BEET PRODUCTION FOR ETHANOL IN WAIKATO: YIELDS AND PROBLEMS ENCOUNTERED IN GROWING THE CROP

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ABSTRACT

Sugar and fodder beet were grown in three years to assess the potential sugar yield for ethanol production in the region. Fresh weight root yields ranged from 70-85 t/ha for sugar beet and 55-136 t/ha for fodder beet. Sugar contents averaged 15% for sugar beet and 10% for fodder beet resulting in sugar yields of 10-12 t/ha and 5-12 t/ha respectively. Consistently higher sugar yield from sugar beet and a 4% higher root dry matter favoured its use over fodder beet.

These sugar beet yields were considered to be below the environmental potential because of erratic, below optimum density plant stands of 40 000-80 000/ha resulting from establishment problems. The herbicide lenacil at 2 kg ai/ha and the insecticides carbofuran or disulfoton at 1.75 kg ai/ha were found to reduce plant stands by 21-27% with disulfoton being increasingly phytotoxic when used with lenacil or starter fertiliser. Without lenacil or insecticide, stand survival was 40-60% and further problems with soil fungi or nematodes were suggested. Though field establishment was improved 50% by methyl bromide soil fumigation, the use of fungicides and nematicides failed to identify the problem's cause.

It was concluded that a 60-70 t/ha sugar beet yield giving 10-11 t/ha of sugar would be a reasonable commercial expectation for the region provided uniform stands of adequate density could be established.

Additional Keywords: establishment, insecticides, herbicides, sugar yield, fungicide, nematicide

INTRODUCTION

In the mid 1970's, the rising cost of imported fuel oil and forseeable limitations in future supplies, led to increased interest in providing an indigenous, renewable resource of liquid fuel from plant biomass. Of the various systems available, that of the single step fermentation of plant sugars to produce ethanol was seen as the least capital intensive and the most readily accessible as the technology required was well proven (NZERDC, 1979). in New Zealand's temperate climate, the beets were seen to provide the most agriculturally advanced, sugar rich crop for the purpose. With no backgound of commercial sugar production from beet, information on the crop's yield potential was limited to the small scale experimental work conducted on sugar beet, mainly in the Canterbury, Southland and Otago regions (Dunn, 1965; Drewitt, 1976; Greenwood, 1980) and fodder beet production for stock (Douglas, 1980). Estimates of regional yield capabilities made from these data have been used in economic analyses of the ethanol fuel production system but have been criticised both as over estimates of commercial potential on account of the small scale of production and under estimates in light of the more recent advances in cultivars and management techniques. However, such trials can give a reasonable estimate of the comparative, regional yield. In the Waikato, where beet production has been confined to fodder beet, the last experimental crops were grown some 15 years ago. To re-assess the regional yield capabilities under current management technology, herbicide, sowing date, cultivar and population studies were run for 1979-1981. The development of effective herbicidal weed control has been reported (Rahman *et al.*, 1982) and the following paper concerns the investigations into the other aspects of the crop's yield and production.

MATERIALS AND METHODS

Sites

Four trials were carried out on the Rukuhia Research Farm on Horotiu Sandy Loam and one (1980 — Trial 1) was sited in a commercial block planted on Ohaupo Silt Loam. Horotiu Sandy Loam comprises the major part of the flat cropping land within the region and has a typically free draining, fine to coarse, sandy subsoil overlain with 150 mm of top soil of 10-12% organic matter. Available water in the top 750 mm is 100 mm (Gradwell, 1968) and, with pasture showing a response to irrigation in two years out of five, (Baars and Coulter, 1974) irrigation was included in one trial.

Cultivar comparison

1979: Fodder beet cultivars, Yellow Daeno and Monoblanc, and the sugar beet, Vytomo, were sown at 25 mm depth with an Oyjord cone seeder in 0.34 m rows at 300,000 seeds/ha on 6 November. Four randomised plots of 5 rows, 10 m long were used for each cultivar. Basal fertiliser was 1250 kg/ha superphosphate, 600 kg/ha potassium chloride and 125 kg/ha nitrolime with 250 kg/ha nitrolime being applied in January. The herbicide phenmedipham at 1.6 kg ai/ha was applied on 27 November and 0.8 kg ai/ha on 6 January. Hand weeding was done in late January. Subsamples of 3.4 m² were harvested on 16 July when plant numbers and root and top fresh weights were recorded. Dry weight contents of roots and tops were determined and the root sugar content measured from the expressed juice using a refractometer.

