SUGAR BEET AS AN ENERGY CROP ON THE CENTRAL PLATEAU

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ABSTRACT

For sugar and fodder beet crops grown over three years, root dry matter yields ranged from 0.9 to 16.9 t/ha and sugar yields were up to 14.1 t/ha. The major problems were with seedling establishment and subsequent weed control. The establishment problem was partially overcome by sowing more seed but there are unanswered questions on the role of soil fungi and nematodes. A range of herbicide treatments were studied and recommendations are given. These are largely based on cycloate pre-emergence followed by several alternative herbicides post-emergence. One treatment, an ethofumesate/metamitron mixture gave good control with a single post-emergence application. There was little variation among sugar beet varieties, though Monoire had slightly greater yields in two years. Sowing dates around mid-October are preferred as soil temperatures earlier are too low to allow rapid germination. Practical and local aspects of establishing a beet/ethanol industry are discussed.

Additional Keywords: ***fodder beet, pumice soil, varieties, sowing date, weed control, fertiliser, lime***

INTRODUCTION

Since the completion of a whey fermentation and ethanol distillation plant at the Reporoa Dairy Factory in 1980, the possibility has arisen of using the same plant to convert sugar beet to ethanol. Potentially the two uses of this plant are complementary with sugar from beets being used as the energy substrate during the dairy off-season. A feasibility study on whey alcohol plants indicated that the economies of operating for 12 months instead of just the dairy season resulted in unit production costs of ethanol being reduced by 36% (Marshall, 1978).

This paper summarises a series of experiments run from 1979 to 1982 looking at the potential for growing beets in the Reporoa district.

METHODS

Soils and Climate

The soils in a 20 km radius of Reporoa are mainly derived from Taupo ash, a rhyolytic pumice (*Typic vitrandepts*). Within this they fall into two major groups:

1. From airfall ash (Taupo silty sand).
2. From pumice alluvium (Whenuaroa Series). These were formed as deposits on the bed of an old lake which once occupied the Reporoa basin.

All the soils are characterised by relatively low bulk densities (Vucetich and Wells, 1978) compared with those soils on which beets are traditionally grown in New Zealand. However, their surface moisture holding capacity is comparable to other silt loams (Noble, 1974).

The area is 300-350 m asl, with a mean annual rainfall of 1300 mm (range 1000-1600) which on average is evenly distributed but there are summer droughts approximately every third year. Winter temperatures are cold, with mean 10 cm soil levels around 6°C for June, July and August (Kinleith meteorological station).

Preliminary Trials

These were laid down on three farms to define problem areas and provide some indication of yields. Each site comprised the corner of a paddock recently cultivated from pasture. One sugar beet and two fodder beet varieties were sown into each site at 160,000 seeds per ha (50 cm between rows × 12.5 cm between seeds) with an air vacuum precision seeder in mid October 1979. Eight rows (100-200 m long) of each variety were sown without replication. A 12.10.10 compound fertiliser (250 kg/ha) and insecticide granules (Thimet 20 G at 10 kg/ha) were sown adjacent to the seed. Weed control was by applying phenmedipham/desmedipham (0.7 1 ai/ha) sprays at both the cotyledon and two true leaf stage to all sites and later by hand weeding as required.

The sugar yield of the roots was determined on a fresh juice sample from the mean of three refractometer readings (adjusted down by 2.5% as per manufacturer's instructions) multiplied by the fresh root yield. The beet roots were sampled with a 2 cm diameter corer and the juice extracted with a centrifugal juice extractor. This procedure was also followed in all subsequent experiments.

Varieties

Variety trials were sown at two sites in 1980 and at one site in 1981. Most of the varieties used were either sugar beets or high dry matter fodder beets. In addition, small areas of alternative 'energy crops', chicory and sugar sorghum were sown in 1980 and 1981 respectively. In 1980, both trials were sown with an air vacuum precision seeder at 114,000 seed per ha. Rows were 50 cm apart. The first trial comprised eight varieties, with four replicates, in 10 × 2 m plots, and was sown on 3 September. The second trial had three varieties, with three replicates in 18 × 4 m plots, and was sown on 4 November. In 1981, eight varieties were sown on 15 October with a cone seeder at 200,000 seeds per ha in 7 × 3 m plots, with four replicates. Weed control in all trials was with pre and post-emergence herbicides plus handweeding where necessary. Harvesting was in April or May.

