RESULTS OBTAINED DURING THE FINAL YEAR OF THE SUGAR BEET PROJECT IN NATAL

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Abstract

The results of eleven experiments dealing with (1) lime application, (2) herbicides, (3) nematicides, (4) varieties, (5) fungicides, (6) sowing date and (7) yield potential, are discussed. Lime was necessary, not to create a more neutral soil reaction, but to eliminate most of the exchangeable aluminium in the soil. It was necessary to incorporate lime to a depth of 200 mm but not deeper. Cycloate and ethofumesate applied at 3,7 and 1,0 kg ai/ha respectively allowed the crop to emerge free of weeds. Broadleaf weeds emerged soon afterwards and were controlled with an application of 0,8 kg ai/ha desmedipham. The efficacy of cycloate depended on the method of incorporation. Nematicides applied at very high rates prevented a decline in the plant population due to *Meloidogyne incognita* but did not prevent serious losses in sucrose yield. Nematodes in clay soils would, for economic reasons, have to be controlled by cultural means. Varieties designated by the breeders as resistant to *Cercospora beticola* outyielded those that were not even though their resistance was only partial. Cremona, Kawerita and AM2 Hybrid B were noted as the best varieties for Natal. Triphenyltin acetate (TPTA) was the most effective fungicide used against *Cercospora* leaf spot while benomyl, which had proved effective in the past, was no longer effective against the disease. Fortnightly applications of TPTA from mid-December to the end of March controlled leaf spot almost completely at all sites. Crops grown at commercially acceptable standards yielded 6 to 8 tons sucrose per hectare in April and 10 to 12 tons sucrose per hectare in August and September.

Introduction

An investigation into the feasibility of growing sugar beet in the Natal Midlands was conducted over a period of three years. The first year served to identify the main problems involved. The second year was devoted largely to resolving the leaf spot problem. Results of both year's work have been presented previously[9, 10, 11].

Most of the relevant information now available on sugar beet production in Natal comes from eleven experiments conducted in the final season. These experiments are discussed briefly in order to elucidate the main factors involved in growing sugar beet in Natal.

Method

Six of the replicated trials to be discussed were conducted on the farm "Lintrose" (1 450 m) at Nottingham Road in the Highland Sourveld and a further three such trials at Baynesfield Estates (880 m) in the Coast Hinterland. A large unreplicated plot of beet was established on the farm "Spring Grove" (1 500 m) near Nottingham Road and another such plot was established on the property of Harden Heights Wattle Co. (1 070 m) in the Midlands Mistbelt. Cultural practices in these two large plots were considered to be commercially practicable. All the experiments were on deep porous clays of the Hutton form. Lime was applied to raise the pH to 5,4 (in water) except where the effect of different levels of lime was to be investigated. All the soils were moderately to highly P-fixing and required large amounts of this nutrient unless P levels were already high. A certain amount of nitrogen mineralization was expected in these soils and nitrogenous fertilizer was applied sparingly (70 to 110 kg N/ha). The amount of P applied ranged from 20 to 100 kg/ha and between 70 and 125 kg of K was applied, according to the results of soil analyses. Seedbeds were prepared with a shallow (50 mm) working of a Lely Roterra or Rotavator and were consolidated by one pass of a Cambridge roller. Drilling was done with a Stanhay precision drill with units mounted 0,5 m apart. Seeds were spaced at 130 mm or more where thinning was to be avoided and at less than 100 mm where thinning was permissible. Thinning of seedlings was permitted only where the ease of crop establishment was not a measure of treatment effects.

