GROWTH AND YIELD OF SUGAR BEET AND FODDER BEET IN CANTERBURY

R.J. Martin
Research Division
Ministry of Agriculture and Fisheries
Lincoln

ABSTRACT

Samples were taken at 4 weekly intervals from three September-sown crops of beet. In one trial, higher root fresh weight yields from the fodder beet were matched by higher sugar percentages in the two sugar beets, so that up to June, there was generally little difference in total sugar yield between the two types of beet. In another trial, where sampling continued until September, one fodder beet cultivar gave higher sugar yields than the other fodder beet or the sugar beet. Both root fresh weights and sugar yield per hectare increased rapidly from December to May. There was little change in root or sugar yields from July to September. Root sugar percentage increased linearly in all but two cases, in one of which sugar percentage decreased after July, and in the other, sugar percentage initially decreased, but increased later. The fact that beet yields continue to increase until July will have to be taken into account by any beet industry.

Additional key words: *Sugar content, crown yield.*

INTRODUCTION

Interest in sugar beet in New Zealand was renewed in the 1970s due to its potential as a source of ethanol for use as a liquid transport fuel (Kardos and Mulcock, 1977). However, Dunn *et al.*(1978) claimed that fodder beet would produce considerably higher yields of fermentable sugars than sugar beet. Economic evaluations based on these claims (NZERDC, 1979) indicated that fodder beet was the most economically attractive crop for energy farming.

However, as Drewitt (1979) found little difference in sugar yield between one sugar beet and two fodder beet cultivars, detailed comparisons of sugar beet and fodder beet were undertaken in the 1979-80 season in the Lincoln area. A cultivar trial has already been described (Martin, 1980). Another approach taken was to compare the growth of fodder beet and sugar beet to see if there was any difference in the rate and pattern of sugar accumulation between the two types of beet over the growing season.

The crops examined were a commercial crop, containing two sugar beets and one fodder beet grown using the best available knowledge in 1979 and part of a large Ministry of Agriculture and Fisheries beet trial, with one sugar beet and two fodder beet cultivars. Data are also presented from a small scale experiment containing fodder beet grown on a Research Station where high yields were expected.

MATERIALS AND METHODS

Leeston

This commercial crop was grown on a Waterton clay loam near Leeston in central Canterbury. No soil test data were available for the site before drilling but a pH of 6.9 was recorded 12 months previously. The crop consisted of adjacent plantings of Kawerenta sugar beet, Kawagigamono sugar beet and Monoblanc fodder beet. There was 1.5 ha of each of the sugar beets and 7 ha of fodder beet.

The previous crop was winter wheat. Compound fertiliser (30 kg N, 24 kg P and 25 kg K) and 2 kg lenacil herbicide were applied per hectare during cultivation.

The fodder beet was sown on 17 September and the sugar beet on 19 September, using a Stanhay drill. Pelleted seed was sown in 50 cm rows, with 12 cm between plants in the row. Depth of seeding was 25 mm. Phorate granules (1 kg/ha) and 8 kg P/ha as superphosphate were applied at drilling in a band 25 mm to the side of the seed and 25 mm below. The crop was steerage hoed on 31 October and sprinkler irrigated between 5 and 19 December.

Lincoln

This crop was grown on a Wakanui-Temuka silt loam complex about 3 km south of Lincoln College and formed part of a time of sowing trial. Soil test data (0-150 mm) prior to ploughing were pH 5.9, Ca 12, K 10, P 29. Three cultivars of beet were grown, Vytomo sugar beet, Yellow Daeno fodder beet and Monoblanc fodder beet. There were four replicates, each plot being 50 m x 2.5 m.

The previous crop was barley, the stubble being grazed through the winter. A mixture of 52 kg N as calcium ammonium nitrate, 48 kg K as potassium chloride and 24 kg P as boron superphosphate and 1 kg phorate per hectare was broadcast before harrowing. Lenacil (2.5 kg/ha) and tri-allate (1.4 kg/ha) were applied before harrowing.

The crop was planted on 23 September in 50 cm rows and at 12.5 cm spacing, using a Stanhay drill and pelleted seed. Sowing depth was 25 mm. After two months, the crop was hand thinned to give 80,000 plant positions per hectare, but singling was not attempted.

The crop was sprayed with phenmedipham + desmedipham (0.51 kg/ha) on 8 November and was handweeded in late November and December to control a heavy infestation of wireweed. The crop was not irrigated.