Weed Control

Weed control trials were laid down at two sites in both 1980 and 1981. The objective was to determine the effectiveness of a range of pre and post-emergence herbicides used at either label or overseas recommended rates. There were no cultivation treatments. These experiments were part of a wider series in Waikato and Poverty Bay and were partly reported previously (Rahman *et al*., 1982). Details of treatments are given in Table 1.

TABLE 1: Herbicide treatment used in the 1980/81 and 1981/82 weed control trials (from Rahman *et al.*, 1982).

Time of application	Chemical	Rate (kg/ha)
PPSI	cycloate	6.0
Pre-em	propham/chlorpropham/fenuron	1.43/0.33/0.28
	metamitron	5.5
	chloridazon	5.0
	lenacil	2.0
Post-em broadleaf	phenmedipham/desmedipham*	0.23/0.23
(1-2 true leaves)	phenmedipham/desmedipham	0.46/0.46
	ethofumesate	2.0
	metramitron/oil**	4.2/2.0
	chloridazon	3.2
	lenacil	2.0
Post-em grass	alloxydim-sodium/oil	2.0/4.0
(2-6 true leaves)	diclofop-methyl	2.0
	fluazifop-butyl/wetter	1.0/0.3%
	2,2-DPA	3.0

* when used as a split application or with ethofumesate the lower rate was applied at each application.

** when used as a tank mix with ethofumesate no oil was added.

Fertiliser and Lime Requirements

The reaction of most pumice soils (pH 5.5-5.8) is well below that normally recommended for beets in New Zealand (Dunn, 1969). As a consequence, lime and fertiliser trials were laid down in both 1980 and 1981. Established problems unrelated to the treatments caused all to be abandoned except one sown in November 1980. This trial was a split plot design. The main plots were pelletised lime drilled at sowing and placed immediately above the seed at 75 kg/ha, with a control of no lime. The sub plots were lime broadcast (2.5 t/ha), side dressings of nitrogen (as urea) at 50 and 100 kg/ha (N50 and N100) and a no lime or fertiliser control. Weed control was the same as for the variety trials.

Sowing Date

Although sowing date trials were commenced in both 1980 and 1981, only the latter was harvested because of pre-emergence herbicide phytotoxicity in 1980 resulting in very low establishment rates in all treatments. Sowing dates for the 1981 trial were mid-September, October and November. Soil temperatures were recorded with a thermograph. The trial was drilled with a cone seeder at 175,000 seeds per ha in 7 × 2 m plots, with four replicates. Chemical weed control was identical for each sowing date, with handweeding also used as required to ensure sowing date treatments were not differentially affected.

RESULTS

Preliminary Trials

Seedling emergence at each site was uneven with the two outer drill rows nearly always having lower populations. This appeared to be associated with compaction by the rear tractor wheels at sowing. Wheel width adjustments in the later trials reduced this problem. The major post-emergence problem on each site was weed control, which occurred in spite of two herbicide applications at rates recommended in Canterbury (T.K. James, pers. comm.). The failure of the herbicides was in part because the weeds had advanced beyond the cotyledon stage by the time the beets were sufficiently advanced to spray. The major weeds were willow weed (*Polygonum persicarea*), red root (*Amaranthus powellii*), fathen (*Chenopodium album*), black nightshade (*Solanum nigrum*) and yarrow (*Achillea millefolium*). Perennial grasses were a problem on one site. These and yarrow were in part, a reflection of poor cultivation techniques. On one site, an area with adequate plant populations was handweeded to provide data on yields. Harvests were made in early May and July. No yield information was obtained from the other two sites.