Results

Lime Application (Experiments 1 and 2)

The treatments planned for Experiment 1 were four rates of lime and two depths of incorporation. An analysis of soil samples taken after the limestone had been applied showed that the attempt to incorporate to a depth of 400 mm had failed and most of the lime had remained in the top 200 mm

TABLE 1

Details of experiments at Lintrose (L), Baynesfield (B), Spring Grove (G) and Harden Heights (H)

No.	Experiment Title	Site	Net plot length m	Net plot width m	Seed spacing mm	No. of reps.	Date of sowing	Date of lifting	Description of Treatments (See results for fuller description)
1	Rate of lime	L	8	2,5	95	6	Sept.	July	0, 3, 6, 12 and 24 t/ha incorporated to 200 mm
2	Depth of lime	L	3	2	95	6	Oct.	July	7 t/ha and 14 t/ha incorporated to 200 mm and 400 mm respectively
3	Herbicide screening	B	3	2	160	4	Oct.	—	7 products in 13 combinations
4	Herbicide incorporation	B	3	2	160	4	Oct.	—	4 methods of incorporation
5	Nematicides	B	10	2	160	6	Oct.	April	Aldicarb and carbofuran
6	Varieties 1	L	10	2	95	3	Sept.	July	Varieties resistant or susceptible to leaf spot, given full or no protection
7	Varieties 2	L	8	2	78	4	Oct.	July	
8	Fungicides	L	10	2	95	6	Sept.	July	10 spraying regimes using 3 chemicals
9	Sowing date	L	10	2	95	3	Various	July	4 dates and 3 levels of disease control
10	Semi-commercial plantings	S	—	—	140	—	Oct.	Various	Varieties: Cremona, Kawerita, Nomo
11	Semi-commercial plantings	H	—	—	130	—	Oct.	Various	Varieties: Cremona and Kawerita

of soil. The effective treatments were therefore five levels of lime application (Table 1).

Seedling emergence was equally high in all treatments. In plots where no lime had been applied, seedlings soon became stunted and chlorotic and many died, leaving several bare patches. These patches were avoided at harvest to minimize the influence of plant population on yield. The plant population on the unlimed plots was 88 000 and it increased to 103 000 plants per hectare at the highest level of lime. Plant populations in this range are considered to have little effect on yields.[7] Root yields increased with increasing lime level up to 12 t/ha. An additional 12 tons lime per hectare had a non-significant depressive effect on yield and an application of half the optimum rate reduced yields only slightly (Figure 1). Root yields were markedly reduced in soils with exchangeable aluminium indices (EAI) greater than 10 ppm. The EAI was reduced to this critical value once the pH had risen to 5,3. The EAI was far more sensitive to lime application than was the pH, which was increased by less than one unit by adding 24 tons lime per hectare.

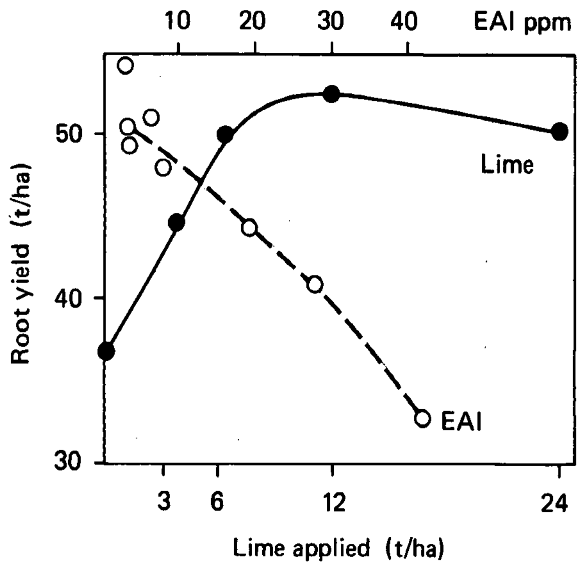

FIGURE 1 Effect of lime application and exchangeable aluminium index (EAI) on root yield.

Judging from the results of soil analyses (Table 2), lime was successfully incorporated by hand into the sub-soil in Experiment 2. Deep incorporation resulted in only a small increase in root length and root yield and had a surprisingly small effect on the amount of fanging of roots.

