted into the soil the day following cutting.
Size-3	Small sprouts (4 nodes) with 3 nodes inserted into the soil the day following cutting.
Plug	Small sprouts (3 nodes) with 1 node inserted into 45 ml plugs, 23 days before transplanting.

Trial management

The experiment was conducted in a commercial field at Dargaville, New Zealand, in a Kaipara clay soil. Superphosphate (NPK 0-10-0) was broadcast (1 t/ha) six months prior to transplanting, then muriate of potash (NPK 0-0-50) at 0.5 t/ha and urea (NPK 46-0-0) at 0.1 t/ha five months later. The soil when sampled at planting had the following analysis: phosphorus 74 g/ml, potassium 1.83 me/100 g, calcium 18.9 me/100 g, magnesium 3.08 me/100 g, sodium 0.20 me/100 g, cation exchange capacity 31.3 me/100 g, available nitrogen 86 kg/ha, pH 5.9, and a volume/weight ratio of 0.95 for dried ground soil. The trial was transplanted into the field on 28 November 1997 and then watered in without any additives, by a tractor-drawn tanker. Weed control was obtained by hand weeding and application of Gramoxone® at 0.5 l/ha (paraquat dichloride, 25 % a.i.), 30 days after transplanting.

The experiment was planted in a modified alpha design (Williams and John, 1989). There were 16 treatments with three replicates, and each plot consisted of four rows of plants with only the two middle rows being harvested. The harvested portion of each plot was 7 m long by 1.5 m wide, and split in half along its length to create two 3.5 m long sub-plots for the two harvest dates. The sub-plots contained 20 plants arranged in two rows, at a 30 cm within-row spacing. At harvest, 16 plants were dug by hand from each sub-plot so that sub-plots were fully buffered by the remaining plants.

Harvests

The two respective sets of trial sub-plots were harvested at different dates, the first on 20 January (53 days after transplanting) and the second on 1 April 1998 (124 days after transplanting). At the first harvest plant survival was recorded, then plant tops were removed and divided into leaves and stems. Leaves were separated at the point where the petiole and lamina met. For each plot, all of the leaves were removed and a leaf sub-sample (60 leaves) was taken at random to allow estimation of the total leaf number (by weight), then the stem, leaf and sub-samples were oven dried at 80°C for 5 days and finally weighed. All root material was hand harvested, apart from the non pigmented (white) fine feeder roots. The harvested root material was divided into underground stems (from the original transplant), pencil roots (up to 15 mm in diameter) and storage roots (above 15 mm in diameter). The number of roots in each size class was recorded before being oven dried at 80°C for 5 days. At the second harvest all of the storage roots were dug by hand. The roots were graded on the basis of diameter (Sterrett *et al.*, 1987): cull (< 2.5 cm), canner (2.5-5 cm), no. 1 (5-9 cm) and jumbo (> 9 cm). Root sub-samples for dry matter calculation were taken from each plot and oven dried at 80°C for 5 days. Data were analysed using the GENSTAT™ statistical software package.

Results and Discussion

Harvest 1

The weather conditions were mild at transplanting and during the early establishment period, so there was little plant loss. At the first harvest, 53 days after transplanting (Table 2), there were no significant differences in plant survival rate among treatments ($P = 0.461$). While some treatments produced significant reductions or gains in plant weight ($P < 0.001$), plants treated with anti-transpirant or fertiliser starter solutions did not differ from those in the commercial control. Jett and Talbot (1998) evaluated a number of anti-transpirants, including Vaporgard®, under Louisiana conditions, but none of these improved plant survival or marketable yield.

Irrespective of the number of nodes inserted into the soil, the 4 node plants had smaller total weights than the commercial control (6 nodes) ($P < 0.001$). Leaf number in these small plants was not significantly reduced but leaf weight, pencil root weight and pencil root number were reduced ($P < 0.001$). Pencil roots are precursors for storage roots and those with active meristems have the potential to swell into storage roots. In these three treatments (Size-1, -2, -3) the growth rate was compromised by a reduced leaf area, and storage root production was further limited by the development of fewer pencil roots.