Root dry matter and sugar yields of Vytomo sugar beet and Monoblanc fodder beet were in the order of 12-15 and 9-12 t/ha respectively. Yellow Daeno fodder beet yields were lower at 8 and 6 t/ha respectively. The variability within site and the lack of replication made any conclusions on harvest date meaningless. The yields from this site were sufficiently high when compared with irrigated South Island beet crops to warrant the subsequent investigations.

Varieties 1980/81

Two months after the main variety trial was sown, beet populations were in the 12,000 - 30,000 per ha range. The low populations were largely the result of phytotoxcity of the pre-emergence soil incorporated herbicides and were too low to warrant harvesting the site. Eight rows of chicory adjacent to the varieties trial established better than the beets but were unable to compete with the resident yarrow.

At the second site, establishment was higher with each variety having around 50,000 plants per ha after four weeks. However, between this point and harvest, over half the plants were lost. There appeared to be a number of contributing factors, including a very dry December, damage to smaller plants during hand weeding and root rot from *Rhizoctonia solani* and *Xanthomonas campestris*. Root and sugar yields were greatest with Monoire and least with Nomo though the differences were not significant (Table 2). Yield of tops for each variety was similar. The root and sugar yields were surprisingly high considering the low populations. By interpolating over the plant population range of 12,000 to 30,000 per ha, each 1000 affected sugar yields by 0.14 t/ha. An area of chicory adjacent to the trial had a higher population, root yield and sugar yield than any of the three sugar beet varieties (70,000 plant/ha, 11.3 t DM/ha, 8.5 t/ha respectively).

TABLE 2: Variety Trial 1980/81. Yields of three sugar beet varieties grown on pumice soils (yields adjusted to a population of 21,300 for each variety).

Variety	Root yield (t DM/ha)	Tops yield (t DM/ha)	Root sugar (% of fresh weight)	Sugar yield (t/ha)
Nomo	6.7	2.0	18.5	5.1
Monoire	7.6	2.1	18.3	5.8
Amono	7.2	2.1	18.2	5.5
Significance	ns	ns	ns	ns
SE	0.5	0.1	0.1	0.4

TABLE 3: Variety Trial 1981/82. Yields of six sugar beet and two fodder beet (FB) varieties grown on pumice soils.

Variety	Root yield (t DM/ha)	Tops yield (t DM/ha)	Root sugar (% of fresh weight)	Sugar yield (t/ha)
Monoblanc (FB)	14.3	4.1	16.3	11.2
Solobeta (FB)	15.9	3.8	19.1	13.1
B 1230	14.6	3.8	20.6	11.4
S 101	14.7	4.7	20.1	12.1
Magnamono	15.7	5.0	20.2	12.6
Unica	14.0	4.5	19.8	11.5
Maribo	14.5	4.3	20.4	11.7
Monoire	16.7	3.8	20.4	13.9
Significance	ns	ns	**	ns
SE	1.0	0.4	0.4	0.8

Varieties 1981/82

In the 1981/82 varieties trial, the plant populations were much higher with between 78,000 and 104,000 plants per ha harvested. The roots and tops were very healthy with little hollow heart or root rot present. Because there was no relationship apparent between yield and the population density (over the range present within the trial), the data were not adjusted to a standard population. In general terms, the yields were much higher than in the previous year (in an adjacent paddock) with root plus top yields in the range of 18 to 21 t DM/ha and sugar yields between 11 and 14 t/ha (Table 3).

Monoire again had the highest sugar yield (though the difference was not significant) being largely a reflection of its higher root yield. Of the two fodder beets, Solobeta had similar yields to the sugar beets but Monoblanc had a lower sugar level which reduced its overall sugar yield. Monoblanc, Unica, Magnamono and Solobeta all had bolters. The highest number were in Solobeta.

An area of sugar sorghum (variety Sugar Drip) grown adjacent to the varieties trial was harvested in early May 1982 after a 173 day growth period. The yield of stems and leaves was 17 t DM/ha and it contained 3 t sugar/ha although it is possible not all the sugar was extracted.

