THE INTERACTION OF HERBICIDES AND NEMATICIDES ON PLANT CANE GROWN IN WEAK SANDY SOILS

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Abstract

Experiments were conducted in trays and in the field to determine the cause of leaf chlorosis and poor growth of plant cane on the weak sandy soils along the Natal north coast. The results indicated that the herbicide Sencor was responsible for these symptoms in the variety N8 and the severity of its effect appeared to be related to the clay content, organic matter %, moisture % and pH of the soil. When these factors promoted the uptake of Sencor by the plant severe damage was evident. Damage to cane was most severe when Sencor was used with the nematicide Curaterr. It is suggested that alternative pre-emergent herbicides be used in cane grown in very weak sands.

Introduction

Several reports of chlorosis and stunted growth in the early stages of plant crops of varieties NCo 376 and particularly N8 on Recent Sands were received from the Mtunzini area on the north coast of Natal. These symptoms were apparently related to the application of nematicides, agricultural limestone, potassium and Sencor, either alone or in combination.

The variety suited to weak sandy soils is N8 because it is evidently able to tolerate parasitic nematodes. The variety has narrow and erect leaves which means that the crop canopy takes a comparatively long time to cover the ground completely. Hence, particularly effective methods of weed control are necessary. Where N8 is planted in weak sandy soils the rows are usually spaced as little as 1 m apart which means that the crop foliage is likely to intercept more of the post-emergent herbicides. Pre-emergent herbicide treatments are therefore preferable because N8, and also N13, are very sensitive to herbicides (Turner[8]).

Both good weed control and control of nematodes are essential for satisfactory yields to be obtained on the sandy soils. The inherently low nutrient status of these soils makes it necessary to apply large amounts of fertilizer, particularly potassium chloride. Dolomitic or calcitic lime may also be required to raise the low calcium and magnesium status.

Between 1979 and 1983, experiments were conducted in the field at Empangeni, Felixton and Emoyeni, while at Mount Edgecombe an experiment was conducted in trays. The objective of the trials was to determine which practices, if any, contribute to chlorosis and poor growth of plant cane in sandy soils.

Methods

Details of the trials are given in Table 1.

Field experiments

A randomised block design was used and the treatments were replicated at least four times. The five or six cane rows in each plot were 8 to 15 m long. The outer two rows and one metre at the end of every row in each plot were discarded when the plot was harvested and the mass of the remaining cane was determined. The quality of the cane was determined from 12 stalks taken at random from each plot.

In Experiment 1, nematicide granules were placed in a 50 mm deep furrow along one side of the cane rows in some plots and on both sides of the rows in other plots. In Experiments 3 and 4, the granules were spread evenly over the setts in the planting furrow and covered immediately with soil. The setts were dipped in a Benlate fungicide solution before being planted.

Herbicides were applied by means of a lever-operated knapsack sprayer fitted with a Spraying Systems TK5,0 floodjet which delivered about 300 ℓ of the spray solution per hectare. The pre-emergent herbicide treatments were applied directly over the cane rows within three days of planting. Post-emergent herbicide sprays were directed across the interrow and away from the cane foliage. Plots which were not treated with a herbicide or in which the herbicide treatments were not effective, were weeded by hand and with hoes.

Varieties N8 and N55/805 were used in the experiment and the cane was fertilized according to recommendations of the Fertilizer Advisory Service of the South African Sugar Association Experiment Station. Additional fertilizer treatments were applied in Experiments 2 and 3.

Tray experiment

Soil for this experiment was collected from a field near Mtunzini where chlorosis and stunted growth had been reported. Ten single-budded setts of varieties N8 and NCo 376 were selected, dipped into a solution of Benlate fungicide and planted directly into trays (300 mm × 300 mm × 100 mm), which had been filled with light sandy soil (4% clay) or very light sandy soil (1% clay). Fertilizer was applied before and after planting in the form of a nutrient solution. Limestone was incorporated lightly into the soil.

