Transplanted versus Direct-Seeded Sugarbeets*

J. C. THEURER AND D. L. DONEY*

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INTRODUCTION

The length of the growing season has a marked effect on sugarbeet production; the longer the season, the greater the yields. Thus, early seeding in the spring is of prime importance if good yields are to be obtained. Early planting allows the early development of an optimal leaf surface area that is available when the environment is most suitable for maximum assimilation of energy and subsequent transfer of photosynthate to the storage root. In sugarbeet plants, the efficacy of early sowing may be limited, however, by poor growth due to cool soil temperatures, the increased vulnerability of seedlings to frost damage, or an increase in bolting tendency.

Seeding sugarbeets in the greenhouse and subsequently transplanting seedlings to the field at the normal seeding time could lengthen the growing season without predisposing plants to the above adverse effects. The transplanted plants would have a better developed leaf area and would be expected to develop more rapidly than conventionally seeded sugarbeets. Scott and Bremmer (18) reported that the greater leaf-area index of transplanted plants remained

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*The authors are Research Geneticists, Crops Research Laboratory, Agriculture Research, Science and Education Administration, U. S. Department of Agriculture.

as such over the growing season. Humphries and French (11) found that transplants had larger root:top ratios during the season, but had about the same number of leaves as direct-seeded plants.

The yield potential of transplanted sugarbeets for commercial sugar production has been studied in Canada (2), Great Britain (3, 11, 12, 17), Japan (6, 7, 8, 10), Belgium (14), Finland (4), the United States (5, 9, 13, 16, 17), and other countries. Most studies have shown that transplants have a higher root yield at harvest with no significant change in sucrose percentage or purity (2, 3, 7, 11, 12, 14, 16, 17, 18). Some researchers have reported a significant increase in sucrose percentage as well as the yield advantage for transplants (4, 5, 6, 13). Hasegawa (10) found no difference between planting method for root yield or sucrose percentage of three varieties. Gaskill (9) obtained greater yield with direct-seeded beets but found no difference in sucrose percentage. From 1969 to 1972, we conducted field trials at Logan, Utah, to compare transplanting with direct seeding of diverse sugarbeet varieties. The results of these experiments are presented in this paper.

MATERIALS AND METHODS

1969 EXPERIMENT

Four varieties were used in transplant studies in 1969; US22/3, an old, open-pollinated variety; UI Hybrid 7, a single-cross hybrid; (A1CMSxL53)x(L28CMSxL60), an experimental double-cross pollen restorer hybrid; and 5.002, a vigorous inbred. The four varieties were seeded April 6, 1979 into soil in Japanese paper pots*, 3 cm in diameter x 10 cm deep, in the greenhouse. The plants were watered daily with ½ N Hoagland's solution and were grown under

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Gro-Lux lamps. Seedlings were 4 weeks old (4- to 6- leaf stage) when they were transplanted to the field on May 8.

The field design was a split plot, consisting of four-row plots, with planting method (transplanted vs. direct seeded) as whole plots and varieties as subplots, in six replications. Rows were 56 cm apart and beets were thinned or transplanted to leave a single beet every 30.5 cm. Direct seeding was done May 7. Seedlings were transplanted into the field May 8 and 9. The field was irrigated immediately after transplanting, to provide adequate moisture for seed germination and for establishment of the transplants.

On October 10, the center two rows of each plot were harvested. Roots of each plot were weighed and sucrose content was determined with the cold digestion pol method (1). An impurity index value was calculated as follows:

$$\frac{10 \times \text{ppm amino N} + 2.5 \times \text{ppm Na} + 3.5 \times \text{ppm K}}{\text{sucrose percentage}}$$

1970 EXPERIMENT

Six experimental hybrids were compared in 1970. These varieties were planted in 3-cm x 10-cm paper pots on April 16, and a duplicate planting was made 2 weeks later on May 1. Seedlings were cultured in the greenhouse similarly to the procedure outlined for the 1969 experiment. Direct seeding was done on May 18 and transplanting was completed May 19. Field plots consisted of five replicates of split-plot experiment with seedings, 2-week-old transplants, and 4-week-old transplants as whole plots and hybrids as subplots. Otherwise, the field planting and harvest procedures were similar to those used in 1969. The field plots were harvested on October 30.