Weed Control

In both of the 1980/81 trials, the dominant effect was the phytotoxicity of lenacil to the emerging beet seedlings (Table 4). Lenacil had a similar effect in the sowing date, lime and variety trials causing them to be abandoned. Of the other pre-emergence herbicides, cycloate had a small effect at one site, and about 30% of seedlings were lost with propham/chlorpropham/fenuron (PCF) at both sites.

TABLE 4: Weed Control Trials 1980/81. Effects of pre-emergence herbicides on beet population two months after sowing.

Herbicide	Population density ('000 ha) Site A	Site B
Nil	41.7	47.0
Lenacil	2.2	5.3
PCF	32.4	31.3
Cycloate	37.0	51.9
Significance	**	**
SE	2.0	3.4

While the trial on site A was abandoned because of the low overall population, three 10 × 2 m plots were created at a population of 80,000 per ha (by transplanting) to provide potential yield information. In mid June 1981, these plots had a mean of 14.5 t DM/ha roots, 3.7 t DM/ha tops and 10.8 t/ha sugar. Site B, harvested at the same

TABLE 5: **Weed Control Trials 1980/81. Site B. Effect of a range of pre and post-emergence herbicides on weed and beet yields.**

Herbicide treatment Pre-emergence	Post-emergence	Weed yield (t DM/ha on 6.1.81)	Beet yields Roots (t DM/ha)	Tops (t DM/ha)	Sugar (t/ha)
nil	nil	21.2	0.9	0.9	0.8
	phen/des + phen/des	3.8	4.7	2.8	4.1
	phen/des + phen/des/etho	0.4	7.8	2.9	7.1
PCF	nil	a	1.9	1.7	1.7
	phen/des + phen/des/etho	0.2	6.2	2.4	5.6
Cycloate	phen/des + phen/des	0.1	10.0	3.0	8.9
	phen/des + phen/des/etho	nil	7.6	2.6	7.1
	phen/des + phen/des/chlor	0.1	10.9	3.2	9.6
Level significance		**	**	**	**
SE		1.0	1.6	0.4	1.4

a = Weed yield not determined.

time, provided strong information on the potential effect of weeds (Table 5). The highest yielding treatments all involved cycloate applied before emergence with phenmedipham/desmedipham twice after emergence. There was also some advantage in using ethofumesate or chloridazon at the final spraying. Yields of the PCF treatments were generally restricted by their lower populations. In the 1981/82 trials, the mean beet population of site A, two months after sowing, was 70,000 per ha in the cycloate pre-emergence treatments compared with 101,000 per ha for those where no pre-emergence herbicide was used. This did not occur at site B. While the plant density of cycloate-treated plots on site A was quite adequate, the loss of seedlings indicated the crop was under some stress from cycloate. This crop later developed very unevenly with loss of some weaker plants. The cause could not be directly ascertained though a *Rhizoctonia solani*/nematode complex was suspected. Root sugar and top yields of those treatments with populations over 60,000 per ha were in the range of 5.6 - 9.0 t DM/ha roots, 4.5 - 7.4 t/ha sugar and 3.0 - 4.5 t DM/ha tops.

Site B (1981/82) was harvested in early April and again treatments involving cycloate followed by phenmedipham/desmedipham (twice) plus lenacil or ethofumesate as additives at the second post-emergence spray gave good weed control and comparatively high beet yields (Table 6). However, these treatments were all poorer than metamitron/ethofumesate applied as a single post-emergence spray, which was 63% greater than the three best cycloate/phenmedipham/desmedipham treatments (1x, 2x, or 2x plus either ethofumesate or lenacil).

Fertiliser and Lime Requirements

In the one lime and fertiliser trial harvested, the soil pH (0-10 cm) was 5.5 prior to the trial being laid down. However, there were no responses to lime applied either as pellets adjacent to the seed at sowing or when broadcast over the whole plot (Table 7). Soil samples on a plot basis (0-10 cm) showed the soil pH was 5.9 and the broadcast application of lime raised this to 6.1. The pelleted lime had no apparent effect on soil pH. Neither the nitrogen nor phosphorus treatments significantly affected root, top or sugar yields though plant populations were lower at the highest rate of nitrogen.

