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EFFECT OF PLANTING METHOD AND PLANT ARRANGEMENT ON LEAF AREA INDEX AND DRY MATTER ACCUMULATION IN SUGAR BEET

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Effect of transplanting and plant arrangement on the accumulation of leaf area index and dry matter yields in sugar beet *(Beta vulgaris* L. cv. Amazon) were investigated during 1981/82 season at Lincoln College, Canterbury, New Zealand. The effect of transplanting seedlings at different growth stages (Cotyledon, 2-leaf, 4-leaf) was also examined. Leaf area index was higher in the transplanted beet(2- or 4-leaf stage than that in the seed-sown or cotyledon transplants especially early in the season.

Transplanted beet increased total dry matter over seed-sown beet by increasing mean crop growth rate which was about 18% greater in the former than in the latter. Maximum crop growth rate in the transplanted beet was 20.7 g m^{-2} d^{-1}, achieved during January-February harvest interval. In contrast, maximum crop growth rate in the seed-sown beet reached to 17.2 g m^{-2} d^{-1} which was achieved about four weeks later than in the transplanted beet. Plants established by transplanting produced significantly higher mean root growth rate (22%) and thus a greater root dry matter yield compared with the seed-sown plants. Plant arrangement showed no effect on leaf area index and total dry matter or root dry matter yield.

INTRODUCTION

The importance of leaf area as a determinant of radiation interception has been appreciated and well recognised since long. Watson (1952) attributed productivity differences in sugar beet to variation in leaf area index (LAI) and identified early canopy closure as a crucial determinant of initial crop growth rate (CGR) in well nourished stands. Differences in initial rates of LAI development may therefore, be reflected in the final yields. Thus agronomic practices that increase early season growth of beet may increase crop yield (Storer *et al.*, 1970). Transplanting beet is a means of overcoming the inherent short growing season which reduces yield.

Uniform stands of beets have also been stressed for higher yield and quality (Nelson, 1969). Robinson and Worker (1969) confirmed that square plantings were more efficient compared with the rectangular arrangements. Developments in mechanisation suggest that radical changes from conventional methods of cultivation might be beneficial in the utilisation of land area.

The present study, therefore, examines the effect of transplanting and plant arrangement on LAI and dry matter (DM) production in sugar beet.

Table 1. The effect of plant arrangement and planting method on leaf area index (LAI) of sugar beet

Treatment		Days after sowing (DAS)						
		52	74	105	136	167	199	229
Plant arrangement								
Square		0.26	1.04	2.32	2.76	3.24	3.05	2.71
Rectangle		0.22	0.94	2.24	2.75	3.42	3.00	2.70
LSD 5%		0.05	0.16	0.20	0.17	0.36	0.11	0.16
Planting method								
Seed-sown	(T1)	0.08	0.56	1.86	2.02	3.03	3.15	2.94
Cotyledon	(T2)	0.15	0.79	2.01	2.71	3.26	2.86	2.71
2-leaf	(T3)	0.23	1.28	2.43	2.86	3.40	2.83	2.58
4-leaf	(T4)	0.49	1.34	2.81	3.44	3.62	3.26	2.59
LSD 5%		0.07	0.23	0.29	0.24	0.50	0.16	0.22
Significant effects								
T1 vs (T2 + T3 + T4)		**	**	**	**	NS	*	**
T2 vs (T3 + T4)		**	**	**	**	NS	**	NS
T3 vs T4		**	NS	*	**	NS	**	NS
Mean		0.24	0.99	2.28	2.75	3.33	3.02	2.70

* = Significant at P = 0.05.
** = Significant at P = 0.01.
NS = Non-significant.

MATERIALS AND METHODS

The experiment was conducted in the 1981/82 season at the Lincoln College Research Area, Canterbury, New Zealand following randomised complete block design with four replicates. The treatments were two plant arrangements (square, rectangular) and four planting methods (seed-sown, cotyledon, 2-leaf, 4-leaf). The plant density of 10 plant m^{-2} was constant in both the plant arrangements. The plot size was 5.0 x 6.5 m, and there were 16 and 10 rows in each plot for the square (316 x 316 mm) and rectangular (500 x 200 mm) planting. Full details of the crop husbandry operations were given by Hussain (1990).