TABLE 2

Effect of depth of lime incorporation on yield components and soil factors

Yield component	Depth (mm) 200	Depth (mm) 400	Soil factor	Depth (mm) 200	Depth (mm) 400
Root length (mm)	170*	190	pH top soil	5,1	5,2
Fanginess (%)	72	65	pH sub soil	4,9**	5,6
Root yield (t/ha)	50	56	Ca sub (ppm)	468**	779
Sucrose (%)	17,9	17,3	EAI sub (ppm)	60**	3

* difference significant at P = 0,05; ** p = 0,01

Herbicides (Experiments 3 and 4)

A wide variety of weeds germinated in profusion in the control areas of Experiment 3. *Amaranthus* sp, *Cyperus esculentus* and annual grasses were equally abundant and were fairly uniformly distributed in the trial area. The assessments of herbicide effects on these classes of weeds can be considered to be reliable.

A pre-plant application of cycloate and ethofumesate followed by a post-emergence application of desmedipham controlled the widest spectrum of weeds (Table 3). The higher rate of ethofumesate proved to be toxic to beet and its effect on weeds was no better than that of the lower rate. A mixture of cycloate and H22234 gave results similar to those obtained with the cycloate-ethofumesate mixture. Metolachlor followed by des-

TABLE 3

European Weed Research Society (EWRS) ratings* on weed control and beet phytotoxicity, eight weeks after pre-plant (treatment 7 to 13) and pre-emergence applications (1 to 4), four weeks after post-emergence applications (5, 6) and two weeks after all treatments except 5 and 6 ended with an application of desmedipham

No.	Herbicide treatment	kg ai/ha†	AMR + DAT	XAN	CYP	ANN	COM	Beet phyto.	Beet germ. %
1	H22234	1,9	2	3	8	5	7	1	93
2		3,8	1	3	7	2	5	2	90
3	Metolachlor	1,4	1	2	7	1	3	2	85
4		2,8	1	3	6	1	4	4	80
5	Desmedipham plus	1,0	1	1	9	2	4	1	91
6	Ethofumesate	1,5	1	—	8	2	6	3	87
7	Cycloate plus	1,9	1	2	3	3	3	3	93
8	H22234	3,8	1	2	2	3	2	3	94
9	Cycloate plus	0,4	1	1	3	3	3	5	61
10	Lenacil	0,8	1	4	2	4	3	4	65
11	Cycloate plus	1,0	1	3	2	2	2	2	89
12	Ethofumesate	2,1	1	2	2	2	3	4	94
13	Cycloate	3,7	1	2	3	5	4	2	89

* 1 = full control and 9 = no control of weeds
1 = no and 9 = maximum phytotoxicity to beet
† Rates of the second component in mixtures. Cycloate and desmedipham levels were constant (3,7 and 0,8 kg ai/ha respectively).
AMR = *Amaranthus* sp; DAT = *Datura* sp; XAN = *Xanthium* sp; CYP = *Cyperus esculentus*; ANN = Annual grasses; COM = *Commelina benghalensis*.

medipham proved to be effective on all weeds except *C. esculentus*. The higher rate of metolachlor was toxic to sugar beet. Ethofumesate applied post-emergence together with desmedipham was effective on emerged grasses but was slightly toxic to sugar beet. Desmedipham alone was effective only on broadleaf weeds. Venzar was the only pre-emergence herbicide to control broadleaf weeds satisfactorily but it was unacceptably toxic to sugar beet. An interaction between the level of cycloate applied and the method of incorporation was found in Experiment 4. Cycloate at 3,7 or even 2,2 kg ai/ha incorporated to a depth of 50 mm with a Rotavator controlled *C. esculentus*, *Commelina benghalensis* and annual grasses adequately (Table 4). The lowest level of cycloate gave unacceptable weed control when incorporated to 100 mm with the Rotavator or to 50 mm with the Lely Roterra. Weed control on plots prepared with a disc harrow was barely acceptable even at the highest level of cycloate. None of the treatments adversely affected seedling emergence or the subsequent growth of sugar beet.