1971 EXPERIMENT

In 1971, two commercial varieties developed by the Amalgamated Sugar Company and two developed by Utah-Idaho Sugar Company were studied. Greenhouse seeding (April 12 and

April 27), culture of transplants, field layout, and harvest procedures were similar to those for the 1970 experiment, with the two following exceptions: A deeper paper pot (3 cm x 13 cm) was used to allow better root development, and transplanting was done May 11 with a tractor-mounted single-row tobacco transplanter. This machine not only made transplanting more rapid than it was with hand methods, but it provided a better stand in the field, because the plants were soaked with water as they were inserted into the soil. The field plots were harvested on October 15.

1972 EXPERIMENT

The 1972 experiment involved three commercial hybrids, a high-yield experimental hybrid, and a high-sucrose-content experimental hybrid. Four replicates of direct-seedings, 2-week-old transplants, and 4-week-old transplants were studied by the methods outlined above for previous years. Transplants were seeded in the greenhouse on April 11 and April 25, transplanted to the field May 10, and harvest was made on October 18.

RESULTS

In general, the transplanted plants grew more rapidly and had larger canopies than the direct-seeded plants for the first 2 months of growth. Thereafter, the foliage appeared similar in plants established by the two methods.

In 1969, roots from the transplanted beets were short and stubby and the sprangled root portions tended to be broken off at harvest. Seeded beets, conversely, had well-shaped roots (Fig. 1). Sugar yield and root weight were significantly greater for the transplanted plants (Table 1). No significant difference in sucrose percentage or impurity index was observed between transplanted and direct-seeded sugarbeets. The impurity components of amino-N, Na, and K also had similar values for each variety, regardless of planting method.

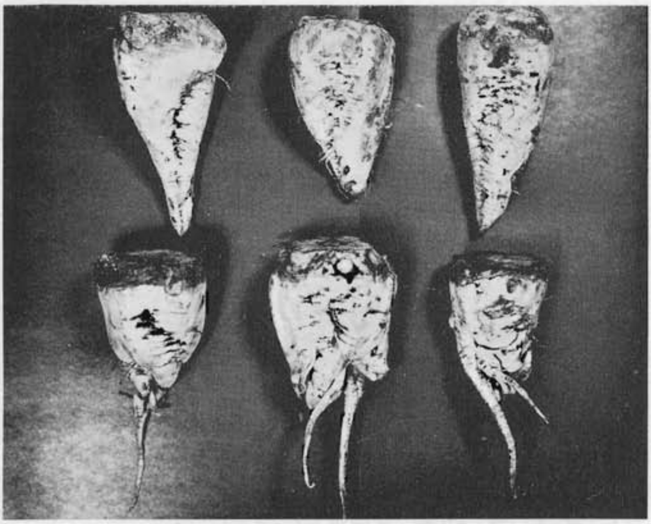

Figure 1. Root shape of seeded beets (upper) and transplanted beets (lower).

In 1970, the transplanted plants again grew more rapidly than the direct-seeded plants, and early in the spring, the 4-week-old transplants had larger canopies than the 2-week-old transplants. At harvest, sprangling was less severe than in 1969, in transplants of both ages. There were significant differences between treatments and treatment x variety interactions for sugar yield and root weight (Table 2). On the average, the 2-week-old transplants and the seeded plants were similar in root weight and sugar yield and had higher root weight and sugar yield than the 4-week-old transplants (Table 2). The 4-week-old transplants of variety 1, (L9xL33)x(L53xL29R), had a higher sugar yield than the 2-week-old transplants or the seeded plants. In all other hybrids, sugar yield was greater for the 2-week-old transplants than for the 4-week-old transplants.

Table 1.-Sugar yield, root weight, sucrose percentage, and impurity index for transplanted and seeded sugarbeets, Logan, Utah, 1969.

	Gross Sugar yield		Root weight		Sucrose		Impurity Index[a]	
Variety	Seed.	Trans.	Seed.	Trans.	Seed.	Trans.	Seed.	Trans.
	kg/ha		MT/ha		%			
1. US 22/3	5113	6150	40.9	49.2	12.5	12.5	596	713
2. U & I Hybrid 7	5832	6515	47.8	53.4	12.2	12.2	689	656
3. (AlxL54)x(L28xRfl)	5652	5872	44.5	46.6	12.7	12.6	573	576
4. 5.002	3760	4375	28.7	33.4	13.1	13.1	471	565
Mean all varieties	5089	5728	40.5	45.6	12.6	12.6	582	628
LSD 0.05, Seeded vs transplants	575		4.2		NS		NS	

[a]See text for calculation.