Table 2. The effect of plant arrangement and planting method on total dry matter (g m^{-2}) of sugar beet

Treatment		Days after sowing (DAS)						
		52	74	105	136	167	199	229
Plant arrangement								
Square		24	180	566	1160	1731	1842	1926
Rectangle		23	165	531	1123	1678	1864	1910
LSD 5%		5	30	59	93	107	78	79
Planting method								
Seed-sown	(T1)	5	72	311	756	1289	1538	1637
Cotyledon	(T2)	17	125	493	1117	1675	1860	1922
2-leaf	(T3)	24	235	637	1210	1830	1940	2013
4-leaf	(T4)	51	259	756	1482	2025	2074	2098
LSD 5%		8	43	84	132	152	110	111
Significant effects								
T1 vs (T2 + T3 + T4)		**	**	**	**	**	**	**
T2 vs (T3 + T4)		**	**	**	**	**	**	**
T3 vs T4		**	NS	**	**	*	*	NS
Mean		24	173	549	1141	1705	1853	1918

* = Significant at P = 0.05.
** = Significant at P = 0.01.
NS = Non-significant.

A total of seven harvests during the season were made at about 4-week intervals. On each occasion, a randomly selected area of 1 m^2 was harvested from each plot except for the final harvest when the area harvested was $2m^2$.

The beet divided into leaves (blades + petioles) and the total root. The roots were washed, dried with a cloth, and the fresh weight of roots and tops was recorded separately. A subsample of 500 g of green foliage was taken and leaf area was measured on an area meter (Licor, Model 3100). Roots of each sample were cut longitudinally into two halves. A subsample of 500 g from one half of the root was finely grated and dried at 70-80°C to constant weight. CGR was calculated as suggested by Hunt (1978). Root growth rate was calculated analogous to CGR.

All statistical analyses were performed using a single degree of freedom contrasts (Little and Hills, 1978). The Genstat Statistical Package was used to analyse the data.

season. Thus an insufficient leaf coverage only could cause yield losses approximately proportional to the area unoccupied by leaves (Ulrich, 1959). The results of this experiment, therefore, suggest that with current cultivation and harvest equipments, no

Table 3. Effect of different planting methods on sugar beet growth rate at various harvest intervals

Planting method		Mean crop growth rate ($g\ m^{-2}\ d^{-1}$)	Crop growth rate ($g\ m^{-2}\ d^{-1}$)			
		52-229 DAS	52-74 DAS	74-105 DAS	105-136 DAS	136-167 DAS
Seed-sown	(T1)	9.2	3.1	7.7	14.4	17.2
Cotyledon	(T2)	10.8	4.9	11.9	20.1	18.0
2-leaf	(T3)	11.2	9.6	13.0	18.5	20.0
4-leaf	(T4)	11.6	9.5	16.0	23.4	17.5
LSD 5%		0.60	1.64	1.75	2.38	3.56
Significant effects						
T1 vs (T2 + T3 + T4)		**	**	**	**	NS
T2 vs (T3 + T4)		*	**	**	NS	NS
T3 vs T4		NS	NS	**	**	NS
Mean		10.7	6.8	12.1	19.1	18.2

* = Significant at P = 0.05.
** = Significant at P = 0.01.
NS = Non-significant.

RESULTS AND DISCUSSION

Plant arrangement: There appeared to be little effect of plant arrangement on TDM or root DM production (Table 2 and 4). This could have resulted from similar canopy growth (Table 1) and non-limiting soil resources to supply nutrients throughout the season. Thus an insufficient leaf coverage only could cause yield losses approximately proportional to the area unoccupied by leaves (Ulrich, 1959). The results of this experiment, therefore, suggest that with current cultivation and harvest equipments, no advantage results from growing sugar beet plants in a square arrangement provided adequate beet stands are established.

Planting method: In the present study, the comparatively superior performance of the transplanted beet in TDM (Table 2) or root DM (Table 4) may be associated with higher LAI (Table 1) early in the growing season.

Table 4. The effect of plant arrangement and planting method on root dry matter (g m^{-2}) of sugar beet

Treatment	Days after sowing (DAS)						
	52	74	105	136	167	199	229
Plant arrangement							
Square	5.3	83	303	726	1143	1368	1465
Rectangle	4.9	78	288	685	1113	1349	1462
LSD 5%	1.3	14	41	74	88	55	73
Planting method							
Seed-sown (T1)	0.6	31	112	430	810	1050	1209
Cotyledon (T2)	2.7	53	274	690	1084	1369	1456
2-leaf (T3)	4.4	113	368	761	1233	1444	1552
4-leaf (T4)	12.7	125	428	942	1384	1572	1636
LSD 5%	1.8	20	58	105	125	77	104
Significant effects							
T1 vs (T2 + T3 + T4)	**	**	**	**	**	**	**
T2 vs (T3 + T4)	**	**	**	**	**	**	**
T3 vs T4	**	NS	*	**	*	**	NS
Mean	5.1	80.5	296	706	1128	1359	1459

* = Significant at P = 0.05.
** = Significant at P = 0.01.
NS = Non-significant.