TABLE 4

EWRS ratings on three types of weeds eight weeks after cycloate was incorporated to two depths by four methods

Weed class	*Commelina* sp.			Grasses			*C. esculentus*		
Cycloate (kg ai/ha)	2,2	3,7	5,2	2,2	3,7	5,2	2,2	3,7	5,2
Rotavator (50 mm)	2,8	2,5	2,0	3,0	2,0	1,8	2,0	1,5	1,2
Rotavator (100 mm)	4,0	2,0	1,8	4,5	2,2	2,0	2,5	1,5	1,5
Lely Roterra (50 mm)	4,0	2,5	3,2	4,0	3,0	2,5	3,5	3,2	2,7
Disc harrow (100 mm)	6,2	4,5	3,2	7,0	4,8	3,8	4,5	3,0	4,5

Nematicides (Experiment 5)

Nematicide application had no effect on crop establishment but it had a substantial effect on the crop as it approached maturity. Untreated plots wilted prematurely and plants began to die leaving a small percentage of the original population surviving at the time of harvest (Table 5). The highest level of aldicarb enabled most plants to survive till harvest but it did not prevent a serious loss in sucrose yield. The split-application of aldicarb was no better than the single application and carbofuran at 4 kg ai/ha was inferior to the lowest level of aldicarb.

TABLE 5

Effect of nematicides applied in the seed furrow on yield components of sugar beet

Treatment		Seedling population per ha	Final population per ha	Root yield (t/ha)	Sucrose content (%)
Nematicide	kg ai/ha				
Control	—	49 100	6 300	3	5,7
Carbofuran	4	49 900	15 400	6	6,9
Aldicarb	1	47 700	21 700	10	7,7
Aldicarb	1 + 2	52 400	28 300	12	9,4
Aldicarb	3	49 500	34 200	15	9,6
Aldicarb	5	49 600	43 600	23	10,9
LSD (p = 0,05)		NS	10 500	5,3	2,4

Varieties (Experiments 6 and 7)

The highest sucrose yields in both experiments were obtained in fungicide-treated plots of Cremona. The yields of AM2 Hybrid B and Kawerita in Experiment 7 were not significantly lower than the yield of Cremona (Table 6).

AM2 Hybrid B appeared to be particularly resistant to leaf spot in Experiment 7 as did H 3190 in Experiment 8 where it outyielded Cremona in unsprayed plots. KWS 737 had a particularly high sucrose content and the sucrose content of Bush Mono G was relatively low.

Susceptible varieties ranked lower than resistant varieties with the exception of (1) Kaweprecercomono which appeared to be more susceptible to leaf spot than the other resistant varieties and (2) Nomo, which yielded well despite its high leaf spot susceptibility. KWS 737 also gave high yields while showing a low tolerance to leaf spot.

All yield components of the treatment combinations varied in this order: unsprayed susceptible < unsprayed resistant < sprayed susceptible < sprayed resistant (Table 7). Susceptible varieties benefited only slightly more than resistant varieties from the fungicide application. In both experiments the spray × variety interaction on root yield was significant (p = 0,05) indicating that varieties differ in their response to fungicide application. These differences were not consistent over the two experiments. The resistant varieties outyielded the susceptible varieties by 40% where no fungicides were applied and by 18% where they were applied.

Fungicides (Experiment 8)

The use of triphenyltin acetate (TPTA) from mid-December to late March resulted in significantly higher root and sucrose

TABLE 6

Sucrose yields of varieties expressed as a percentage of that of Cremona, all varieties receiving fungicide treatment