TABLE 1

Details of the experiments

Experiment	Crop	Age at harvest (months)	Site	Soil series	Clay % 0–200 mm	pH 0–200 mm	OM % 0–200 mm	Rainfall on crop (mm)	Variety
1	Ratoon	10,3	Empangeni	Fernwood	4	5,3		703	N55/805
2	Plant	3,6	Mt Edgecombe	Fernwood Fernwood	4 1	6,1 6,6	0,15 0,10	Irrigated daily	N8 & NCo 376
3	Plant	12,4	Felixton	Fernwood	5	6,4	1,71	964	N8
4	Plant	12,0	Emoyeni	Fernwood	2	6,5	0,40	875	N8

Sencor (metribuzin) was applied to some trays by means of a gas-operated knapsack sprayer fitted with a Spraying Systems 8003-E fanjet. The spray solution was applied directly over the cane foliage eight weeks after planting when the cane was about 50 mm tall.

Chlorosis was assessed visually at intervals after spraying. The height of the stalks from the level of the soil to the top visible dewlap of the main shoot was recorded and the tillers and shoots were counted on several occasions and when the cane was harvested at the age of 3,6 months. The aerial parts of the plant and the roots were weighed when they were harvested. The physical and chemical characteristics of soil samples, taken before planting and at the time of harvesting, were determined; results are shown in Table 2.

TABLE 2

Characteristics of the two soils used in Experiment 2

CHEMICAL

Soil	pH	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Zn (ppm)
Light	6,1	36	26	70	26	0,7
Very light	6,1	20	14	50	22	0,4

PHYSICAL

Soil	OM %	Clay %	Silt %	Fine sand %	Medium sand %	Coarse sand %
Light	0,15	4	3	48	44	1
Very light	0,10	1	3	36	59	1

Treatments

Experiment 1 at Empangeni:

This experiment was established in ratoon cane. Responses to Curaterr in the previous crop which had also been treated with Sencor and diuron were small and it was suspected that Curaterr and Sencor had interacted. Temik (aldicarb) and Curaterr (carbofuran) were applied about six weeks after the previous crop was harvested. Herbicides and nematicides were applied on the same day and after four weeks Sencor and diuron were applied to some plots for the second time. The treatments and rates at which chemicals were applied were as follows:

Treatment	Rates of application kg or ℓ ai or ae/ha
1. Control (no nematicide) Sencor + diuron	2,5 + 2,5
2. Curaterr (one side of row) with Sencor + diuron	3 + 2,5 + 2,5
3. Curaterr (one side of row) with Lasso + atrazine	3 + 1,6 + 1,25
4. Curaterr (both sides of row) with Lasso + atrazine	3 + 1,6 + 1,25
5. Temik (one side of row) with Lasso + atrazine	3 + 1,6 + 1,25

Experiment 2 in trays at Mount Edgecombe:

Treatments 1 to 10 were applied to trays containing very light sandy soil (1% clay) and treatments 11 to 14 were applied to trays containing light sandy soil (4% clay). In an observation trial, a separate set of treatments which was replicated twice only, was applied to variety N8 which was planted in very light sandy soil to test the possible effects of applying KCl fertilizer in some treatments. Chemicals were applied at the same rates as in treatments 1 to 5. KCl fertilizer was applied at the equivalent of 222 kg/ha. Treatments in the observation trial were:

(1) Control - only standard fertilizer
(2) KCl (additional)
(3) Sencor
(4) KCl + Sencor
(5) KCl + Curaterr
(6) KCl + Curaterr + Sencor
(7) KCl + Curaterr + lime
(8) KCl + Curaterr + lime + Sencor

The treatments and rates at which chemicals were applied were:

Treatment	Rates of application kg ai or ae/ha	Lime tons/ha
1. Control - only standard fertilizer		
2. Sencor - 8 weeks after planting	2,1	
3. Curaterr - at planting	3,0	
4. Temik - at planting	3,0	
5. Limestone		2
6. Limestone + Sencor	2,1	2
7. Limestone + Curaterr	3,0	2
8. Limestone + Sencor + Curaterr	2,1 + 3,0	2
9. Sencor + Curaterr	2,1 + 3,0	
10. Sencor + Temik	2,1 + 3,0	
11. Control - only standard fertilizer		
12. Curaterr	3,0	
13. Limestone + Sencor + Curaterr	2,1 + 3,0	2
14. Sencor + Curaterr	2,1 + 3,0	

Experiment 3 at Felixton:

This experiment was conducted on a site which had been fallowed for some time and where a dense sward of *Panicum maximum* had to be ploughed and disced repeatedly to produce a fine tilth before planting. The treatments and rates at which chemicals were applied were:

Treatments:

(1) Control (no KCl)
(2) KCl
(3) KCl + Sencor
(4) KCl + Sencor + filtercake
(5) KCl + Curaterr + limestone
(6) KCl + Temik + limestone
(7) KCl + Sencor + Curaterr + filtercake
(8) KCl + Sencor + Curaterr + limestone
(9) KCl + Sencor + Curaterr + limestone + filtercake
(10) Sencor + Curaterr + limestone

Rates of application:

KCl : 300 kg/ha
Lime : 1,5 tons/ha
Sencor : 2,1 kg ai/ha
Curaterr : 3 kg ai/ha
Temik : 3 kg ai/ha
Filtercake : 40 tons/ha

The KCl was placed in the planting furrow and then Temik or Curaterr and filtercake were applied over the setts of variety N8. Limestone was broadcast on the surface a day after planting. Sencor was applied to some plots on 26 November, six weeks after planting when the cane had about three leaves and was between 250 and 300 mm tall.

Experiment 4 at Emoyeni:

The site for this experiment was selected because of its very low soil clay and organic matter contents. The yield from variety NCo 376 in this field had been less than 15 tons cane per

hectare and the field was therefore ploughed for replanting. Variety N8 was planted on 7 December 1982 and the treatments and rates at which chemicals were applied were:

Treatments:

(1) Control with Dual + atrazine - pre-emergent
(2) Temik with Dual + atrazine - pre-emergent
(3) Curaterr with Dual + atrazine - pre-emergent
(4) Temik with Sencor - pre-emergent
(5) Temik with Sencor - post-emergent
(6) Curaterr with Sencor - pre-emergent
(7) Curaterr with Sencor - post-emergent

Rates of application as kg ai or ae/ha for all treatments:

Temik : 3,0
Curaterr : 3,0
Sencor : 1,4
Dual : 1,8
Atrazine : 1,0

Temik and Curaterr were applied over the setts in the furrow immediately before they were covered with soil. Pre-emergent herbicide treatments were applied across the planted furrow three days after planting while the pre-emergent herbicide treatments were applied 42 days after planting when the cane had three or four leaves. The spray was directed across the interrow and away from the cane foliage.

Results

Experiment 1 at Empangeni:

Because crop growth measurements (Table 3) taken when the crop was 2.5.5 and 7 months old showed that there had been no response to treatment with nematicides, the yields in this experiment were not recorded. It appeared that cane growth was not affected by the herbicides which were applied.

TABLE 3

Growth characteristics resulting from treatments applied in Experiment 1

Treatments	Stalk counts x10^{-3}/ha			Stalk heights (mm)		
	2 months	5,5 months	7 months	2 months	5,5 months	7 months
Control with Sencor + diuron	268	200	162	320	1 180	1 460
Curaterr (one side) + Sencor + diuron	290	204	188	310	1 110	1 430
Curaterr (one side) with Lasso + atrazine	264	200	188	330	1 115	1 320
Curaterr (both sides) with Lasso + atrazine	290	204	186	340	1 118	1 500
Temik (one side) with Lasso + atrazine	290	186	176	330	1 118	1 490
Mean	280	199	180	330	1 116	1 440

The low rainfall which occurred at Empangeni during the course of this experiment may have nullified any benefits which might otherwise have been gained from treatment with nematicides.

Experiment 2 in trays at Mount Edgecombe:

The results (Table 4) indicate that Curaterr and Temik both stimulated growth of NCo 376 and resulted in an increase in the production of tillers, and in fresh mass of the aerial parts of the plant and the roots. In N8 shoot growth was not affected, but root mass was substantially decreased by these chemicals. Sencor had no effect on the growth and yield of NCo 376 but it caused chlorosis, stunting and reduced yields in N8. There was a small response to limestone in NCo 376 in terms of shoot

TABLE 4

Visual ratings of leaf chlorosis and the effect of treatments on yield and crop characteristics at 3,6 months of age of cane grown in trays (Experiment 2)