1980-Trial 1: Yellow Daeno and Monoblanc fodder beet and Amono sugar beet were sown 29 September within a commercial scale planting of Amono. Sowing was at 120,000 seeds/ha using 0.5 m rows with 150 kg/ha 18:20:0 and 1.75 kg ai/ha disulfoton. Cycloate at 4.3 kg ai/ha was incorporated preplant. Harvest was on 18 March when two 5 m^2 subsamples were taken from each block. Data recorded was as in 1979 with an additional count made of diseased beet.

Sowing date, plant population, irrigation

1980-Trial 2: Amono sugar beet and Monoblanc fodder beet were sown at four dates (22 August, 24 September, 20 October and 5 December) at three populations (80,000, 160,000 and 230,000 plants/ha) with and without irrigation. The trial was a split plot design with sowing dates ± irrigation as main plots replicated four times and randomised sub-plots of cultivar × population consisting of 8 rows at 0.5 m centres, 24 m long. Basal fertiliser was 2.5 t/ha lime, 500 kg/ha 30% potassic, boron supplemented, superphosphate and 200 kg/ha urea. Pelletted seed (with the exception of Amono sugar beet in the first sowing) of 80% germination was sown at 40% above the desired populations at 25 mm depth with a Nodet vacuum, precision planter. Diammonium phosphate (150 kg/ha) was placed below and to the side of the seed and 1.75 kg ai/ha each of disulfoton and carbofuran granules above the seed. Herbicides, cycloate at 4.3 kg ai/ha and lenacil at 2.0 kg ai/ha (reduced to 3 and 1 kg ai/ha respectively after the first planting) were incorporated before planting and phenmedipham/desmedipham at 0.23/0.23 kg ai/ha applied after the two true leaf stage except for the December planting when 4.2 kg ai/ha metamitron with crop oil was used. Hand weeding was also done. Irrigation was commenced in December and reapplied when the soil moisture deficit reached 50 mm. Harvesting was carried out in late June 1981 but, because of establishment problems, it was confined to the medium density plots. Data recorded was as in the 1979 trial.

TABLE 1: Herbicide, insecticide and fertiliser treatments 1980 — Trial 3.

	Sub plots		
Main plots	Fertiliser kg/ha 18:20:0	Carbofuran kg ai/ha	Disulfoton kg ai/ha
	0	0	0
1. No herbicides	0	1.75	0
	75	1.75	0
2. Lenacil 2.0 kg	0	0	1.75
ai/ha	75	0	1.75
3. Cycloate 4.0 kg	75	0	0
ai/ha	75	0.88	0.88
4. Cycloate (4) lenacil (2)	150	1.75	1.75

Herbicide, insecticide, fertiliser interaction

1980-Trial 3: The effects of the individual herbicides, insecticides and starter fertiliser used in trial 2, on the establishment of unpelletted, Amono sugar beet seed were tested in a sowing made on 5 December using 220,000 seeds/ha. The trial consisted of herbicides as main plots replicated three times with combinations of fertiliser and insecticide rates in sub plots (Table 1). Sub plot size was 2 rows at 0.5 m centres and 6 m long. Phenmedipham/desmedipham at 0.23 kg ai/ha was applied to all plots on 31 December. Plant counts were made weekly from 15 December to 21 January.

TABLE 2: Sugar yield and yield components of beet cultivars in three trials.

Year (trial) Cultivar	Fresh wt. t/ha	% dry matter	% sugar (FW)	Sugar t/ha	Plant No. 000's/ha
1979					
Yellow Daeno F-B	136	16.9	9.5	12.9	203
Monoblanc F-B	108	18.8	11.0	11.9	174
Vytomo S-B	79	24.3	14.1	11.1	153
Significance	**	***	*	ns	ns
LSD 5%	12	1.7	3.7		
1980 — Trial 1					
Monoblanc F-B	69	19.5	11.4	7.9	81
Yellow Daeno F-B	55	15.3	9.1	5.0	71
Amono S-B	72	20.7	17.2	12.3	65
Significance	*	ns	*	*	*
LSD 5%	8		5.1	3.5	5
1980 — Trial 2 — August sowing					
Monoblanc F-B	84	15.9	9.3	7.8	60
Amono S-B	86	18.2	13.3	11.4	44
Significance	ns	***	***	**	**
LSD 5%		9.0	2.0	2.3	10