Varieties in Experiment 7		Relative sucrose Yield t/ha	Relative sucrose Content %	Varieties in Experiment 8		Relative sucrose Yield t/ha	Relative sucrose Content %
Cremona	(R)	100	100	Cremona	(R)	100	100
Kawerita	(R)	89	92	Kawerita	(R)	75	92
AM2 Hybrid B	(R)	81	95	H.3190	(R)	84	97
KWS 737	(R)	75	103	KWS 737	(R)	70	105
Nomo	(S)	73	94	Nomo	(S)	83	97
KWS 692	(R)	72	92	H.3837	(R)	72	93
Kawegigamono	(S)	71	91	H.3838	(R)	73	98
Salohill	(S)	71	104	Kaweprecercomono	(R)	61	100
Kaweprecercomono	(R)	66	102				
Monofort	(S)	64	99				
Bush Mono G	(S)	60	91				
LSD (p = 0,05)		20	5			16	7
Actual values for Cremona		8,0	17,4			7,6	16,7

R = designated resistant by breeders; S = susceptible to leaf spot

TABLE 7

Comparison of the means of six resistant varieties (R) and five susceptible varieties (S) under full (F) or no (N) protection from fungicides

Yield component	Fungicides (F)			No Fungicides (N)			F/N %	
	R	S	R/S%	R	S	R/S%	R	S
Root (t/ha)	38	32	117	22	17	127	172	187
Sucrose (t/ha)	6,4	5,4	118	3,5	2,5	140	183	216
Sucrose (%)	17,0	16,7	102	15,6	14,9	105	109	112
Leaf cover (%)	80	73	110	70	59	119	114	123

yields than where other spraying regimes, even those in which TPTA replaced benomyl in January, were used (Table 8). There was a slight but non-significant advantage in applying fungicides every week rather than every fortnight. This was probably due to better control of leaf spot by benomyl, in the more frequent application, before it was replaced by TPTA (cf treatments 4, 5 and 8). Applications of benomyl throughout the season had very little effect on leaf spot. After the 4th January only four and three further applications of TPTA were made in treatments six and seven respectively, yet yields from these plots were not much lower than where more regular applications of TPTA were given (treatments 4 and 5).

Sowing date (Experiment 9)

Root and sucrose yields declined as the sowing date was delayed. The root yield of disease-free crops decreased by 11% due to a six-week delay in drilling from late September to mid-November. A further three week delay resulted in an additional 27% decrease in yield. The three successive intervals between sowing dates were associated with sucrose yield losses of 28 kg, 43 kg and 81 kg per hectare respectively for each day's delay in drilling. Yield losses due to delayed drilling were even greater in crops where disease control was inadequate.

Leaf spot had a more harmful effect on an unprotected susceptible variety sown in late October or early November than on one sown earlier or later in the season, judging from the response to disease control measures (Fig. 2). Disease control had a smaller effect on sucrose content than on root yield, particularly in crops sown later in the season.

Yield potential (Experiments 10 and 11)

The changes in root and sucrose yields throughout the lifting season are shown in Figure 3. Yield values for April, May and June were obtained from small samples and therefore serve only as a guide. Values for the last three months are accurate having been obtained by harvesting eight to twelve 20 m² plots per site each month.

Root yields appear to remain static during the first three months but they then increase steadily as spring approaches. Root yields at Nottingham Road were about 10 t/ha more than at Harden Heights even though both crops were free of leaf spot. Dirt tares of roots decreased from about 12% in April to 5% in June and remained low during the winter.