Variety	Soil	Treatments	Chlorosis *	Fresh mass (g)	Germination %	Tillers at harvest	Shoot length (mm)	Fresh root mass (g)
NCo 376	Very light	Control	2	83	100	4	90	8
		Sencor	2	84	93	3	97	9
		Curaterr	2	122	100	9	103	16
		Temik	1	137	87	11	100	19
		Limestone	2	88	97	5	93	10
		Limestone + Sencor	2	100	100	7	87	11
		Limestone + Curaterr	3	52	100	0	67	5
		Limestone + Sencor + Curaterr	2	49	97	1	73	4
		Sencor + Curaterr	1	68	93	4	93	5
		Sencor + Temik	2	83	93	4	90	7
	Light	Control	2	113	87	8	107	14
		Curaterr	1	157	100	14	123	27
		Limestone + Sencor + Curaterr	2	33	93	0	60	3
		Sencor + Curaterr	2	63	87	3	93	7
N8	Very light	Control	1	86	80	1	107	18
		Sencor	3	33	83	0	67	2
		Curaterr	2	78	87	0	87	3
		Temik	1	83	93	1	100	5
		Limestone	2	69	93	0	77	9
		Limestone + Sencor	3	32	80	0	63	2
		Limestone + Curaterr	2	47	80	0	80	4
		Limestone + Sencor + Curaterr	2	34	93	0	57	1
		Sencor + Curaterr	3	34	87	0	73	3
		Sencor + Temik	3	34	87	0	67	5
	Light	Control	2	73	77	0	100	6
		Curaterr	2	71	80	0	97	6
		Limestone + Sencor + Curaterr	3	33	87	0	67	2
		Sencor + Curaterr	2	30	77	0	80	2

* **Note:** The ratings of chlorosis are based on a 1 to 9 scale where 1 = no effect and 9 = complete chlorosis

and root production but growth was slightly suppressed in N8. When Sencor and limestone were applied together to NCo 376, the yields did not appear to decrease more than when they were applied separately but when they were applied to N8 chlorosis increased and growth decreased. Applying Curaterr with limestone resulted in depressed growth compared with the untreated control in both NCo 376 and N8. The damage caused by Sencor was marginally greater than that due to Curaterr and limestone combined in N8 but not in NCo 376.

Sencor and Curaterr applied together had phytotoxic effects on NCo 376 whereas with N8, the effect on growth was similar to that caused by Sencor alone. The response of NCo 376 to Temik was negated by the addition of Sencor whereas the effect of Temik with Sencor on N8 was similar to that of Sencor alone. The effects of all the chemicals were greater on cane grown in the very light soil (1% clay) than in the light soil (4% clay).

The results of the separate observation experiment are shown in Table 5 and they confirm those of the main tray experiment. The response to KCl in terms of yield was substantial even though KCl caused slight chlorosis. The benefit from KCl alone was reduced by the addition of Sencor. The adverse effects of Sencor with Curaterr were not lessened by the addition of KCl or of KCl and limestone. As in the main trial, Sencor alone had the effect of decreasing the fresh mass of the aerial parts and the roots.

The positive and negative effects of each treatment on chlorosis, the fresh mass of the aerial parts and the roots, tiller numbers and shoot length have been integrated and rated, as shown in Table 6. The severe negative effect of Sencor on the growth of N8 was evident, as was the increased effect of Curaterr on N8 when it was applied with limestone. The negative effect of Curaterr and limestone applied at the same time was more evident on NCo 376 because the response to Curaterr alone was strongly positive and when limestone was applied alone it had no effect on this variety.

Experiment 3 at Felixton:

Germination was retarded in plots where KCl alone was applied in the furrow but germination was not affected where it was applied with either limestone, filtercake or a nematicide or a combination of these treatments (Table 7). The poor germination of setts in the presence of KCl alone resulted in reduced stalk populations for most of the growing period, but at

TABLE 6

An integrated rating showing positive or negative effects of treatments on cane growth and yields of NCo 376 and N8

Treatments	NCo 376	N8
Control	0	0
Temik	+ + + + +	0
Curaterr	+ + + +	−
Sencor	+	− − − − − −
Limestone	0	− −
Limestone + Sencor	+	− − − − −
Limestone + Curaterr	− − − −	− − − −
Limestone + Sencor + Curaterr	− − − −	− − − − − −
Sencor + Curaterr	− −	− − − − − −
Sencor + Temik	0	− − − − − −