Templeton

This crop was grown on border dyked Templeton silt loam at the Ministry of Agriculture and Fisheries' Templeton Research Station and formed part of an entomology trial (Pearson and Goldson, 1980). Soil test data (0-150 mm) prior to ploughing were pH 6.1, Ca 11, K 7, P 14. The experiment consisted of 8 blocks of 40 m x 8 m of Monoblanc fodder beet, of which 4 were sampled in this study.

The site was previously occupied by a mixed cereal trial. The same fertilizer mixture as at Lincoln was applied before harrowing but no phorate was mixed with the fertilizer. Lenacil (2.5 kg/ha) was also applied before harrowing.

The crop was planted on 27 September using the same drill, spacing and seed depth as at Lincoln. This crop, however, was not thinned. The crop was handweeded on 13 November and 8 January and was flood irrigated on 20 December and 30 January.

Sampling details

Samples were taken at 4 weekly intervals from mid December to early June. A 1.5 m x 1.5 m quadrat was used for sampling. At Leeston, 4 quadrats were taken in each cultivar, each quadrat being in a separate quarter of the crop. Quadrats at subsequent harvests were taken adjacent to and in the same rows as quadrats already taken. At Lincoln, one quadrat was taken from each plot in each of the 4 replicates. At Templeton, 1 quadrat was taken from each of the 4 blocks sampled.

For each quadrat, plants were lifted, counted, cleaned and topped by hand with a single cut through the root at the lowest leaf scar so as to remove all green matter. The tops and roots were weighed separately and 6 tops and 6 roots were taken to a cool room to await further processing. The 6 roots were washed, reweighed and subsampled for dry matter and sugar determinations. Dry matters were determined by drying in an oven for 2 days at 70 °C. For sugar analysis, 52 g of gratings were taken from cut surfaces of longitudinally quartered beet and stored in a freezer until analysed by the method of Quin *et al.*(1980). At some harvests, crowns were separated from the rest of the top subsample, weighed and dried for 24 hours at 70 °C.

RESULTS

Actual and average rainfall and temperature data at Lincoln from September 1979 to September 1980 are given in Table 1. The Leeston site was 19 km south west of Lincoln, and Templeton 12 km north of Lincoln. Rainfall over the year was slightly above the average, if somewhat erratic in distribution. Temperatures were at or, particularly in mid summer and late winter, above average during the period.

TABLE 1: Actual and average* rainfall and mean daily temperature at the Lincoln College Meteorological Station from September 1979 to September 1980.

Month	Rainfall (mm)		Mean Daily Temperature (°C)	
	Actual	Average	Actual	Average
September	21	46	9.7	8.5
October	111	48	10.8	10.9
November	51	53	13.9	12.8
December	33	58	17.3	14.8
January	135	56	16.5	16.0
February	55	56	15.9	15.8
March	106	66	14.1	14.1
April	47	58	11.8	11.4
May	8	76	9.2	8.1
June	79	58	5.7	5.6
July	40	58	5.6	4.8
August	48	56	7.7	6.4
September	1	46	10.4	8.5

* from New Zealand Meteorological Service (1973).

Yields of fresh roots at each sampling date are given in Fig. 1, and final harvest yields in Table 2. Changes in sugar percentage and sugar yield over the sampling period are given in Figs 2 and 3 respectively. In the figures, the data points are the mean of the four samples taken at each harvest.

Linear and quadratic regression analyses was applied to the data from each cultivar at each site, individual sample data being used rather than the mean. The regression equations are given in Table 3, the quadratic expression being given if it was significantly better than the linear expression, otherwise the linear expression is given. The regression equations are numbered and the numbers correspond to the regression lines in the three figures.

TABLE 2: June and September root fresh weight and sugar yields (t/ha) (standard errors in brackets).

Site/ Cultivar	June		September	
	FWT	Sugar	FWT	Sugar
Leeston				
Monoblanc	69.4 (8.6)	10.7 (1.7)	—	—
Kawerenta	56.9 (5.8)	11.1 (1.1)	—	—
Kawagigamono	54.6(12.4)	10.4 (2.5)	—	—
Lincoln				
Monoblanc	79.9(17.3)	9.1 (2.3)	91.6 (6.4)	13.1 (1.9)
Yellow Daeno	83.2(18.3)	8.5 (2.1)	84.6(14.4)	10.1 (1.5)
Vytomo	51.5(10.4)	8.1 (1.9)	59.9 (8.2)	10.6 (1.4)
Templeton				
Monoblanc	79.4 (9.7)	11.0 (2.2)	—	—

TABLE 3: Regression equations and R^2 (% variation accounted for) of root fresh weight, FWT (t/ha), percentage sugar content (%S), and root sugar yield, SY (t/ha), against days from sowing (x) with standard errors in brackets (quadratic expressions given if significantly better fit than linear expression).