Table 2.-Sugar yield, root weight, sucrose percentage, and impurity index for transplanted and seeded sugarbeets, Logan, Utah, 1970.

Experimental Hybrid	Gross sugar yield			Root weight		
	Seed.	Trans. A[a]	Trans. B[a]	Seed.	Trans. A	Trans.B
		kg/ha			MT/ha	
1. (L9xL33)x(L53xL29R)	6162	7236	6815	43.4	49.9	47.0
2. (L33x35.53)x(L53xL29R)	6105	6322	7178	43.3	43.3	48.5
3. (L33x0461S)x(L53xL29R)	6395	4882	5875	43.8	33.9	40.8
4. (L33x0461S)x(R2xL29R)	6653	5510	6494	46.2	38.8	45.1
5. (A902)x(L53xL29)	7119	5877	7236	49.1	41.1	49.9
6. (L33xL5)x(L53xL29)	7279	4540	7229	50.9	32.9	50.2
Mean all varieties	6619	5728	6805	46.1	40.0	46.9
LSD 0.05, Seeded vs transplants		822			4.9	

	Sucrose			Impurity index[b]		
	Seed.	Trans. A	Trans. B	Seed.	Trans. A	Trans. B
		%				
1. (L9xL33)x(L53xL29R)	14.2	14.5	14.5	572	571	564
2. (L33x35.53)x(L53xL29R)	14.1	14.6	14.8	628	614	596
3. (L33x0461S)x(L53xL29R)	14.6	14.4	14.4	583	600	491
4. (L33x0461S)x(R2xL29R)	14.4	14.2	14.4	628	648	682
5. (A902)x(L53xL29)	14.5	14.3	14.5	564	565	519
6. (L33xL5)x(L53xL29)	14.3	13.8	14.4	561	667	573
Mean all varieties	14.4	14.3	14.5	589	611	571
LSD 0.05, Seeded vs transplants		NS			NS	

[a]Transplant A = 4-week-old seedlings, Transplant B = 2-week-old seedlings.

[b]See text for calculation.

Rhizoctonia disease and an error in fertilization in the greenhouse in the 4-week-old seedlings (transplant A) were the probable causes for the poor yield performance of this treatment and for the planting-method x hybrid interaction for sugar yield and root weight. Therefore, the comparisons involving this planting method are not considered entirely reliable. There was no significant difference in sucrose percentage and impurity index between treatments.

The deeper paper pots used in 1971 reduced much of the sprangling of roots observed in 1969 and 1970. However, the transplanted roots still had poor shape. The 2-week-old transplants again had less sprangling at harvest than the 4-week-old transplants. There was no significant difference between varieties and no significant variety x treatment interactions. Significant differences were observed, however, between planting methods. The 4-week-old transplants (transplant A) produced the greatest yield of the three treatments, significantly better than that of the seeded plants (Table 3). The 2-week-old transplants (transplant B) also had a slightly higher yield than the direct-seeded plants. Sugar percentages and impurity index values were similar for all planting methods.

In 1972, there were significant differences between the hybrids and significant variety x planting method interactions for root weight and sugar yield. In general, the 2-week-old transplants had greater root weight and sugar yield than the seeded plants (Table 4). The 4-week-old transplants of US H20 also significantly outyielded the seeded plants. In fact, US H20 was mainly responsible for the significant differences between seeded and transplanted plants. In contrast to the results of previous years, in 1972, there were significant differences between planting methods for sucrose percentage. The 4-week-old transplants had a sucrose percentage on the average 0.4 higher than that of the seeded plants. The 2-week-old transplants of US H20 and experimental hybrid, L53 CMS x L37, also significantly exceeded seeded plants in sucrose content.

Table 3.-Sugar yield, root weight, sucrose percentage, and impurity index for transplanted and seeded sugarbeets, Logan, Utah, 1971.