TABLE 5

Visual ratings of leaf chlorosis and the effect of treatments on yield and crop characteristics of variety N8 in an observation trial with KCl (Experiment 2)

Variety	Soil	Treatments	Chlorosis *	Fresh mass (g)	Germination %	Tilliers at harvest	Shoot length (mm)	Fresh root mass (g)
N8	Very light	Control	2	54	70	2	100	3
		KCl	3	108	100	1	115	18
		Sencor	2	32	85	0	65	1
		KCl + Sencor	2	52	100	0	80	3
		KCl + Curaterr	3	65	95	0	95	10
		KCl + Sencor + Curaterr	3	37	95	0	65	2
		KCl + limestone + Curaterr	4	60	95	0	90	3
		KCl + limestone + Sencor + Curaterr	3	43	90	0	80	3

* **Note:** The ratings of chlorosis are based on a 1 to 9 scale where 1 = no effect and 9 = complete chlorosis

TABLE 7

The effect on leaf chlorosis, vigour of growth, final yield and crop characteristics of treatments applied to cane in Experiment 3

Treatments	Yield components			Crop measurements		Ratings*		
	Cane t^{-ha}	Suc % cane	Suc t^{-ha}	Stalk length (cm)	Stalk popln. $\times 10^{-3-ha}$	Chlorosis		Vigour
						3 days	11 days	53 days
Control - no KCl	52	11,3	5,9	171	119	1	1	3
KCl	57	10,5	6,0	173	122	2	2	2
KCl + Sencor	58	11,6	6,8	178	133	3	3	2
KCl + Sencor + filtercake	53	11,1	5,9	168	121	3	4	3
KCl + limestone + Curaterr	63	12,0	7,5	181	130	1	1	4
KCl + limestone + Temik	65	11,4	7,4	188	136	1	1	3
KCl + limestone + Curaterr + filtercake	58	11,8	6,8	175	132	1	1	4
KCl + limestone + Curaterr + Sencor	58	11,5	6,7	179	131	3	4	3
KCl + limestone + Curaterr + Sencor + filtercake	60	11,8	7,1	177	131	3	4	4
Limestone + Curaterr + Sencor	58	11,7	6,8	176	132	2	4	4
CV %	6,2	7,9	10,8	2,8	5,1			
LSD (P = 0,05)	5,2	1,0	1,0	7,3	9,4			
LSD (P = 0,01)	7,0	1,4	1,4	9,8	12,8			

Note: Ratings of leaf chlorosis were on a 1 to 9 scale where 1 = no chlorosis and 9 = complete chlorosis.
Vigour ratings were done on a 1 to 5 scale where 1 = very poor growth and 5 = excellent growth.

harvest yield was increased by 5 tons cane/hectare. Growth increased due to treatment with nematicides at an early stage and this led to an increase in cane yields. Three days after Sencor was applied the leaves became very chlorotic but the effect disappeared after five weeks. The adverse effects that KCl had on growth were not increased by Sencor. The highest yields were obtained where a nematicide, KCl and limestone had been applied. Where either Sencor or filtercake was applied to cane treated with Curaterr, KCl and limestone, yields were reduced by 5 tons cane/ha and where Sencor and filtercake were applied in addition to this combination, yields decreased by 3 tons/ha. This may be due to some of the Sencor being adsorbed by the organic matter in the filtercake and less being absorbed through the roots of the sugarcane.

Experiment 4 at Emoyeni:

Both pre- and post-emergent sprays of Sencor caused leaf chlorosis which was more evident in cane treated with Curaterr than in cane treated with Temik. No chlorosis was observed in cane treated with Dual and atrazine. Stunted growth was associated with chlorosis and was less severe in cane treated with Temik. The effects of the various treatments on the height and population of stalks are shown in Figure 1 while their effects on yield and cane quality are given in Table 8.