The transplanted beet had more leaves $plant^{-1}$ than the seed-sown beet. This enabled the plants in the transplanted beet to develop the leaf canopy rapidly, thus enhancing their ability to intercept solar radiation and the accumulation of DM. The LAI measured early in the growing season up to January harvest also showed significant differences between these treatments (Table 1). Similarly, the plants established at the 4-leaf stage were superior in both the TDM (Table 2) and the root DM (Table 4) than those established at the 2-leaf or cotyledon stage. These advantages were probably the direct result of higher LAI early in the season. The main effect of transplanting on LAI and DM accumulation was, therefore, consistent with previous work (Scott and Bremner, 1966).

The results showed that mean CGR was about 18% greater in the transplanted beet compared with the seed-sown beet

(Table 3). However, the increase in mean CGR was in general associated with the active, early vegetative growth phase when CGR differences were also significant between the two planting methods. Higher CGR is usually dependent upon rapid expansion of LAI to intercept available radiation early in the season (Biscoe and Gallagher, 1977). In this experiment, an average CGR of about 11 g m^{-2} d^{-1} and mean maximum rate of 19 g m^{-2} d^{-1} were achieved (Table 3). Inzumiyama (1984) quoted mean and maximum CGR values of about 11 g m^{-2} d^{-1} and 20 g m^{-2} d^{-1}, respectively for sugar beet crops in Japan.

Generally, root growth rates responded to alternations in LAI in a similar way to CGR. Plants established by transplanting produced significantly higher root growth rates (Table 5), and thus a greater root DM yield (Table 4) compared with the seed-sown plants. This was a direct result of greater LAI early in the season (Table 1) when radiation was also high, followed by a period in which the ratio of root to TDM was increased (Humphries and French, 1969). The mean root growth rate achieved in this experiment was 8 g m^{-2} d^{-1} (Table 5), which is similar to the value of 7 g m^{-2} d^{-1} found in Japan (Izumiyama, 1978).

Table 5. Effect of different planting methods on sugar beet root growth rate at various harvest intervals

Planting method		Mean root growth rate (g m^{-2} d^{-1})	Root growth rate (g m^{-2} d^{-1})			
		52-229 DAS	52-74 DAS	74-105 DAS	105-136 DAS	136-167 DAS
Seed-sown	(T1)	6.8	1.4	2.6	10.2	12.3
Cotyledon	(T2)	8.2	2.3	7.1	13.4	12.7
2-leaf	(T3)	8.7	4.9	8.2	12.7	15.2
4-leaf	(T4)	9.2	5.1	9.8	16.6	14.3
LSD 5%		0.57	0.83	1.55	2.50	3.39
Significant effects						
T1 vs (T2 + T3 + T4)		**	*	**	**	NS
T2 vs (T3 + T4)		**	**	**	NS	NS
T3 vs T4		NS	NS	NS	**	NS
Mean		8.2	3.4	6.9	13.2	13.6

* = Significant at P = 0.05.
** = Significant at P = 0.01.
NS = Non-significant.

The evidence given above suggests that TDM and root DM yields would increase if maximum LAI was increased early in the season. It was also shown that, at certain times of the year, leaf area limits the yield and that there is scope for improvement. Increasing LAI early in the growth would be the best. Yield is unlikely to increase with maximum LAI above 3-4 for sugar beet, but neither is it likely to be depressed. The LAI, measured at 167, 199 and 229 DAS for each treatment was 3.0 (Table 1), which is sufficient to intercept more than 80% of the incoming radiation (Sibma, 1968). The similarity in radiation interception suggests comparability of growth rates between the treatments, which is not unexpected.

In conclusion, high root DM yields require husbandry techniques that produce greater LAI especially early in the season. The use of transplanted seedlings offers possible new practice that can increase the early season leaf growth in cool temperate regions like Canterbury. Further increases in yield are most likely to come from techniques which promote earlier leaf area development.

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