Variety	Gross sugar yield			Root weight		
	Seed.	Trans. A[a]	Trans. B	Seed.	Trans. A	Trans. B
		kg/ha			MT/ha	
1. Amal. Hybrid #1	7504	9101	8010	49.7	59.1	52.7
2. Amal. Hybrid #3	7384	8861	8375	48.9	58.3	55.1
3. UI Hybrid B	7925	8804	8695	51.8	56.8	56.1
4. UI Hybrid D	8769	9511	9469	55.5	60.2	60.7
Mean all varieties	7896	9069	8637	51.5	58.6	56.2
LSD 0.05, Seeded vs transplants		1020			5.9	
	Sucrose			Impurity index[b]		
	Seed.	Trans. A	Trans. B	Seed.	Trans. A	Trans. B
		%				
1. Amal. Hybrid #1	15.1	15.4	15.2	462	453	450
2. Amal. Hybrid #3	15.1	15.2	15.2	450	517	484
3. UI Hybrid B	15.3	15.5	15.5	453	478	464
4. UI Hybrid D	15.8	15.8	15.6	470	502	474
Mean all varieties	15.3	15.5	15.4	459	488	468
LSD 0.05, Seeded vs transplants		NS			NS	

[a]Transplant A = 4-week-old seedlings, Transplant B = 2-week-old seedlings.

[b]See text for calculation.

Table 4.-Sugar yield, root weight, sucrose percentage, and impurity index for transplanted and seeded sugarbeets, Logan, Utah, 1972.

Variety	Gross sugar yield			Root weight		
	Seed.	Trans. A[a]	Trans. B	Seed.	Trans. A	Trans. B
		kg/ha			MT/ha	
1. Amal. Hybrid #1	5934	7154	7526	41.5	49.0	53.0
2. UI Hybrid #7	7338	6946	6938	48.6	45.4	47.2
3. USH20	7237	10570	9969	48.9	66.9	63.5
4. L53 CMS X L37	8895	8284	8105	60.1	52.1	51.3
5. L53 CMS X L19	8164	7222	8205	52.0	48.8	54.7
Mean all varieties	7514	8035	8149	50.2	52.4	53.9
LSD 0.05, Seeded vs transplants		581			3.7	

	Sucrose			Impurity index[b]		
	Seed.	Trans. A	Trans. B	Seed.	Trans. A	Trans. B
		%				
1. Amal. Hybrid #1	14.3	14.6	14.2	656	728	729
2. UI Hybrid #7	15.1	15.3	14.7	623	629	630
3. USH20	14.8	15.8	15.7	651	710	624
4. L53 CMS X L37	14.8	15.9	15.8	716	656	626
5. L53 CMS X L19	15.7	14.8	15.0	649	687	707
Mean all varieties	14.9	15.3	15.1	659	682	663
LSD 0.05, Seeded vs transplants		.28			NS	

[a]Transplant A = 4-week-old seedlings, Transplant B = 2-week-old seedlings.

[b]See text for calculation.

However, there were no differences between treatments for sugar percentage of Amalgamated #1 and UI Hybrid 7. The seeded plants of variety L53 CMS x L19 had a higher sucrose content than the transplants of either age. Impurity index values were similar for the planting methods.

DISCUSSION

Results of our experiments agree with those of other researchers (2, 3, 5, 7, 11, 12, 13, 14, 17) that transplanting is a means of lengthening the growing season for sugarbeets and that it results in increased tonnage of roots at harvest. This response is a direct result of the more rapid development of the leaf canopy early in the spring of the year, early expansion of leaves, enlargement of the root, increased photosnythesis, and subsequently greater transport of assimilate to the sugarbeet root.

Transplanted sugarbeets tend to have branched taproots that break off during harvest and reduce yield. In addition, they tend to hold soil and gravel between the root branches, which makes processing more difficult. Transplanting bare-root sugarbeets results in a stubby, branched root. Transplanting in soil cubes (3) or Japanese paper pots (7, 15) decreases this branching, but does not completely eliminate it. We observed that the deeper the paper pot, the less the branching of the taproot; and the older the seedling at the time of transplanting, the greater the root branching at harvest.

Use of the single-row tobacco transplanter allowed uniform spacing with virtually little mortality of seedlings when they were transferred to field plots. It was, however, a slow process, still requiring much hand labor and is not feasible for large-area transplanting. Sprinkler irrigation was required immediately after transplanting to maintain a good stand. The Japanese have developed transplanting machines especially for sugarbeets (7, 15) and are using them on a limited area. However, their labor market is different from that in the United States. A proposal was made in 1970 to develop a transplanter for use in the United States (13), but this has not materialized. Research and development of a precision transplanter would be required if we were to apply the transplanting method in this country.