Equation No.	Site/ Cultivar	Factor	Constant	X Coefficient	X^2 Coefficient ($x10^3$)	R^2
	Leeston					
1.	Monoblanc	FWT	-93 (16)	1.294 (0.194)	-2.53 (0.54)	90.2
2.	Kawerenta	FWT	-66 (14)	0.912 (0.168)	-1.67 (0.47)	88.6
3.	Kawagigamono	FWT	-76 (16)	1.052 (0.195)	-2.09 (0.55)	84.9
	Lincoln					
4.	Monoblanc	FWT	-58 (18)	0.892 (0.177)	-1.37 (0.38)	68.6
5.	Yellow Daeno	FWT	-75 (17)	1.120 (0.162)	-1.90 (0.35)	72.8
6.	Vytomo	FWT	-32 (12)	0.559 (0.118)	-0.84 (0.26)	67.2
	Templeton					
7.	Monoblanc	FWT	-107 (19)	1.621 (0.243)	-3.49 (0.71)	85.8
	Leeston					
8.	Monoblanc	%S	8.9 (1.1)	0.027 (0.006)		44.7
9.	Kawerenta	%S	10.9 (1.3)	0.035 (0.007)		47.3
10.	Kawagigamono	%S	9.6 (1.4)	0.041 (0.007)		52.8
	Lincoln					
11.	Monoblanc	%S	9.6 (0.8)	0.018 (0.003)		39.5
12.	Yellow Daeno	%S	9.0 (0.6)	0.010 (0.002)		29.1
13.	Vytomo	%S	8.1 (1.9)	0.074 (0.018)	-0.13 (0.04)	45.2
	Templeton					
14.	Monoblanc	%S	18.2 (2.7)	0.915 (0.034)	-0.30 (0.10)	27.9
	Leeston					
15.	Monoblanc	SY	-11.2 (3.1)	-0.148 (0.037)	-0.23 (0.10)	86.6
16.	Kawerenta	SY	-10.5 (2.8)	0.139 (0.034)	-0.21 (0.09)	88.5
17.	Kawagigamono	SY	-13.1 (3.4)	0.171 (0.041)	-0.30 (0.11)	83.8
	Lincoln					
18.	Monoblanc	SY	-8.2 (2.8)	0.117 (0.028)	-0.16 (0.06)	69.8
19.	Yellow Daeno	SY	-7.8 (1.7)	0.114 (0.017)	-0.18 (0.04)	79.6
20.	Vytomo	SY	-6.6 (2.3)	0.104 (0.022)	-0.15 (0.05)	69.6
	Templeton					
21.	Monoblanc	SY	-9.4 (3.0)	0.140 (0.038)	-0.23 (0.11)	81.2

At both Lincoln and Leeston, root fresh weight yields of fodder beet increased more rapidly than sugar beet. At all three sites, fodder beet fresh root yields reached 70-80 t/ha by June whereas sugar beet yields were 50-60 t/ha. At Lincoln, yields, although rather variable, levelled off after July at around 80-90 t/ha for fodder beet and around 60 t/ha for sugar beet.

Total sugars as a percentage of root fresh weight (Fig. 2) were higher for sugar beet than fodder beet at both Leeston and Lincoln. At Lincoln, Monoblanc fodder beet had a higher sugar percentage than Yellow Daeno fodder beet. Although the February and June harvest data appear to deviate from the general pattern, there was a linear increase in sugar percentage for four of the six sets of data in Fig. 2. The exceptions were Vytomo sugar beet at Lincoln, where sugar percentage tended to decrease after July, and Monoblanc fodder beet at Templeton, where sugar percentages initially declined until April and then increased.

Root total sugar yields, as calculated from root fresh weight and sugar percentage, are shown in Fig. 3. Fitted curves for Monoblanc fodder beet at all three sites and Kawerenta and Kawagigamono sugar beet at Leeston are very similar and show that sugar yields for these four sets of data increased from less than 1 t/ha in December to over 5 t/ha in February, 8 t/ha in April and 11 t/ha by June. At Lincoln, sugar yields of Monoblanc fodder beet continued to increase to over 13 t/ha in August and September. The other two cultivars at Lincoln, Vytomo sugar beet and Yellow Daeno fodder beet, increased their sugar yield at a lower rate, levelling off at around 11 t/ha by August.

Sugar contents of crowns were not measured, but mean crown fresh and dry weights for the June harvest, are given in Table 4, except for Templeton, where crowns were only measured in May. Crown dry matter yields were 0.9 to 1.7 t/ha over the different sites and cultivars.