TABLE 6: **Weed Control Trials 1981/82 Site B. Yields of Monoire sugar beet following application of a range of herbicides.**

Herbicides	Weed yield (t DM/ha on 22.1.82)	Population harvested ('000/ha)	Root yield (t DM/ha)
Cycloate + phen/des + phen/des	0.4	64	7.5
Cycloate + phen/des/etho	0.2	60	7.4
Cycloate + etho	0.3	56	2.7
Cycloate + phen/des/lenacil	0.7	59	6.4
Cycloate + meta/oil	2.0	42	4.1
meta/etho	0.1	60	11.6
phen/des + phen/des/etho	1.7	40	3.8
Level significance	**	*	**
SE	1.1	9	1.0

TABLE 7: The effects of lime, nitrogen and phosphorus on sugar beet plant populations and yields.

Treatment	Population harvested ('000/ha)	Root yield (t DM/ha)	Top yield (t DM/ha)	Sugar yield (t/ha)
Pelleted lime at sowing	21.6	7.2	2.0	5.5
No lime	20.9	7.2	2.1	5.5
SE (diff)	1.2	0.5	0.1	0.4
No fertiliser	23.4	7.7	2.2	5.8
Lime broadcast	21.6	7.0	2.0	5.3
N 50	21.8	7.3	2.1	5.7
N 100	16.8	6.4	1.8	4.8
N 50 + Lime	22.1	7.8	2.2	5.9
N 50 + P 400	21.9	6.8	2.1	5.2
SE	2.5	0.7	0.2	1.0

The site of the trial had been farmed for at least ten years and then cultivated for a winter brassica crop. The fertility built up during the period it was farmed appeared to be sufficient to preclude any fertiliser responses.

Sowing Date

The speed of emergence from the earliest sowing was nine days slower than from the mid-October sowing (Table 8) which was probably a reflection of the higher soil temperatures in late October. Seedling emergence was slower at the final sowing date. Since soil temperatures had risen by a further 1 °C by this time, the slower emergence was attributed to moisture stress, though other factors may also have contributed. The final sowing had only 32,000 plants per ha after 50 days, suggesting that damping-off may have been implicated. Both the September and October sowings had adequate populations and high sugar yields (differences were not significant). The final sowing was not harvested because of its low population.

TABLE 8: The influence of sowing date on the speed of seedling emergence, plant populations and yields of Monoire sugar beet.

Sowing date	17.9.81	15.10.81	11.11.81
Sowing-emergence mean temperature (°C)[a]	10.0	12.8	13.8
Period to emergence (days)	21	12	19
Populations harvested ('000/ha)	65.0	64.4	b
Root dry weight (t/ha)	16.9	18.0	b
Sugar yield (t/ha)	14.1	14.8	b

a Mean 0900 hr soil temperature at 10 cm.
b Not harvested due to low population.

DISCUSSION

The fodder and sugar beet crops grown over the three seasons ranged from very poor to relatively high yielding. The success or failure of individual sites was nearly always determined by crop establishment and/or weed control factors. Provided these problems are minimised, the area within a 20 km radius of the Reporoa dairy factory should produce beet crops containing 8-14 t/ha sugar, without irrigation. This is similar to sugar beet crops grown in Canterbury, sometimes with irrigation (Martin, 1981). It is recognized that farmers frequently fail to obtain yields as high as those in trials and more realistic sugar yield expectations are in the 6-10 t/ha range.