The Plug and Held-2 treatments had significantly higher total plant weights than the commercial control ($P < 0.001$). While plants in the Plug treatment had a similar leaf weight to the control, they had a significantly higher leaf number ($P < 0.001$) and, therefore, a greater potential for a rapid increase in leaf area. The treatments Plug, Held-2, and Sand-2 produced plants with a higher total root weight than those in the control ($P < 0.001$). These three treatments had pencil root weights comparable to the control, but the Plug treatment had more pencil roots ($P< 0.001$) and, therefore, the capacity for increased storage root numbers by the second harvest. The treatments Sand-2 and Sand-3 had significantly higher storage root weights ($P < 0.001$) than the control, while treatments Plug and Held-2 showed increases in both storage root weight and number ($P < 0.001$).

In sweetpotato plants, roots form at the callus base of the transplanted sprout and at the buried leaf nodes

Table 2. The main components of sweetpotato cv. Owairaka Red plants 53 days after transplanting, expressed as mean dry weights (g) and number per plant.

Propagation treatment[1]	Total plant weight	Leaf		Stem weight	Total root		Pencil root[2]		Storage root[2]	
		Weight	Number		Weight	Number	Weight	Number	Weight	Number
Plug	21.9	6.7	67.2	5.5	9.3	9.0	3.2	7.2	6.4	1.7
Held-1	16.9	5.8	52.3	4.6	6.0	6.9	2.5	5.7	3.7	1.1
Held-2	21.7	7.3	47.4	6.0	7.3	7.4	2.8	6.2	4.6	1.2
Held-3	16.2	5.1	40.1	5.8	5.0	6.5	2.8	6.1	2.1	0.5
Sand-1	15.8	6.0	54.2	4.9	4.5	6.5	2.8	6.0	1.7	0.6
Sand-2	19.6	7.5	60.3	5.3	6.4	7.8	2.5	6.9	3.8	0.9
Sand-3	16.4	5.5	54.7	4.2	6.3	6.1	1.8	5.1	4.2	1.0
Mould	18.9	6.7	62.0	5.0	6.3	7.6	2.9	6.6	3.2	1.0
Control	16.2	6.1	46.4	4.7	4.3	6.2	2.7	5.6	1.6	0.7
Anti-1	15.9	5.7	54.9	4.1	5.8	6.9	2.4	6.0	3.2	0.8
Anti-2	15.7	6.2	56.2	4.8	3.8	7.3	3.0	6.9	1.0	0.4
Start-1	16.0	6.2	41.4	5.3	3.8	6.0	2.9	5.6	1.0	0.3
Start-2	16.8	6.0	60.6	5.1	5.2	6.4	2.1	5.3	3.2	1.0
Size-1	9.2	3.6	36.1	2.8	2.5	4.2	2.0	4.0	0.5	0.2
Size-2	10.5	4.0	38.1	3.4	3.0	3.8	1.9	3.5	1.2	0.3
Size-3	10.3	4.4	35.5	3.2	2.6	4.1	2.0	4.0	0.7	0.3
$LSD_{(0.05)}$	3.45	1.53	16.23	1.57	1.95	1.28	0.66	1.29	2.10	0.52
$LSD_{(0.01)}$	4.66	2.06	21.92	2.12	2.63	1.73	0.89	1.74	2.83	0.70
P-VALUE	<0.001	<0.001	<0.001	0.002	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

[1]Refer to Table 1.
[2]Pencil roots included pigmented roots up to 15 mm in diameter, storage roots had a diameter greater than 15 mm.

(Sirju-charran and Wickham, 1988). The Plug treatment was originally a 3 node sprout with only one node inserted into the soil, while the commercial control had 6 nodes with 4 inserted. Despite its smaller size and fewer points for root formation, the Plug treatment out yielded the commercial transplant for root weight and number. This is in direct contrast to all the 4 node treatments, which regardless of the number of nodes inserted into the soil produced reduced root yields under mild establishment conditions. The plugs had an extra 23 days of growth prior to transplanting, allowing them to establish a comprehensive root system which was transplanted intact. Root growth in the Plug treatment more than compensated for the reduction in plant size and decreased sites for root initiation as it also diminished the growth check at transplanting. The Held-2 treatment was initially identical to the commercial control apart from being stored for 6 days. The 6-day storage allowed the formation of only small root initials, yet this treatment produced plants significantly larger than the commercial control 53 days after transplanting. The rapid establishment of the Plug and Held-2 transplants demonstrated that even a small period of root initiation delivered significant gains by reducing the growth check at transplanting.