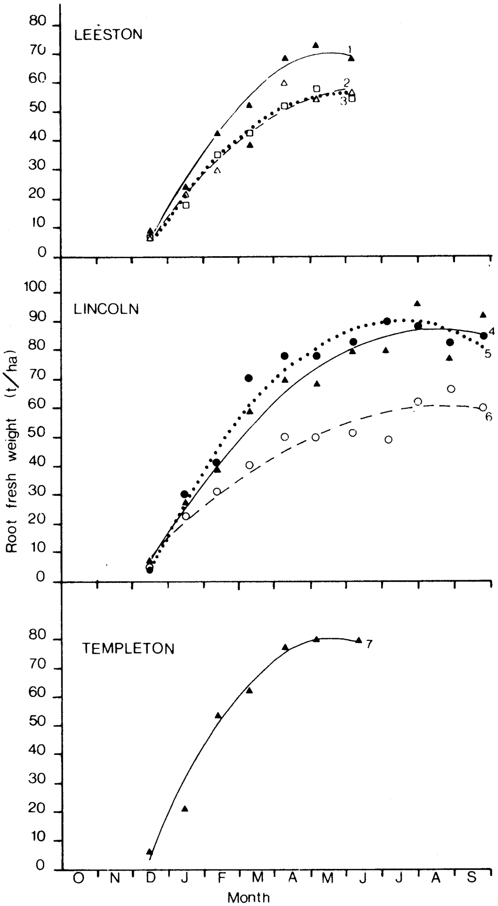

Figure 1: **Change in root fresh weight from December 1980 to September 1981:**
Monoblanc F.B. ▲———————▲
Kawerenta S.B. △ — — — — — — △
Kawagigamono S.B.□ . . . . □
Yellow Daeno F.B.● . . . . ●
Vytomo S.B. ○ — — — — — — — ○
Numbers on regression lines refer to equations listed in Table 3.

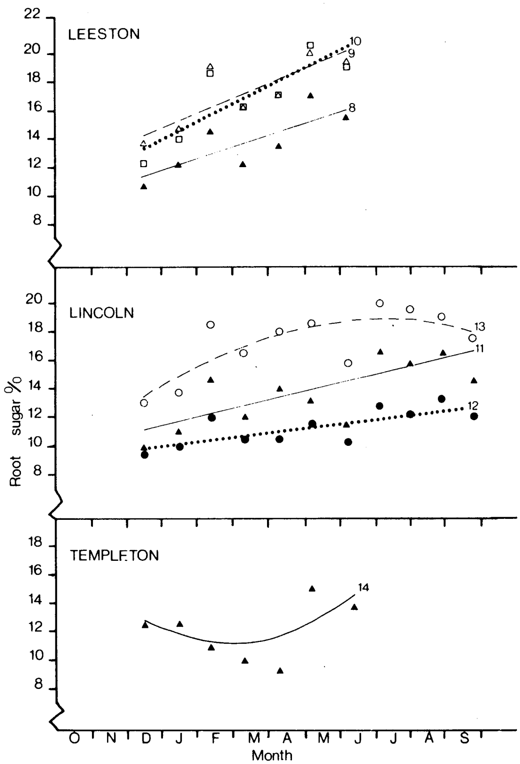

Figure 2: **Change in root total sugar percentage from December 1980 to September 1981:**
Monoblanc F.B. ▲———————▲
Kawerenta S.B. △ — — — — — — △
Kawagigamono S.B.□ . . . . □
Yellow Daeno F.B.● . . . . ●
Vytomo S.B. ○ — — — — — — — ○
Numbers on regression lines refer to equations listed in Table 3.

DISCUSSION

At Lincoln, Monoblanc fodder beet outyielded Vytomo sugar beet in total sugar yield by an increasing amount as the harvesting period progressed and yielded 2 t/ha more sugar from July onwards. However, at Leeston, Kawerenta and Kawagigamono sugar beet gave sugar yields very similar to Monoblanc until June. Other sugar beet cultivars gave sugar yields significantly higher than Vytomo (Martin, 1980) and have superseded Vytomo in the United Kingdom (Kimber & McCullagh, 1980). In other studies, Drewitt (1979) and Martin (1980) found that there was little difference in yield of total sugars between high yielding fodder beets and sugar beets.

At Lincoln, root fresh weight and sugar yields increased until July or August when sugar yields were 1-2 t/ha higher than in June. If sampling at Leeston and Templeton had been continued after June, yields would probably have been higher than the 10-12 t/ha achieved at the June harvest. The Lincoln data suggest that the later harvesting can be delayed in the autumn and early winter, the higher the sugar yields that will be obtained.

