Preliminary study on sweetpotato growth: I. Dry matter partitioning

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

New Zealand Institute for Crop & Food Research Limited, Mount Albert Research Centre, Private Bag 92 169, Auckland, New Zealand

[1] Department of Statistics, University of Auckland, Private Bag 92 019, Auckland, New Zealand

Abstract

Three diverse commercial sweetpotato cultivars were selected for evaluation. The cultivars Owairaka Red (New Zealand), Beauregard (USA) and Beniazuma (Japan) were grown in a replicated field trial established at the Pukekohe Research Centre, New Zealand. Cultivar growth was evaluated by 10 harvests at weekly intervals over the period of storage root development, beginning 71 days after transplanting. At each harvest, the plants were divided into leaf, vine and root tissue, before being oven-dried. Cv. Owairaka Red produced the largest plants by dry weight, followed by cv. Beniazuma then cv. Beauregard ($P<0.001$). In cv. Owairaka Red, root dry weight contributed the lowest percentage (57.9%) to total plant dry weight ($P<0.001$), while cv. Beniazuma (66.2%) and cv. Beauregard (65.8%) did not differ ($P>0.05$). The mean root dry weight per plant did not differ for cv. Owairaka Red and cv. Beniazuma (148 g), while cv. Beauregard produced considerably less at 114 g ($P<0.001$). Cv. Owairaka Red partitioned significantly more dry matter into stem material ($P<0.001$) than the other two cultivars. The mean leaf weight for cv. Beauregard was significantly less ($P<0.001$) than that of cv. Owairaka Red or cv. Beniazuma, which did not differ ($P>0.05$). The proportions of leaf to stem dry weight were cultivar specific and were constant throughout the harvest period. Cv. Owairaka Red was the only cultivar to partition more dry matter into stem tissue than leaf tissue.

Additional key words: Ipomoea batatas, *cultivar, and storage root.*

Introduction

The sweetpotato (*Ipomoea batatas* (L.) Lam.) or kumara was introduced to New Zealand by Polynesian voyagers, the Maori, who settled the country in the thirteenth century (Lewthwaite, 1997). Since then there has been a succession of sweetpotato cultivars, from the first introductions until those of the present day. The cultivar Owairaka Red, which was released in 1954, still dominates the New Zealand crop. It was a mutation of cv. Waina, a cultivar introduced from Rarotonga by whalers in the 1850s (Berridge, 1913). The sweetpotato has been important throughout New Zealand's history and remains a traditional crop, within which cv. Owairaka Red has become a traditional cultivar.

Contrasting with the early origins of cv. Owairaka Red, modern sweetpotato breeding uses selected parent clones, which are deliberately crossed to produce desired groupings of attributes. Science-based breeding, followed by screening for useful traits, produced the two commercial cultivars, Beauregard (USA) and Beniazuma (Japan). Cv. Beniazuma was produced by crossing selected male and female parents in 1977. The clone was screened for useful characteristics and was released in 1985 (Shiga *et al.*, 1985). Cv. Beauregard was produced in a polycross nursery (1981), where the female parent was known, but not the pollen source (Rolston *et al.*, 1987). Cv. Beauregard was screened for agronomically useful traits until its release in 1987. The cultivars Owairaka Red, Beniazuma and Beauregard represent varied breeding methods, diverse germplasm and different markets.

Cultivation and breeding may bring about a shift in the partitioning of resources between plant organs. Even the relative amount of assimilate partitioned between compounds, within organs, may be modified (Halford, 1999). In sweetpotato, the relationship between the assimilate source (photosynthetic tissue) and main assimilate sink (storage roots) and their relative importance to crop yield has been studied. Source potential (leaf area and photosynthetic rate) and sink capacity (mean storage root weight and number) vary amongst sweetpotato cultivars (Hahn, 1977, 1982; Bouwkamp and Hassam, 1988). The rate of photosynthate translocation between source and sink is important to root yield (Austin and Aung, 1973; Kays *et al.*, 1982; Bhagsari and Ashley, 1990). The source potential and sink capacity interact in that an increasing sink capacity stimulates an increase in photosynthetic rate (Zhong, 1991). During plant growth the relative importance of source potential to sink capacity varies, as a strong storage root sink during early growth competes with the development of further source leaves. However, in the later stages of plant growth a relatively strong root sink is required to maximise storage root yield (Bhagsari, 1990). While wild relatives of sweetpotato such as *Ipomoea trifida* tend to produce thin roots, in the future their agronomically useful traits such as pest resistance may be incorporated into sweetpotato (Komaki and Katayama, 1999). In this paper we compare the pattern of dry matter partitioning between major plant organs for the three commercial cultivars, Owairaka Red, Beniazuma and Beauregard, over the period of storage root development.