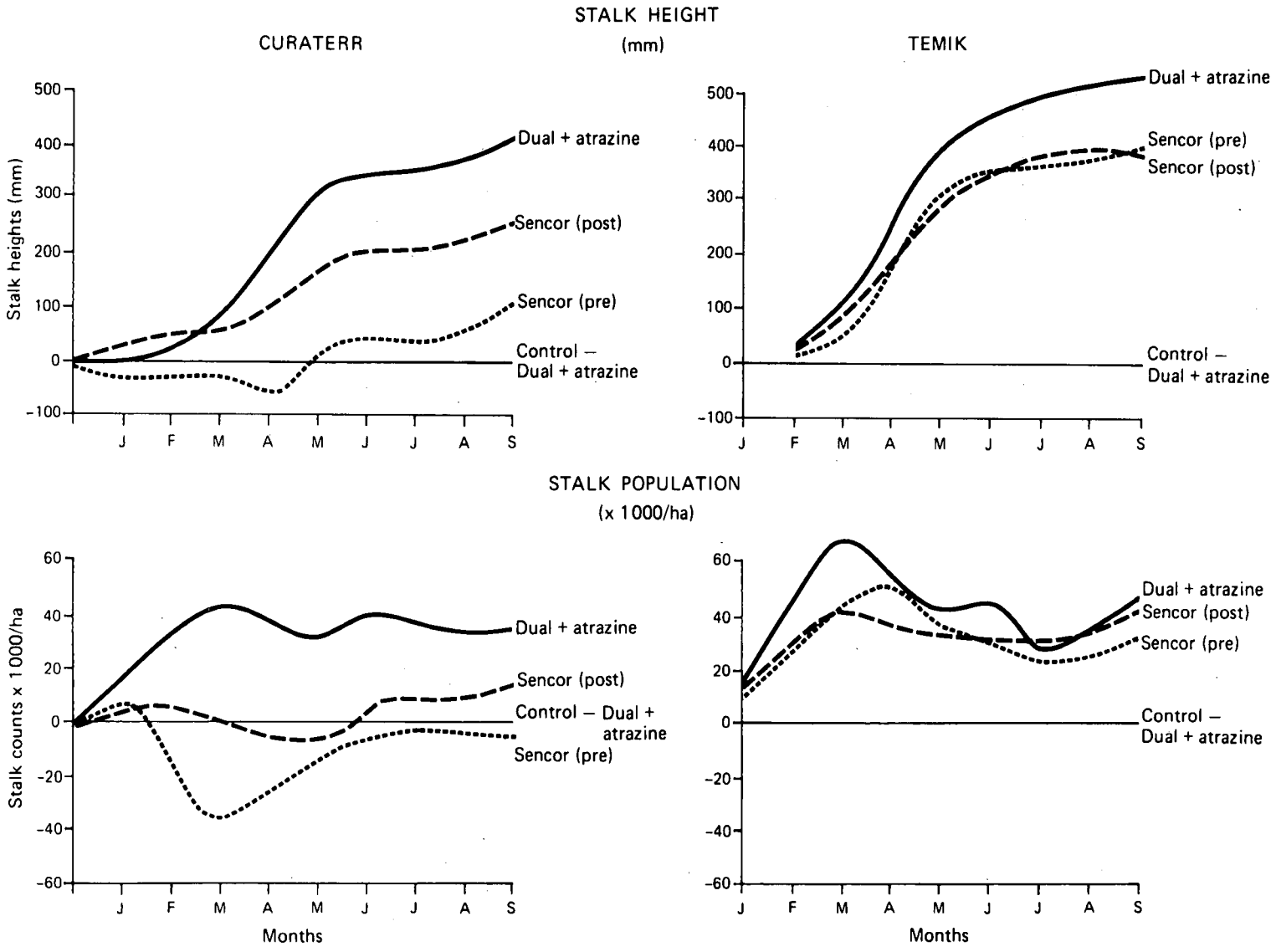

FIGURE 1 Growth responses to treatments shown as differences from control (no nematicide and treated with Dual + atrazine) in Experiment 4.