In general, the transplants had no advantage or disadvantage in sugar content or impurity factors. Some (2, 3, 11, 17) have reported root yield advantage of 8-22 metric tons/ha in favor of transplanted sugarbeets. However, in our experiments, the transplants averaged only 4-7 metric tons/ha more root yield than the direct-seeded sugarbeets of the same varieties. Considering the additional cost for seedling culture and transplanting, we conclude that the economic margin is not great enough to recommend transplanting as a standard practice in the intermountain area of the western United States.

In recent years, interest has been expressed in the possibility of using potato cellars in the early spring as propagation units for sugarbeets for transplanting. Considering the energy costs for lighting, the high labor costs, and the margin of yield we observed in our 4 years of experiments, this method does not appear to be practical. Current trends are to deintensify and reduce hand labor in sugarbeet production, which is directly opposed to the introduction of transplanting.

LITERATURE CITED

(1) Association of Official Agriculture Chemists. 1955. Official methods of analysis. 8th Ed. Washington, D. C. p. 564-568.

(2) Anderson, D. T., S. Dubetz, and G. C. Russell. 1958. Studies on transplanting sugar beets in southern Alberta. J. Amer. Soc. Sugar Beet Technol. 10 (6):150-55.

(3) Bremner, P. M. and B. Wilton. 1965. Transplanting sugar beet. Univ. of Nottingham School of Ag. Rep. p. 69-73

(4) Brummer, V. 1975. Transplanting of pot-raised sugar beet seedlings. Proc. 38th Inst. Int. de Rech. Betteravieres, Winter Congr. Session I. Report No. d.1.

(5) Dillon, M. A., B. D. McCaslin, and W. R. Schemhl. 1972. Effect of transplanting and cover on growth of sugar beet. Agron. J. 64:183-186.

(6) Ebata, M., K. Aihoshi, and M. Hirohama. 1964. On the transplanting time and nursery periods of sugar beet. Jap. Bull. Sugar Beet Res. Suppl. No. 4. p. 1-6.

(7) Eto, H., A. Kajimoto, Y. Umeki, and H. Kawagoe. 1964. On the transplanting cultivation of sugar beet using paper pots. Jap. Bull. Sugar Beet Res. Supply. No. 4. p. 7-14.

(8) Fujita, S., W. Saito, and Y. Takohoshi. 1964. Investigation with the transplanters devised in 1964. Jap. Bull. Sugar Beet Res. Suppl. No. 3. p. 13-18, 132.

(9) Gaskill, J. O. 1942. Comparison of field seeding of sugar beets and mangel wurzels with two methods of transplanting. Proc. Am. Soc. Sugar Beet Technol. 3:377-381.

(10) Hasegawa, T., T. Takeda, T. Tutumi, and K. Sekimura. 1971. The effects of transplanting on the individual variation and selection by root weight and sugar content of beets. Jap. Bull. Sugar Beet Res. Suppl. No. 13. p. 1-8.

(11) Humphries, E. C. and S. A. W. French. 1969. Effect of seedling treatment on growth and yield of sugar beet in the field. Ann. Appl. Biol. 64:385-393.

(12) Ivins. J. D. and P. M. Bremner. 1966. Growth studies with the sugar beet crop. Ag. Progr. 41:77-83.

(13) Kessinger, D. 1970. An experimental systems approach to transplanting sugar beets. Handout summary of paper presented at Am. Soc. Agron. Mtg.

(14) Martens, M., R. Vanstallen, and A. Vigoureux. 1975. Field experiments on transplantation of sugar beets. Proc. 38th Inst. Int. de Rech. Betteravieres Winter Congr. Session I. Report No. 6.

(15) Nippon Beet Sugar Mfg. Co. 1967. Practical guide for the paper-pot transplanting method. 20 p.

(16) Nuchols, S. B. 1931. Transplanting sugar beets in Utah and Idaho. U. S. Dept. of Ag. Circ. 156. p. 15.

(17) Pritchard, F. J. and L. E. Longley. 1916. Experiments in transplanting sugar beets. J. Am. Soc. Agron. 8:106-110.

(18) Scott, R. K. and P. M. Bremner. 1966. The effects of growth, development, and yield of sugar beet of extension of growth period by transplantation. J. Ag. Sci. 66:379-388.