Materials and Methods

Three sweetpotato cultivars were selected for the experiment, cv. Owairaka Red (Lewthwaite, 1997) from New Zealand, cv. Beauregard (Rolston *et al.*, 1987) from the United States and cv. Beniazuma (Shiga *et al.*, 1985) from Japan. All three sweetpotato cultivars were propagated by inserting one node of 3 node apical cuttings into 45 ml plugs containing commercial peat/-pumice bedding mix, 30 days before transplanting (Lewthwaite, 1999; Lewthwaite and Triggs, 1999). The plugs were hand transplanted (29 November 1995) into a field consisting of Patumahoe clay loam soil (Orbell, 1977) at the Pukekohe Research Centre (Lat. 37° 13' S), New Zealand. A base fertiliser of 30% potassic superphosphate (N:P:K 0:7:14) was broadcast at 1 t/ha and incorporated prior to planting. General cultural practice followed commercial recommendations (Coleman, 1972). Rainfall was supplemented by overhead irrigation throughout the season. The experiment included three cultivars and 10 harvest dates with three replicates, arranged in a modified alpha design (Williams and John, 1989), 6 plots wide by 15 plots long. Each plot was four rows wide by 3.5 m long; only the middle two rows (20 plants) were harvested, the outer rows being buffers. The cultivar Northland Rose, formerly clone 93N9/2 (Lewthwaite *et al.*, 1997), was planted in all rows apart from those harvested. Each row was 0.75 m wide and within-row plant spacing was 0.30 m. The plots were hand harvested on 10 occasions over the period of storage root development (71, 78, 85, 91, 99, 105, 112, 120, 127 and 134 days after transplanting (DAT)). At harvest, plant tops were removed at soil level and divided into leaves and stems. Leaves were separated at the juncture of the petiole and lamina, and then counted. For each plot, all leaves and stems were removed and weighed before sub-samples (10% by weight) were taken at random. The stem and leaf sub-samples were oven-dried at 80°C for 5 days before weighing. Roots with a diameter greater than 5 mm were harvested. Three roots (diameter 2.5 - 4.5 cm) were selected at random from each harvested plot and cut in half longitudinally. Three halves were bulked and used to determine % dry weight by drying at 80°C for five days.

Results

The data required $\log_e$ transformation to stabilise the variance. The field trial was constructed as a row and column design, but as analysis by the residual maximum likelihood (REML) method showed no spatial effects at row, column or replicate level, the analysis was completed using analysis of variance (ANOVA). Exponential growth curves were fitted for each cultivar and all data are presented on a dry weight basis.

Averaged over all the harvests, there were large differences in total plant weight between the cultivars, with cv. Owairaka Red producing the largest plants at 261 g ($\log_e$, 5.6), then cv. Beniazuma at 220 g ($\log_e$, 5.4) and cv. Beauregard at 176 g ($\log_e$, 5.2) per plant ($P<0.001$). The pattern of total plant weight increase over sequential harvests did not differ significantly among cultivars ($P=0.32$).

The cultivars showed different responses over harvests for root weight ($P=0.016$). However, pairwise analysis demonstrated that the pattern of root dry weight accumulation did not differ for cv. Beniazuma and cv. Beauregard ($P=0.74$), while cv. Owairaka Red differed (Fig. 1) from each of the other cultivars ($P=0.011$ and 0.013, respectively). Cv. Owairaka Red and cv. Benia-