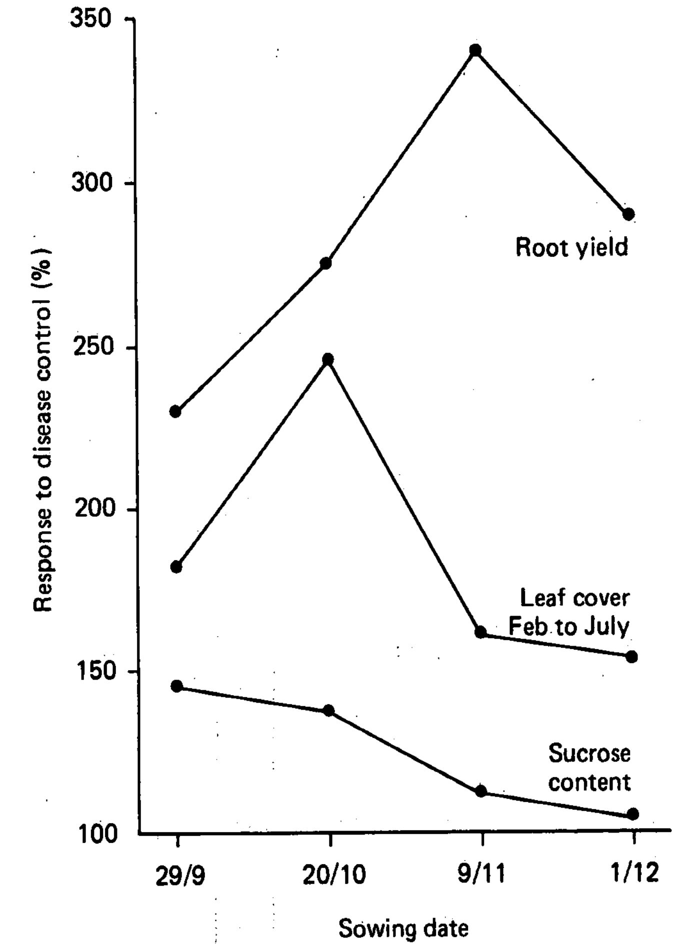

FIGURE 2 Yield components of a sprayed resistant variety as a percentage of those of an unsprayed susceptible variety as affected by sowing date.

TABLE 8

Effect of fungicides and spray regimes on yield components of sugar beet

	Fungicide	Intended spray interval Days	Intended spray interval rain (mm)	No. of sprays	Root yield t/ha	Sucrose content %	Leaf cover %
1	Brestan	14	50	10	48	16,5	86
2	Brestan	21	75	8	47	17,3	84
3	Benlate + Dithane	21	75	8	34	16,0	74
4	Benlate from 14.12.77 to 18.1.78 Brestan thereafter	7	—	15	36	17,3	80
5		14	50 (E)	9	31	17,2	78
6		—	50	6	31	16,8	78
7		—	75	5	30	17,3	74
8	Benlate	14	50	10	24	16,2	69
9	Benlate	21	75	8	20	16,5	66
10	Control	—	—	0	19	15,7	64
	LSD (p = 0,05)	—	—	—	5,0	1,1	5,0

(E) Terminating at the end of February, 1 month before the other regimes.

