NEMATICIDE EXPERIMENTS IN THE SOUTH AFRICAN SUGAR INDUSTRY: 1971/72

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Abstract

Excellent growth responses were achieved by treating a sugarcane plant crop with the following nematicides: Di-Trapex, EDB, aldicarb, a combination treatment of EDB and aldicarb and a combination treatment of soil and foliar applied oxamyl. Fairly satisfactory responses were obtained when using oxamyl as a foliar spray only, and as a soil treatment only, and as a foliar treatment in combination with soil applied methomyl. Only a small growth response was measured when the crop was treated with phenamiphos. There was no response to treatment with metmercapturon or prophos.

Aldicarb applied to ratooning sugarcane caused satisfactory growth responses. EDB, aldicarb and 'D-D' applied to a plant crop produced residual responses in a first ratoon crop. Rates of aldicarb ranging from 0,7 to 5,6 kg active ingredient per hectare produced large growth responses.

Plant-parasitic nematodes found in these experiments were *Xiphinema*, *Longidorus*, *Trichodorus*, *Criconemoides*, *Dolichodorus*, *Rotylenchulus*, *Meloidogyne*, *Pratylenchus*, *Tylenchorhynchus* and Hoplolaims.

Introduction

In the South African sugar industry, nematode control and the use of nematicides have now become a practical and commercial undertaking. This paper concerns experiments which were designed to assess the effects of nematicides on nematodes and on sugarcane growth, the ultimate object being the development of effective and efficient control methods.

The experiments discussed here were conducted on deep sandy structureless soils, known locally as recent sands. All areas were nematode-infested and had in the past yielded consistently poorly. The sugarcane variety N55/805 was used in all experiments.

Experiment 1: Screening Trial

Materials and methods

Numerous trials conducted in the sugarbelt have shown ethylene dibromide (EDB); 1,3 — dichloropropene and 1,2 — dichloropropane ('D-D'); and aldicarb to be effective nematicides, each of which can substantially increase sugarcane yields.

A trial was therefore designed to compare the effects of aldicarb and EDB with a number of chemical formulations and combinations. The experimental area was ridged out for planting on the 11th November, 1971, after which the following treatments were established:

1. Control.
2. EDB 4,5 (in hydrocarbon diluent). Rate applied: 225 l/ha, 3 weeks before planting, at a depth of 23 cm, using a hand injector-gun. Injections were made 30 cm apart, one along the centre of the ridge on either side of the planting furrow, one half-way down either side of the furrow and one into the furrow base.
3. A 10% granular formulation of 2 — methyl — 2 — (methythio propionaldehyde O — (methylcarbamoyl) oxime, (aldicarb).
   Rate applied: 56 kg/ha (6,7 g/m) in the furrow at planting.
4. Methyl isothiocyanate + chlorinated C_3 hydrocarbons including dichloropropenes, dichloropropane and related chlorinated hydrocarbons (Di-Trapex). Applied as for treatment 2.
   Rate: 225 l/ha.
5. Combination of treatments 2 and 3.
6. Liquid: S- methyl 1 — (dimethylcarbamoyl) — N — [(methylcarbamoyl) oxy] thioformimidate, (oxamyl).
   Four knapsack applications onto the foliage until run-off, 41, 70, 98 and 132 days post-plant.
   Spray concentration: 2,4 g active ingredient/l of water plus 0,5 ml Triton B — 1956 spreader/sticker per l of mixture.
   Total rate 11,9 kg active ingredient/ha.
7. A 10% granular formulation of oxamyl applied as for treatment 3.
   Rate: 67 kg/ha (8 g/m) in furrow.
8. Combination of treatments 6 and 7.
9. A 90% wettable powder formulation of S-methyl N [(methylcarbamoyl) oxy] thioacetimidate,[2] (methomyl). Applied as for treatment 3. Rate: 16,25 kg/ha (2 g/m) in furrow, plus 3 sprayings of equal concentrations of liquid oxamyl at 41, 98 and 132 days post-plant.
   Total rate 9,9 kg active ingredient/ha.
10. A 10% granular formulation of 0 — ethyl — 0 — (3 — methyl — 4 — methylthiophenyl) — isopropylamido — phosphate or isopropyl — phosphoroamidic acid — 0 — ethyl — 0 — (3 — methyl — 4 — methylthiophenyl) — ester, (phenamiphos — suggested name).
    Applied as for treatment 3.
    Rate: 84 kg/ha (10 g/m) in the furrow.
11. An 80% wettable powder formulation of 3,5 — dimethyl — 4 — methyl — mercaptophenyl — N — methyl — carbamate (metmercapturon) mixed in water and sprayed into the furrow at planting.
    Rate: 21,25 kg/ha (2,6 g/m) in furrow.
12. A 10% granular formulation of O — Ethyl S, S — dipropyl phosphorodithioate, (prophos). Applied as for treatment 3.
    Rate: 67 kg/ha (8 g/m) in furrow.