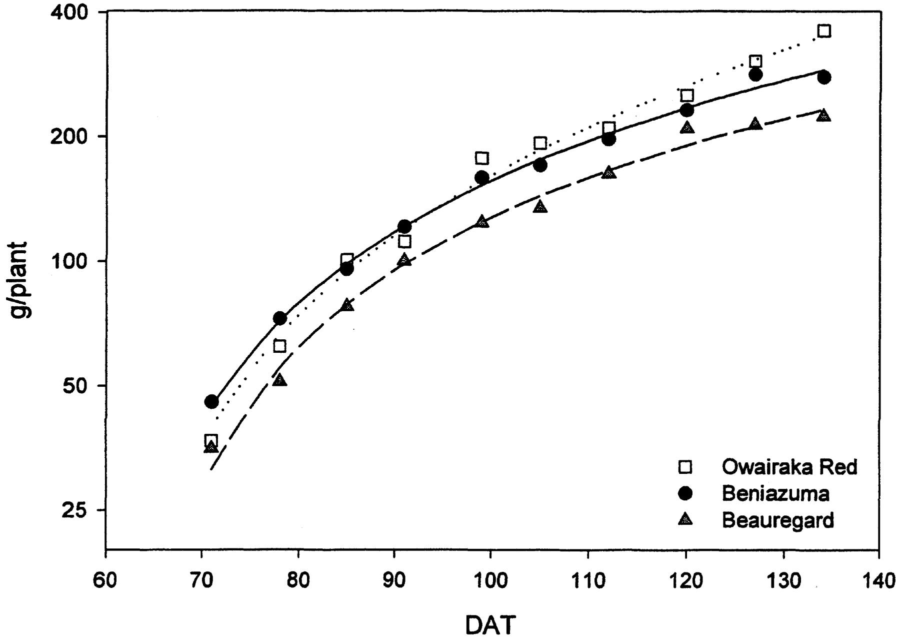

Figure 1. The relationship between storage root dry matter accumulation ($\log_e$ scale) and days after transplanting (DAT), for three sweetpotato (*Ipomoea batatas* (L.) Lam.) cultivars.

zuma produced the same mean root dry weight (Table 1), while cv. Beauregard produced significantly less ($P<0.001$). The multiple correlation coefficients (R^2) for the fitted exponential curves for each of the cultivars were 96.9% or greater.

The harvest index (root weight/total plant weight) averaged across all harvest dates was significantly lower in cv. Owairaka Red at 57.9% ($P<0.001$) than in both cv. Beniazuma (66.2%) and cv. Beauregard (65.8%), which did not differ ($P>0.05$).

The relative pattern of dry matter accumulation for either stem or leaf weight did not differ across harvests for the cultivars (P=0.54 and 0.59, respectively). On average, cv. Owairaka Red partitioned significantly more

Table 1. The mean dry weight of sweetpotato (*Ipomoea batatas* (L.) Lam.) plant components, averaged across 10 harvest dates. Transformed ($\log_e$) and back-transformed data for three cultivars. Exponential curves were fitted and the multiple correlation coefficients (R^2) are shown. P values of <0.001 were obtained for all fitted curves, apart from leaf tissue of cv. Owairaka Red (P=0.008).

	Root		Stem		Leaf	
Cultivar	g/plant	R^2 (%)	g/plant	R^2 (%)	g/plant	R^2 (%)
Owairaka Red	148 (5.0)	97.3	68 (4.2)	81.7	37 (3.6)	25.1
Beniazuma	148 (5.0)	96.9	35 (3.6)	59.5	35 (3.6)	40.2
Beauregard	114 (4.7)	97.8	32 (3.5)	83.6	25 (3.2)	42.8
$LSD_{0.95}$	(0.05)		(0.07)		(0.07)	

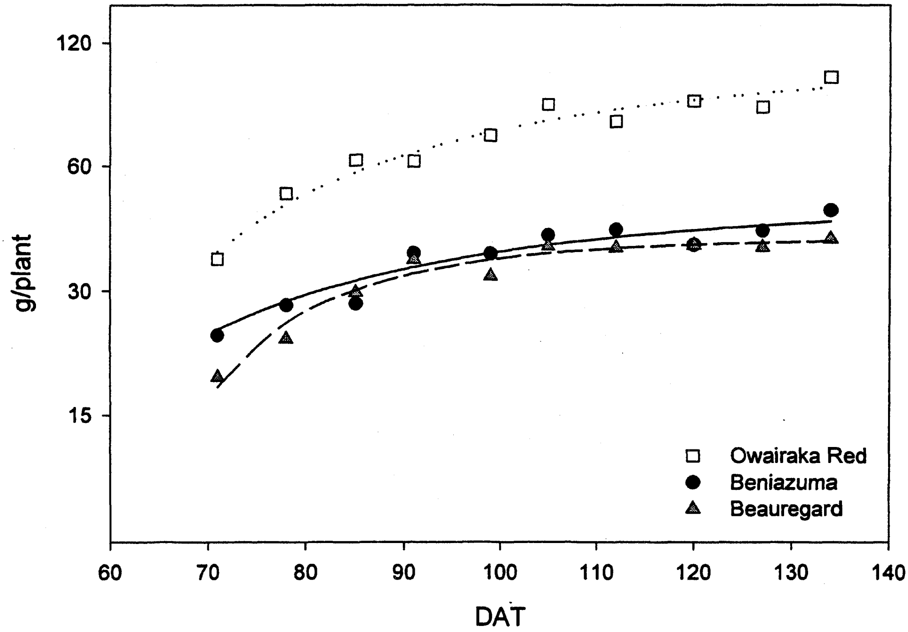

Figure 2. The relationship between stem dry matter accumulation ($\log_e$ scale) and days after transplanting (DAT), for three sweetpotato (*Ipomoea batatas* (L.) Lam.) cultivars.