Crop Establishment

In every year there were problems with low seedling emergence and subsequent uneven plant distribution. Several factors are implicated. Phytotoxicity of lenacil applied prior to planting was a major contributing factor to poor establishment in the 1980/81 trials. This does not explain the establishment problems on the lime and fertiliser trial site in 1981/82 where the symptoms were very similar to 'Docking Disorder' that occurs on light soils in Great Britain (Jones and Dunning, 1972). In this, nematode infection is associated with loss of plants and uneven stands. In the present trials, *Pratylenchus* and *Meloidogyne* spp. were isolated from roots and soils but their numbers were too low to explain the problem (G Yeates pers. comm.). At one site, *Rhizoctonia solani* was isolated from roots. This frequently causes post-emergence damping off on light soils in California (F Jackson Hills, pers. comm). Its effects are reduced by fungicidal seed treatment providing a 'zone of protection' until the plants are fully established. Further work is required to determine the primary cause of poor beet establishment. It is impossible to prescribe an effective remedy unless the cause is clear.

In the later trials, most of the problems with low beet populations were overcome by sowing more seed (175,000 -200,000 viable seeds per ha). This enabled adequate crops to be established from mid-October sowings. On most pumice soils there is no soil moisture limitation to prevent cultivation during winter. While it is technically feasible to sow beets in late August, in the one sowing date trial harvested, there appeared to be no advantage from such early sowings.

Weed Control

A study in the South Island showed that the critical period when weeds must be controlled is in the first 8 to 10 weeks after sowing (Field and Chong Woon Sum, 1982).

Some of the weed control problems were in part consequent on poor cultivation techniques. Most farmers on the Central Plateau do not have a high level of expertise in cultivation, mainly because their brassica forage crops do not have exacting cultivation requirements. If a beet industry were developed around the Reporoa Dairy Factory the overall standard of cultivation would have to improve in order to avoid perennial plant weed problems (browntop and yarrow.

The main approach to weed control is likely to be with herbicides. The trials identified a number of suitable products. The problems experienced with lenacil have also occurred in Great Britain where it is not recommended for use on coarse sands, sand, fine sand and loamy coarse sands, or on soils with 5 to 15% organic matter (Anon, 1979). Combinations of cycloate (pre-emergence with either ethofumesate, chloridazon or phenmedipham /desmedipham as post-emergence treatments generally gave adequate weed control except for yarrow. In the final trial, a mixture of metamitron/ethofumesate as a single post-emergence treatment gave excellent weed control and consequently a high root yield. There is a considerable cost advantage if weed control can be confined to a one-pass operation (some options involve up to three separate applications).

General

In the present trials, cultural practices had much greater effects on sugar yields than the variety sown. Within the sugar beet varieties, the differences were comparatively small, though Monoire had slightly greater sugar yields in 1980/81 and 1981/82. The higher sugar percentage of the sugar beet and some of the 'high dry matter fodder beet' varieties would favour their use in commercial production as there is substantially less bulk to be transported than with the fodder beets. Of the other species, chicory performed better than sugar beet in 1980/81 in a situation where yield of sugar beet was severely limited by low population. The potential of sugar beet was realised on an adjacent site in the following year when sugar yields were 250% higher than the previous year and 50% higher than that of chicory. Difficulties associated with mechanical harvesting of the chicory tap root and its lower sugar percentage also weigh against chicory. Sugar yield from the sugar sorghum crop grown in 1981/82 was much lower than sugar beet which probably reflects the sub-optimal temperatures for sugar sorghum in the Reporoa district.

A beet/ethanol industry based on the Reporoa Dairy Factory for 90 days per annum (May-July) would require 450 ha of sugar beet yielding 10 t/ha of sugar. About 250 tonnes of fresh beet roots would be required daily. While the major factor in the future of growing beets on the Central Plateau is the value of ethanol there are also important local factors. Most farmers within a 20 km radius of Reporoa already grow brassica crops for winter forage, occupying 5 to 8% of each farm. The beet 'tops' would be used as stockfeed, and provided the crushed beet pulp were returned and used as stockfeed, no large increase would be needed in the area under cultivation. This would eliminate the problem of disposing of beet pulp and spread the beet growing costs over two products. Because cropping for winter forage and pasture renewal are an integral part of most farming systems, it is unlikely the same land would be cropped for more than two years in succession.

Preliminary costings indicate that the present world price of ethanol is too low to justify a beet/ethanol operation. A relatively small increase in ethanol prices would make the process profitable. It is not inconceivable that this will occur in the near future.

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