TABLE 8

The effect of different combinations of nematicides and herbicides on cane and sucrose yields in Experiment 4

Treatments	Cane t^{-ha}	Suc % cane	suc t^{-ha}
Control with Dual + atrazine	14	9,7	1,4
Temik with Dual + atrazine	40	10,9	4,4
Curaterr with Dual + atrazine	37	10,5	3,9
Temik with Sencor - pre-emergent	36	11,0	3,9
Temik with Sencor - post-emergent	36	11,0	3,9
Curaterr with Sencor - pre-emergent	22	9,8	2,1
Curaterr with Sencor - post-emergent	27	10,0	2,8
CV %	21	6,4	24,4
LSD (P = 0,05)	7,6	9,8	0,9
LSD (P = 0,01)	10,4	1,1	1,3

Pre-emergent sprays

Growth responses to Temik and Curaterr where Dual plus atrazine had been applied as a pre-emergent treatment, were obvious within three months from time of planting. Yields of cane were increased by about 26 and 22 tons/ha (equivalent to increases of 185% and 157%) following treatment with Temik and Curaterr, respectively. The response to Temik was reduced by about 10% where Sencor was applied as a pre- or post-emergent spray. Stalk populations and to a lesser extent, stalk heights of cane treated with Curaterr and sprayed with Sencor were severely reduced within three months of planting during which time growth was poorer than where no nematicide had been applied and Dual and atrazine had been used. During the ensuing nine months, new tillers emerged and appeared to be

less affected. The heights and populations of the stalks of cane treated with Sencor and Curaterr were greater at the time of harvesting than those of cane which was not treated with a nematicide but which was sprayed with Dual and atrazine. Cane treated with Curaterr and Sencor (pre-emergent) yielded about 43% (P = 0,01) less than cane treated with Curaterr and Dual and atrazine.

Post-emergent sprays

Six weeks after spraying the post-emergent treatment of Sencor onto cane which had been treated with Curaterr, stalk populations were similar to those of cane which had not been treated with a nematicide but had been sprayed with Dual and atrazine. At the time of harvesting, however, the stalk population was slightly higher than that of untreated cane sprayed with Dual and atrazine. Stalks of cane treated with Curaterr and sprayed with Sencor (post-emergent) were consistently longer than those of cane sprayed with Dual and atrazine only. The yields of cane treated with Curaterr and sprayed with Sencor (post-emergent) were about 27% (P = 0,01) less than yields of cane treated with Curaterr and sprayed with Dual and atrazine.

Discussion and Conclusions

Abdellatif *et al*[1] have shown that the uptake of the active ingredients of Temik (aldicarb) and Curaterr (carbofuran) is greatest in sandy soils. Bhirid and Pitre[2] showed that the moisture content of the soil influenced the availability of the active ingredients to the plant and also that the activity of these pesticides were dependent on the organic matter content of the soil; activity decreased with an increase in the organic matter content. Getzin (cited by Homeyer[4]) indicated that the degradation of Curaterr was greatest in alkaline soils (pH 7,8).

Savage[7] and Ladlie *et al*[5,6] have shown that the availability of the herbicide Sencor (metribuzin) is influenced by the clay content, the organic matter content and pH of the soil. Ladlie *et al*[6] also showed that leaching of metribuzin increases with increasing soil pH.

The low clay content, higher soil moisture content, relatively low organic matter content and the application of lime in Experiments 2 and 4 may have increased the availablity of the nematicides and herbicides to the plants. Cane treated with Sencor was damaged much more where Curaterr had been applied than where Temik had been applied. Hammond[3] reported that Sencor and various soil insecticides caused similar damage to soybean.

The results indicate that the herbicide Sencor (metribuzin) and the nematicide Curaterr (carbofuran) interact in soils with low organic matter and clay contents and the resulting phytotoxicity has a severe effect on the growth of plant cane. Where Sencor and Temik (aldicarb) were used, the damage to plant cane was slight. The herbicides Dual and atrazine appeared to have no effect on the growth of sugarcane and it is expected that Lasso and atrazine will also be safe as pre-emergent treatments for sugarcane. The results from two trials confirm that lime may reduce the efficacy of nematicides (Getzin cited by Homeyer[4]) if it is applied shortly before nematicides are applied.

Acknowledgements

The co-operation of the cane growers on whose farms field experiments were conducted is gratefully acknowledged. Thanks are also due to the technical staff of the Agronomy department and the staff of the Chemistry and Biometry departments of the South African Sugar Association Experiment Station. We would also like to acknowledge the valuable discussions held with the staff of Bayer South Africa.

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