dry matter into stems (Table 1) than the other two cultivars ($P<0.001$). Cv. Beniazuma partitioned significantly more photosynthate to stem tissue than cv. Beauregard ($P<0.05$). While all the exponential curves for stem dry matter accumulation fitted the data well, cv. Beniazuma was more variable than the other two cultivars (Fig. 2). Cv. Beauregard produced significantly ($P<0.001$) less leaf dry matter (Table 1) than cv. Owairaka Red or cv. Beniazuma, which did not differ ($P>0.05$). Fitted exponential curves for leaf dry matter accumulation were significant ($P<0.001$) for each cultivar, but were poor in describing the data (Fig. 3), as the highest multiple correlation coefficient was 42.8%.

A ternary diagram (Daniels and Alberty, 1961) for each cultivar (Fig. 4) shows the relative proportions (%) of dry matter partitioned into root, leaf and stem tissue across harvest dates. As the plants developed, the relative amount of root tissue increased for all cultivars. The proportional increase in root tissue over time was well approximated by a line for each cultivar, which demonstrates a constant ratio between the proportion of leaf and stem tissue. The ratio for each cultivar was Owairaka Red (leaf 0.44: stem 0.56), Beniazuma (leaf 0.65: stem 0.35) and Beauregard (leaf 0.52: stem 0.48). Cv. Owairaka Red was the only one that partitioned more into stem than leaf tissue.

Discussion

Cv. Owairaka Red represents a commercial cultivar selected by mutation from early germplasm of limited range, under a cropping system dependent on vigorous vine and sprout growth for the production of propagation material with minimal inputs. Although cv. Owairaka Red produced the largest plants it had the lowest harvest index, indicating that despite a high biological yield it was not efficient at partitioning dry matter into storage roots (Bhagsari and Harmon, 1982). While cv.

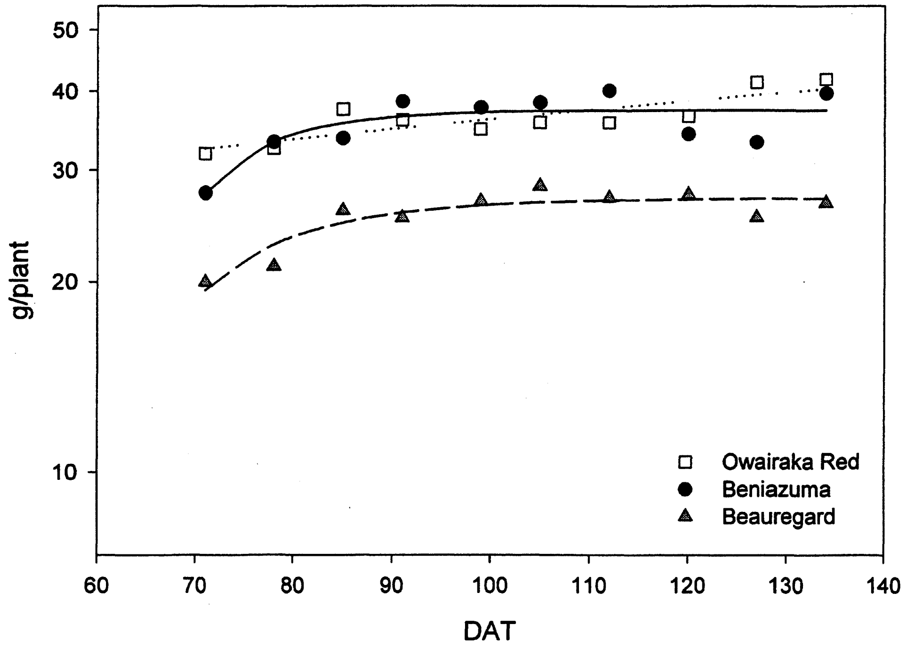

Figure 3. The relationship between leaf dry matter accumulation ($\log_e$ scale) and days after transplanting (DAT), for three sweetpotato (*Ipomoea batatas* (L.) Lam.) cultivars.