Among the treatments with stored sprouts there appeared to be an optimum holding period. The 3-day (Held-1) storage period may not have undergone enough root initiation to give a significant growth advantage, but the treatment stored for 6 days (Held-2) produced a significant gain in total plant weight with 21.7 g/plant compared to the control at 16.2 ($P < 0.001$). By contrast,

the 9-day (Held-3) treatment did not give a growth gain despite increased root development. Hammett (1981) suggested that relatively extensive bare root growth as seen in the 9-day treatment, is more easily damaged during the transplanting operation, negating any gains. Nakatani (1993) found that lignification of the root meristem also increases with the holding period, at a rate which varies with cultivar. Sprout storage in sand for 6 days (Sand-2) significantly increased total root weight from 4.3 g/plant to 6.4 and number from 6.2 per plant to 7.8 ($P < 0.001$), but not total plant weight. Storage in sand for 3 (Sand-1) or 9 (Sand-3) days did not give significant increases in total plant weight or total root weight. The significant growth increases seen in both of the 6-day storage treatments (Held-2 and Sand-2), but not for the 3 or 9-day storage periods, reinforces the concept of an optimal holding period. Storing plants in air for relatively short periods produced disproportionate gains over the commercial control. These gains were retained well into the growing season. Nakatani (1993) suggested that root developmental stages were accelerated by holding treatments.

The significant growth advantages accumulated by the Plug and Held-2 treatments over the first half of the growing season demonstrated a decreased growth check at transplanting and the production of more robust plants during the early establishment phase.

Harvest 2

The main effect seen at the second harvest (Table 3), 124 days after transplanting, was the significant reduction in total root number for all of the 4 node plants (Size-1,-

Table 3. Mean graded root yields and root numbers produced by the sweetpotato cv. Owairaka Red 124 days after transplanting, expressed as mean dry weights (g) and number per plant.

Propagation treatment[1]	Total root Weight	Number	Combined grades[2] Jumbo + No.1 Weight	Combined grades[2] Jumbo + No.1 Number	Combined grades[2] Jumbo + No.1 + Canner Weight	Combined grades[2] Jumbo + No.1 + Canner Number
Plug	206.1	5.0	142.4	1.8	203.4	4.3
Held-1	199.8	5.2	126.6	1.6	196.6	4.4
Held-2	200.1	4.3	142.5	1.8	198.3	3.8
Held-3	142.0	2.8	108.0	1.2	140.9	2.5
Sand-1	222.2	5.0	142.2	1.6	219.4	4.3
Sand-2	193.0	4.9	130.4	1.6	189.9	4.1
Sand-3	172.8	3.6	132.0	1.6	171.5	3.2
Mould	205.2	3.9	138.2	1.6	203.9	3.6
Control	180.3	4.4	123.9	1.5	178.4	3.8
Anti-1	176.2	3.8	118.6	1.4	173.4	3.3
Anti-2	208.3	4.8	108.5	1.3	205.8	4.2
Start-1	186.3	4.0	117.1	1.2	183.6	3.4
Start-2	185.6	3.7	131.8	1.5	183.7	3.3
Size-1	120.6	2.1	93.1	1.0	119.4	1.8
Size-2	137.3	2.7	103.6	1.1	135.9	2.3
Size-3	158.0	2.6	124.9	1.3	156.6	2.4
$LSD_{(0.05)}$	45.89	1.16	42.64	0.40	45.58	0.90
$LSD_{(0.01)}$	61.79	1.56	57.41	0.55	61.38	1.22
P-VALUE	0.003	<0.001	0.462	0.005	0.003	<0.001

[1]Refer to Table 1.
[2]Roots were graded by diameter: Cull (< 2.5 cm), Canner (2.5-5 cm), No. 1 (5-9 cm) and Jumbo (> 9 cm).