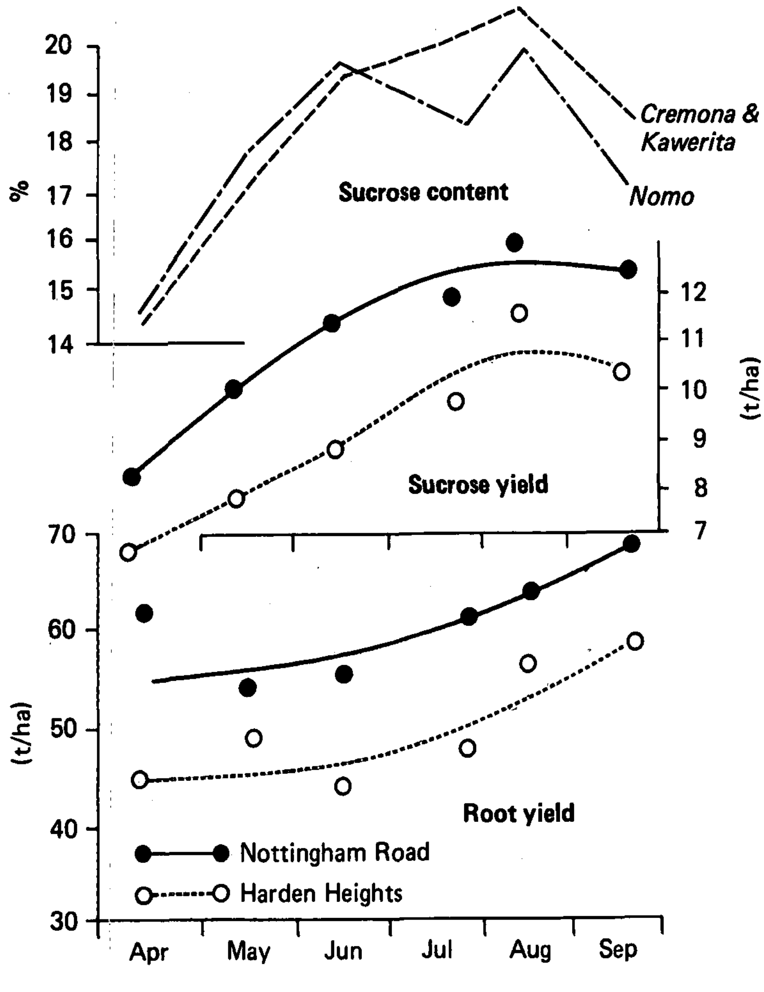

FIGURE 3 Changes in root and sucrose yields over the lifting period in crops at Nottingham Road and Harden Heights. The sucrose % curves are means of both sites for two varieties (after Inman-Bamber).[10]

Sucrose contents at both sites followed the same trend but the pattern for Nomo was slightly different from that of Cremona and Kawerita.

Sucrose yields at Nottingham Road rose from 8 t/ha in April to over 12 t/ha in August and September. The same pattern was found at Harden Heights but yields were 2 t/ha lower than those at Nottingham Road.

Discussion

Lime application: Contrary to the widely accepted contention that, for sugar beet, lime should be applied to soils with a pH of less than 6,5, it was found necessary to add lime in amounts sufficient only to eliminate most of the exchangeable aluminium in the soil. This occurs at a pH of about 5,3 and in a clay soil would require about 6 tons lime per hectare well incorporated into the top 200 mm of soil. The results show that high Al levels in the sub-soil have only small effects on yields and do not appear to prevent the roots from extracting moisture held at depth in the soil profile during winter.

The need for deep incorporation of lime foreseen by Meyer and Wood[12] appears to be minimal.

Herbicides: Weed control in beet crops in Natal would make high demands on the accuracy and timeliness of spraying. The results show that cycloate thoroughly incorporated into the top 50 mm of soil will adequately control *Cyperus esculentus* which is probably the most important weed species. Several products are available to control grass weeds but desmedipham sprayed post-emergence would be the only means of controlling broadleaf weeds initially. Great care needs to be exercised in using this product. Sugar beet seedlings cannot tolerate an application of desmedipham when in the cotyledon stage or when temperatures rise much above 22° C after spraying.[18] Many broadleaf weeds become tolerant to this chemical after the two leaf stage and it should therefore be sprayed soon after weeds emerge. A preplant application of cycloate × ethofumesate would fortunately retard the emergence of broadleaf weeds and would therefore result in a longer period suitable for spraying desmedipham. Grasses that emerge after the beet could be controlled by a mixture of desmedipham and ethofumesate but more work is needed to prove that pre-plant applications of cycloate plus a grass killer do not predispose the beet to damage by this post-emergence mixture.

Nematicides: The results show that nematicides are not likely to offer the beet crop sufficient protection in a clay soil heavily infested with *Meloidogyne incognita*. Aldicarb is widely used for sugar beet elsewhere but is not recommended unless aphids, nematodes and other soil inhabiting pests are to be controlled simultaneously. The level applied is seldom more than 1 kg ai/ha. An economical level such as this may protect the beet crop in Natal against low nematode infestations and other soil pests but a crop rotation system will need to be adopted to avoid the build up of high populations of nematodes in the soil.