Owairaka Red had a similar amount of leaf tissue to cv. Beniazuma (Fig. 3), it placed a greater dry matter investment into stem tissue (Fig. 2). Cv. Owairaka Red was the only cultivar to produce proportionally more stem than leaf tissue. Dry matter accumulation in cv. Owairaka Red stems continued throughout storage root development (Fig. 2). This suggests that cv. Owairaka Red yields might be increased through cultural practices that discourage vine growth late in the season (Nair and Nair, 1992). The vines of cv. Owairaka Red show relatively vigorous spreading growth, which may be considered advantageous for reducing early weed competition (Lewthwaite and Triggs, 2000). The rate of dry matter accumulation in the roots of cv. Owairaka Red was higher than in the other cultivars (Fig. 1), suggesting that in this cultivar root yield might be relatively more sensitive to harvest date.

Cv. Beauregard and cv. Beniazuma are examples of modern sweetpotato breeding and it is noteworthy that they produced similar high harvest indices. Cv. Beauregard partitioned significantly less dry matter into leaf and stem tissue than either of the other cultivars. However, the fresh weight yield of cv. Beauregard is relatively high, with proportionally low root dry matter content. Cv. Beauregard partitioned equivalent amounts of photosynthate into leaf and stem tissue (Fig. 4) while cv. Beniazuma allocated almost twice as much dry matter into leaves than stems. In these two cultivars, the total amount of dry matter in leaf tissue remained almost constant throughout a considerable period of storage root development.

Conclusion

These three cultivars differ considerably in their growth habit, but in each case cultural practice might be used to maximise the root yield, through the relationship between source and sink. Cv. Owairaka Red produces

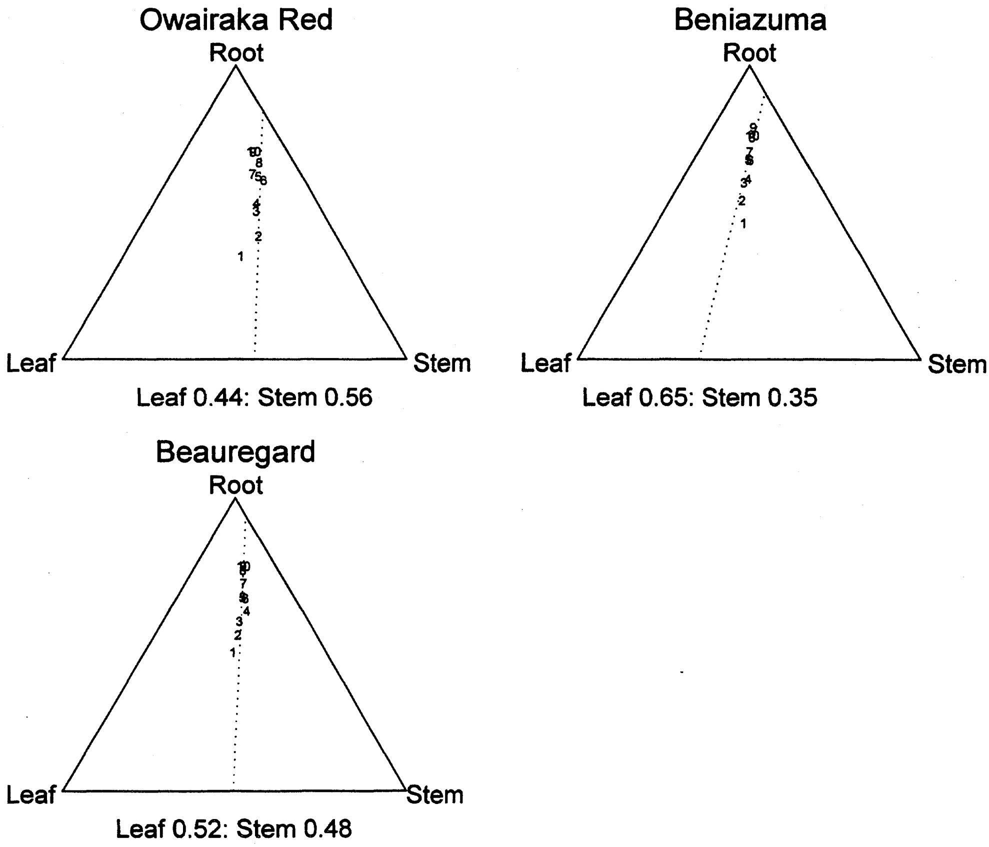

Figure 4. Ternary diagrams of the mean dry matter distribution (%) between the main organs (leaves, stems and roots) for three sweetpotato (*Ipomoea batatas* (L.) Lam.) cultivars. Data recorded over 10 harvests 71, 78, 85, 91, 99, 105, 112, 120, 127 and 134 days after transplanting (labelled 1 to 10 respectively).