RESULTS AND DISCUSSION

Root and Sugar Yields

In 1979, with a high seeding rate and a 60% establishment, final plant stands were twice the 70,000-90,000/ha commonly recommended for sugar beet (Draycott *et al.,* 1974). With a good summer moisture supply, exceptionally high root yields of fodder beet were recorded and fodder beets outyielded Vytomo sugar beet by 35-70% (Table 2). However, sugar beet with a 4% higher root sugar content produced a comparable sugar yield to the fodder beets. In 1980, Amono sugar beet, sited within a field scale planting (trial 1), gave similar root and sugar yields to Vytomo in 1979. In this instance, the plant population was about normal but the summer moisture supply was less favourable with the soil moisture deficit increasing steadily from mid January and being close to wilting point by the end of March. Under these conditions, the yields of the fodder beets were halved and the sugar yields correspondingly reduced to 50-75% of that of Amono sugar beet. While the 1980-81 summer rainfall was 40% below normal, no yield response to irrigation was apparent in trial 2 though a critical assessment of effect was restricted by non uniform stands of variable population. Despite having low density, non uniform stands, the August sowings of Amono sugar beet and Monoblanc fodder beet in trial 2 produced similar sugar yields to those in trial 1 (Table 2). However, for all later sowings of either beet type in trial 2, root and sugar yields were substantially reduced (Table 3).

TABLE 3: Effect of planting date on sugar yield and yield components of beet.

Planting Date	Fresh wt. t/ha	% dry matter	% sugar (FW)	Sugar t/ha	Plant No. 000's/ha
22.8.80	85	17.0	11.3	9.6	52
24.9.80	51	17.8	13.5	6.9	62
20.10.80	46	18.2	13.1	6.0	62
5.12.80	41	16.4	13.0	5.3	59
Significance	***	*	ns	***	ns
LSD 5%	10	1.1		1.7	

The range of fodder beet yields obtained under the different circumstances was similar to the 7-16 t/ha dry matter previously recorded for the region (Douglas, 1980). Comparative data for sugar beet in the region were not available but yields from sugar beet were more consistent than from fodder beet which, together with a higher root dry matter content, resulted in a greater yield of sugar being produced for less field weight. In this respect, sugar beet appeared the more appropriate for the purpose of ethanol production. The sugar beet root yields compared favourable with those from the Canterbury region under irrigation (Drewitt, 1976; Martin, 1981) and from Southland and Otago (Greenwood, 1980) but sugar content tended to be 2-3% lower and total sugar yields correspondingly less. However, the root yields obtained were considered to be below the environmental potential for the region with its warm climate and long growing season. The major factor limiting yield in the trials was seen as the repeated inability to obtain uniform stands of adequate density.

Establishment problems

The beets were sown assuming 65-70% survival of the seed sown which was considered to be a reasonable allowance. In only two of the five trials, that in 1979 on Horotiu Sandy Loam and trial 1 in 1980 on Ohaupo Silt Loam, was a survival level of 60% achieved. In the sowing date trial (1980 — Trial 2), the maximum level of emergence in the August sowing was 34%. Emergence improved with the later sowings but in all instances continued plant losses after emergence reduced final plant stands to 25% of the seed sown. The leaf tip necrosis and wrinkled leaves observed was considered to be indicative of chemical damage possibly arising from one or other of the herbicides, insecticides or the fertiliser applied at planting. When the effects of the individual components were assessed (1980 — Trial 3), insecticides were identified as a major cause of the high plant mortality (Table 4).

The herbicide cycloate had no effect on plant numbers or vigour but with lenacil, plant numbers were less and vigour reduced. Subsequent work (Langland *et al.*, 1981; Rahman *et al.*, 1982) has shown lenacil to be toxic on beet even at low levels. Both of the insecticides reduced plant numbers markedly though, at equal rates, disulfoton (10% reduction) was not as lethal as carbofuran (30% reduction). The toxicity of carbofuran was limited to the use of the insecticide alone and there was a tendency for fertiliser to lessen its effect. Disulfoton interacted with both lenacil and fertiliser increasing the stand reduction to 40%. Fertiliser alone had no effect on plant numbers and increased plant vigour. The subsequent application of phenmedipham /desmedipham led to further reductions in plant stands ranging from 21-56% where the seedlings were already suffering from the effects of lenacil or either insecticide. The cause of the reduction in plant numbers where fertiliser alone had been used at planting was not clear though it may have related to growth stage and the presence of more vigourously growing, softer plant tissue.