The rapid increase in root sugar yield from December to May was mainly due to the increase in root fresh weight. The increase in root sugar percentage over this period was considerably lower and also less consistent, particularly at Templeton, where beet western yellows virus caused yellowing of the leaves and probably disrupted sugar

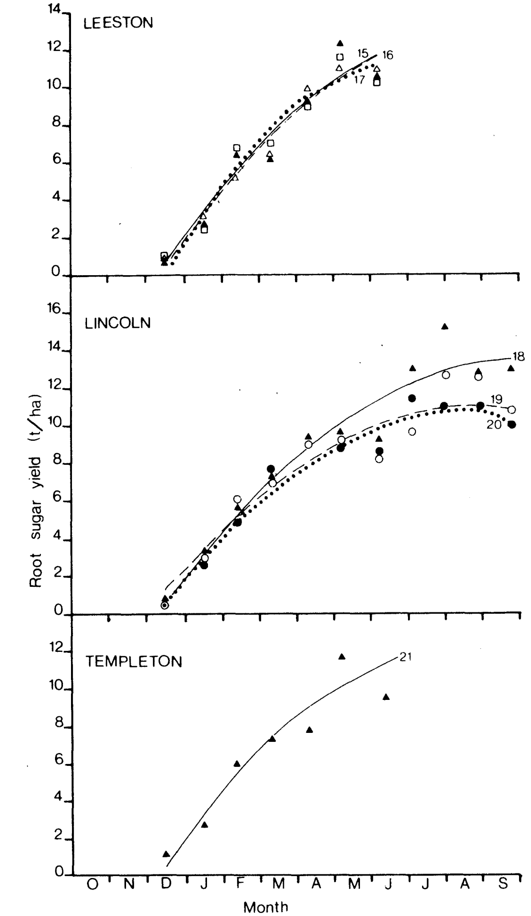

Figure 3: **Change in root total sugar content from December to September 1981:**
Monoblanc F.B. ▲————▲
Kawerenta S.B. △.............△
Kawagigamono S.B.□.......□
Yellow Daeno F.B.●........●
Vytomo S.B. O————O
Numbers on regression lines refer to equations listed in Table 3.

accumulation (Watson and Watson, 1953).

For the extraction of white sugar, beet are topped at the lowest leaf scar so that no green material, which interferes with sugar extraction, is taken to the processing factory. However, for fermentation, it may not be necessary to remove the crown. Crown sugar yields were not measured in these trials but dry weights ranged from 0.9 to 1.7 t/ha which, if crowns had a similar dry matter : sugar ratio to the roots, would mean up to 1.2 t sugar/ha. Akeson *et al.*(1979) found that the overall sucrose percentage of

TABLE 4: June crown fresh weight and dry weight (t/ha) (standard error in brackets).

Cultivar	FWT	DWT
Leeston		
Monoblanc	7.2 (1.8)	1.5 (0.4)
Kawerenta	7.3 (2.7)	1.6 (0.3)
Kawagigamono	6.8 (2.3)	1.6 (0.6)
Lincoln		
Monoblanc	6.1 (2.1)	1.1 (0.4)
Yellow Daeno	4.5 (0.9)	0.9 (0.1)
Vytomo	7.5 (3.9)	1.7 (1.0)
Templeton		
Monoblanc*	9.0 (4.0)	1.7 (0.9)

* harvested in May.

roots and crowns together was slightly lower than of roots alone but that reducing sugar percentage was not affected. Even allowing for a slight reduction in sugar percentage, inclusion of the crowns would add between 5 and 15% to root sugar yields.

CONCLUSIONS

Fodder beet had higher root fresh weights, but lower sugar percentages than sugar beet throughout the growing season so that, except after July at Lincoln, yields of sugar from the two types of beet were similar. Thus, providing high yielding cultivars are used, factors other than sugar yield will determine which type of beet is grown (Martin 1980).

Sugar yields increased rapidly from about 1 t/ha in December to 9-12 t/ha in May at all sites and for all cultivars. At Lincoln, maximum yields were obtained in July and August. If these patterns of sugar yield development are typical, then the fact that yields continue to increase until the middle of winter will have important implications for both the farmer trying to incorporate the beet crop into a rotation and for the processor trying to spread the operation season of his factory.

Crowns provided another 5 - 7.5 t/ha of fresh material or 0.9 to 1.7 t/ha of dry matter. This indicates that inclusion of crowns could raise root sugar yields by up to 15%.

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