2,-3 with 2.1, 2.7 and 2.6 roots per plant, respectively) compared with the commercial control at 4.4 per plant ($P < 0.001$). The reduction in root numbers occurred in both the canner ($P = 0.002$) and No. 1 ($P = 0.004$) grades for the Size-1 and Size-2 treatments, but only in the canner grade for the Size-3 treatment. The treatment with one node inserted into the soil (Size-1) also produced plants with a significantly lower total root weight of 120.6 g/plant compared to the control with 180.3 ($P < 0.003$). Commercial growers of the cultivar Owairaka Red typically plan a growing season of 120 days, but as predicted by the first harvest the small plants did not develop as many roots as the commercial control.

The two treatments (Plug and Held-2) showed considerable growth gains relative to the commercial control at the first harvest, but had lost those gains by the second harvest. None of the parameters measured for these two treatments differed from the control at the 5% significance level. This is in contrast to previous results, as in the 1994/95 season the Plug treatment displayed a yield increase under well watered conditions (Lewthwaite and Triggs, 1999). Other researchers have also found variable results. Research in both the USA and Japan demonstrated commercial yield increases from holding plants in some years, but not others (Hammett, 1982; Nakatani, 1993), implying a seasonal effect.

In the Dargaville area, due to a limited water supply, the sweetpotato crop is not irrigated beyond watering in transplants at establishment with tractor-drawn water carts. The 1997/98 growing season was warmer than usual and the crop received less rain than average (Fig. 1), particularly over the period of storage root development (January). Storage roots swell and develop from pencil roots through the activity of secondary and tertiary meristems (Wilson, 1982). Under certain environmental conditions, such as drought, the meristems may become irreversibly lignified so that storage root development is limited (Togari, 1950). On the basis of these and previous results it is suggested that in this experiment the dry season may have limited the potential commercial yield of the Plug and Held-2 treatments, despite their growth gains during early plant establishment.

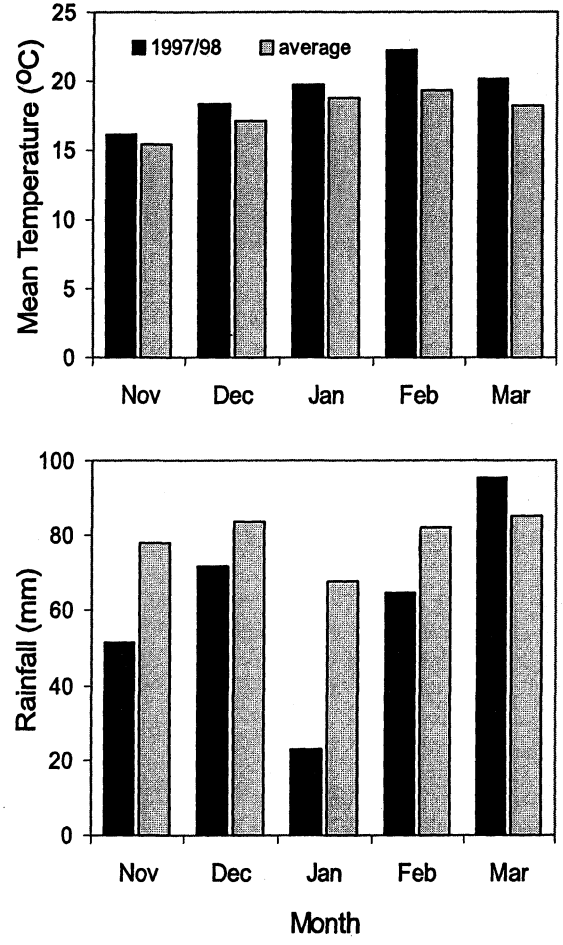

Figure 1. Mean monthly temperature (°C) and monthly rainfall (mm) at Dargaville over the 1997/98 growing season, contrasted with long term averages (50-55 years). Data courtesy of the National Institute of Water and Atmospheric Research Ltd.

Conclusions

Plug transplants and held sprouts of the sweetpotato cultivar Owairaka Red were more robust than sprouts transplanted directly into the field. There was an optimum period (6 days) for holding sprouts following cutting. Periods shorter or longer than the optimum did not confer growth gains and may be detrimental. Even if small unrooted transplants survive they may be unable to achieve the yields produced by commercial transplants of standard size. Under the conditions of this experiment, anti-transpirants, starter solutions and modifying the mould at transplanting did not confer any

useful gains in growth. While holding sprouts before transplanting may produce more robust plants with little extra effort, their full yield potential will only be realised under favourable seasonal conditions.

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