TABLE 4: Effects of herbicides, insecticides and fertiliser on seedling establishment before and after application of phenmedipham/desmedipham.

Treatment kg ai/ha	Before: Vigour score 0-5	Before: Plants/3m^2	After: Plants/3m^2
Control	2.7	30.3	26.0
Lenacil 2	2.1*	23.5 ns	11.4***
Cycloate 4	2.8 ns	31.9 ns	25.0 ns
Fertiliser 75 (18:20:0)	3.9***	29.1 ns	20.5**
Carbofuran 1.75	2.7 ns	22.1***	20.3**
Disulfoton 1.75	2.3***	23.9***	16.4***

Interactions: plant numbers before application of phenmedipham/desmedipham

	No disulfoton	Disulfoton	
No lenacil	33.4	30.8	SED: rows = 5.4
Lenacil	29.7	18.8	columns = 2.0
No fertiliser	31.5	28.5	SED: rows/columns
Fertiliser	31.5	21.2	= 2.0

ns, *, **, *** Effect non significant or significant at 5, 1, 0.1% level respectively compared to control.

Both of the insecticides are commonly used on beet and the problems encountered here relate to the excessive use of them in an effort to control soil insects (carbofuran), protect the crop against aphids and virus (disulfoton) or both. While carbofuran is used at planting with potatoes and carrots at rates of up to 3.3 kg ai/ha, toxic effects on beet have been recorded in the range 1.2-1.7 kg (Dunning and Winder, 1973) and at 1.75 kg ai/ha in our trial. Similarly, high rates of disulfoton can be used with potatoes and carrots but 1.1 kg ai/ha appears to be a more normal rate for use with beet (Wedderburn *et at.*, 1973). The same authors found increased phytotoxicity with disulfoton in the presence of cycloate although this was not apparent in our trial. The interaction observed between lenacil and fertiliser does not appear to have been reported previously.

The absence of any additive at planting in the preliminary trial (1979) and the use of disulfoton alone in the off-station trial (1980 — Trial 1) partially explain the 60% establishment achieved. However, losses of up to 55% of the seed sown in the non treated controls in trial 3, 1980 and in a further sowing date trial started in 1981, using only cycloate and fertiliser at sowing, remain unexplained. The possibility of nematode damage (Docking disorder) associated with sandy soils has been suggested but it is not supported by the reasonable establishment in some sowings. An alternative possibility is a soil fungal problem. Certainly, beet established 50% better in field plots sterilised with methyl bromide, (A. Rahman, pers. comm.) but, in pot trials using nematicides and/or fungicides, no pathogens were positively identified (R. Watson, pers. comm.).

Estimate of commercial yield

The brief experience with the effect of sowing date suggested that sowing as early as possible is as equally important for high yield in the region as elsewhere (Drewitt, 1976). Though no measure of the effect of summer drought on yield was gained, experiences with other annual crops in the region indicate that yield restrictions are likely in some years and that early-sown crops will be the least affected.

Disease could also prove to be a yield limiting factor. *Cercospora* leaf spot was at a high incidence in the 1979 trial from early March and present in all trials. *Rhizoctonia* root rot was recorded on 40% of the roots in the trial 1, 1980 and on 10% in trial 2. While both diseases can be controlled to some extent by rotation and leaf spot by spraying, the effect of either on yield remains unknown. Virus was not recorded in these brief, small scale trials even though aphid control was restricted to insecticide at planting or omitted. In repeated large scale production some virus problem would be expected.

CONCLUSIONS

Sugar beet can provide a consistently higher yield of sugar for ethanol production than fodder beet. An estimate of commercial production potential is 60-70 t/ha of roots and 10-11 t/ha of sugar. An inability to establish uniform, vigorous stands of adequate density is currently a major restriction to realising this potential. The problem is considered to be related to an, as yet unidentified, soil factor.

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