excessive vine growth late in the season, a secondary sink that competes with the storage roots for dry matter. Cv. Beauregard, conversely, produces relatively less leaf material, so that the application of water or nitrogen fertiliser early in the season might encourage the establishment and maintenance of a larger source of photosynthate. Alternatively, cv. Beauregard might be planted more densely than cv. Owairaka Red to maximise dry matter production per unit area.

References

Austin, M.E. and Aung, L.H. 1973. Patterns of dry matter distribution during development of sweet potato (*Ipomoea batatas*). *Journal of Horticultural Science* ***48***, 11-17.

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

Bhagsari, A.S. 1990. Photosynthetic evaluation of sweetpotato germplasm. *Journal of the American Society of Horticultural Science* ***115***, 634-639.

Bhagsari, A.S. and Ashley, D.A. 1990. Relationship of photosynthesis and harvest index to sweet potato yield. *Journal of the American Society of Horticultural Science* ***115***, 288-293.

Bhagsari, A.S. and Harmon, S.A. 1982. Photosynthesis and photosynthate partitioning in sweet potato genotypes. *Journal of the American Society of Horticultural Science* ***107***, 506-510.

Bouwkamp, J.C. and Hassam, M.N.M. 1988. Source-sink relationships in sweet potato. *Journal of the American Society of Horticultural Science* ***113***, 627-629.

Coleman, B.P. 1972. Kumara growing. A.R. Shearer, Government Printer, Wellington, New Zealand, 42pp.

Daniels, F. and Alberty, R.A. 1961. Ternary systems – graphical representation. *In* Physical Chemistry (2nd edition), pp. 257-258. John Wiley & Sons Inc, USA.

Hahn, S.K. 1977. A quantitative approach to source potentials and sink capacities among reciprocal grafts of sweetpotato varieties. *Crop Science* ***17***, 559-562.

Hahn, S.K. 1982. Screening sweetpotato for source potentials. *Euphytica* ***31***, 13-18.

Halford, N.G. 1999. Metabolic signalling and the partitioning of resources in plant storage organs. *Journal of Agricultural Science* ***133***, 243-249.

Kays, S.J., Chua, L.K., Goeschl, J.D., Magnuson, C.E. and Fares, Y. 1982. Assimilation patterns of carbon in developing sweet potatoes using ^{11}C and ^{14}C. *In* Sweet potato. Proceedings of the First International Symposium, (eds., R.L. Villareal and T.D. Griggs), pp. 95-118. Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan.

Komaki, K. and Katayama, K. 1999. Root thickness of diploid *Ipomoea trifida* (H.B.K.) G. Don and performance of progeny derived from the cross with sweetpotato. *Breeding Science* ***49***, 123-129.

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. 1999. Field establishment of sweetpotato transplants. *Agronomy New Zealand* ***29***, 51-57.

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***, 33-41.

Lewthwaite, S.L. and Triggs, C.M. 1999. Plug transplants for sweetpotato establishment. *Agronomy New Zealand* ***29***, 47-50.

Lewthwaite, S.L. and Triggs, C.M. 2000. Weed control in sweetpotatoes. *New Zealand Plant Protection* ***53***, 262-268.

Nair, D.B. and Nair, V.M. 1992. Nutritional studies in sweetpotato. *Journal of Root Crops* ***18***, 53-57.

Orbell, G.E. 1977. Soils of part Franklin County, South Auckland, New Zealand. *N.Z. Soil Survey Report* ***33***, DSIR Soil Bureau, New Zealand.

Rolston, L.H., Clarke, C.A., Cannon, J.M., Randle, W.M., Riley, E.G., Wilson, P.W. and Robbins, M.L. 1987. 'Beauregard' sweet potato. *HortScience* ***22***, 1338-1339.

Shiga, T., Sakamoto, S., Ando, T., Ishikawa, H., Kato, S., Takemata, T. and Umehara, M. 1985. On a new sweet potato cultivar 'Beniazuma'. *Bulletin of the National Agriculture Research Center* ***3***, 73-84.

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

Zhong, R.S. 1991. Studies on the source-sink relationship in sweetpotato. *Jiangsu Journal of Agricultural Science* ***7***, 44-48.