Varieties: Varieties that have been developed for resistance to *Cercospora beticola* do not play a major role in combating the disease even in countries such as Greece where the disease is at its worst in Europe.[2] This is because they are outyielded by susceptible varieties when both receive fungicide.[1] Defoliation of resistant varieties by leaf spot occurred about three weeks after susceptible varieties were defoliated in the presence of a heavy infestation at Baynesfield.[10] Despite this small difference in tolerance to leaf spot, resistant varieties consistently outyielded the susceptible varieties whether or not fungicides were applied. The reasons for the success of the resistant varieties in Natal is thought to be (1) that the climatic conditions here are more favourable to the disease than in most areas where it is a problem, (2) the growing season here is longer than in most beet growing countries and this allows the less vigorous resistant varieties sufficient time to realize their potential yields.[10]

Fungicides: Benomyl was used fairly effectively against leaf spot in 1976[9] but it appeared to have little effect on the disease in Experiment 8. Benomyl is considered to be one of the most effective fungicides against *C. beticola*[13, 14, 17] but it appears to lose its effect within a few years of general use. Strains of *C. beticola* that are resistant to benomyl developed rapidly in the Greek beet industry[4] and in Arizona[16] where the chemical was used on a wide scale. Although triphenyltin acetate could be used effectively in Natal at first, it would be necessary to find other fungicides with which it could be used in rotation in order to forestall the build-up of resistant strains. Strains resistant to triphenyltin compounds have now been found in Greece in areas where these chemicals have been used for many years.[5]

The results of Experiment 8 indicate that fungicide applications in December and January had a greater effect on yield than applications in February and March. It will be necessary to ascertain how soon spraying can be terminated without affecting yields unduly.

Sowing date: Sowing date trials in 1975/76 showed that about 50 kg sucrose per hectare would be lost for each day's delay in drilling,[9] but subsequent trials indicated a value of twice this amount.[10] The results of Experiment 9 indicate that the yield loss would be small at the beginning of the drilling season in September but would increase to over 80 kg/ha per day for delays occurring at the end of the drilling season (November). This is more in agreement with the results of sowing date trials in Europe.[6] The relationship between response to disease control measures and sowing date, obtained in Experiment 9, confirms the results obtained previously.[9, 10] The study by French and Humphries[3] helps to explain this relationship. It is the 6th to 20th leaves that contribute most to the yield of the sugar beet plant. The active life of these leaves would have been considerably shortened by delaying the drilling date from September to November because leaf spot would have killed most of these leaves in February. Crops sown later than November tend to be immature and therefore resistant[15] to leaf spot in February and do not respond to disease control measures to the same extent.

Early drilling is advantageous in (1) reducing the risk of yield loss because of leaf spot, (2) avoiding the rapid weed growth that occurs later in the season, (3) allowing the crop to germinate before soils dry out rapidly under summer conditions, (4) making full use of the growing season.

Yield potential: The sucrose yields obtained are high compared with world standards. The world's highest average sucrose yields in the 1976/77 sugar beet season were obtained in Greece (9,9 t/ha) and California (9,5 t/ha).[8] Crops in both countries are grown under irrigation. Sucrose yields in Europe ranged from 4,3 t/ha in Britain to 7,8 t/ha in Austria.

The crop in Natal could be lifted over a six or seven month period starting in April. The dry conditions of this period would be ideal for harvesting equipment and would result in fairly clean roots being delivered to the factory. The length of the lifting period in Natal would be similar to that in California which is the longest in the world. The costs of lifting and processing the crop are inversely proportional to the length of these operations.

Conclusions

Sugar beet could be grown successfully in the Natal Midlands and would give rewarding yields. The Highland Sourveld is more suited to the crop than the Coast Hinterland because of the higher leaf spot incidence and the higher evaporative demand in the lower region. The suitability of the Midlands Mistbelt is intermediate.

Sugar beet would require more care than most crops currently grown. There would be little margin for error in the spring operations of seedbed preparation, drilling and herbicide application. Once properly established the crop is robust. It recovers quickly from hail and drought and leaves remain turgid throughout the winter because of its deep root system. It is considered that much of the technology required for commercial sugar beet production in Natal is now available.

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