The fumigant treatments Nos 2 and 4 were made when the soil moisture and temperature at 25 cm depth were 9% and 21°C respectively. With the exception of the foliar sprays all treatments were made at planting when the soil water was at field capacity (±10%) and the temperature at 23 cm depth was 23°C.

A randomized design with 4 replications was used. Plots were 6 m long by 5 rows spaced 1,2 m apart. The sugarcane, from this experiment was harvested 340 days after planting.

At different times during the trial samples from all plots were screened for nematodes. At 10 localities along the centre 3 rows of each plot soil and root samples were taken down to 46 and 23 cm respectively. Using a centrifugal-flotation technique (Jenkins[2]), a total count was made of nematodes extracted from sub-samples of the soil from each plot. A flask incubation technique was used for extracting nematodes from sub-samples of roots.

responses when applied separately. However, in combination the response was excellent and appeared to be additive, indicating that the separate treatments did not provide optimum protection against nematodes. When using oxamyl (treatment 6), it was observed that by the time there had developed sufficient leaf area to accept the first foliar application, a large amount of root damage had already occurred. In order to derive the full benefit from nematode control it is important to protect the roots from nematodes during their early stage of development. It seems therefore that oxamyl foliar spray could be used successfully in combination with a suitable soil-applied nematicide.

Assuming the foliar oxamyl treatments in treatments 9 and 8 to have been equally effective, the results shown in Table 1 indicate that methomyl at the rate applied was less effective than the oxamyl granular which in turn was not as effective as the aldicarb granular. There appeared to be an interaction in the aldicarb-EDB combination treatment again indicating that these chemicals when applied separately did not provide optimum protection.

Results

TABLE 1
Final yield results

Treatment No.	Treatment	Ranking	Tons cane/ha	Response Tons cane/ha	Tons ERS/ha
4	Di-Trapex	1	103	+36	14,8
5	Aldicarb/EDB	2	99	+32	14,4
2	EDB	3	93	+26	13,2
3	Aldicarb	4	94	+27	13,1
8	Soil/foliar oxamyl	5	93	+26	13,1
9	Comb. Methomyl/oxamyl	6	82	+15	11,9
7	Soil — oxamyl	7	80	+13	11,3
6	Foliar — oxamyl	8	79	+12	11,2
10	Phenamiphos	9	75	+ 8	11,0
11	Metmercapturon	10	68	+ 1	9,3
1	Control	11	67		9,1
12	Prophos	12	63	− 4	8,9
L.S.D. (0,05)			15,2		1,93
(0,01)			20,4		2,60
C.V.			12,7%		11,4%

(a) *Effects on crop*

The plant crop yields and ERS (estimated recoverable sugar) are shown in Table 1. Compared with the untreated control, treatments 4, 5, 2, 3 and 8 caused dramatic growth responses. This was evident from the time of sprouting, when relatively more shoots were produced. Stalk elongation was particularly striking in the Di-Trapex treatment. Aldicarb, although associated with excellent tillering, did not initially cause as good stalk elongation as did the Di-Trapex and EDB treatments. This initial growth lag associated with aldicarb could have been due to the relatively dry period immediately after planting, preventing the nematicide being released into the soil and taken up by the roots in sufficiently large quantities. These conditions did not persist however, and the aldicarb treated cane subsequently made rapid growth.

The oxamyl treatments caused fairly satisfactory

Shoot development and growth habits in the young plant indicated that both phenamiphos and in particular prophos were mildly phytotoxic. Phenamiphos did however cause an 8 ton growth response which approached significance at the 5% level.

Although not generally used as a nematicide, metmercapturon was tested because *Pratylenchus* was present, and it is reported as controlling a species of the genus (Thompson and Willis[3]). It seemed to suppress the numbers of this nematode slightly, but caused no growth response.

(b) *Effects on nematodes*

The genera of plant-parasitic nematodes most frequently found associated with sugarcane roots were *Xiphinema*, *Trichodorus*, *Criconemoides*, *Meloidogyne*,

TABLE 2

Nematodes extracted from 100 cc of soil. Nos of saprozoic nematodes to closest multiple of 5

Treatment	Di-Trapex	Ald/EDB	EDB	Ald.	Soil/foliar oxamyl	Methomyl/oxamyl	Oxamyl-soil	Oxamyl-foliar	Phenamiphos	Metmercapturon	Prophos	Control
No.	4	5	2	3	8	9	7	6	10	11	12	1
Sampling time												
						Xiphinema						
Preplant	0	0	0	6	0	0	2	1	0	3	1	0
30 wks post-plant	0	0	1	31	18	23	49	13	53	20	23	57
						Trichodorus						
Preplant	0	1	0	9	6	5	2	7	4	5	2	3
30 wks post-plant	84	172	0	49	8	46	69	16	76	23	47	39
						Criconemoides						
Preplant	0	0	0	0	0	0	0	0	0	1	1	0
30 wks post-plant	1	124	3	51	17	80	48	35	53	31	228	60
						Meloidogyne larvae						
Preplant	0	0	0	0	2	0	0	0	0	0	1	0
30 wks post-plant	1	6	5	35	17	97	68	78	259	110	296	213
						Pratylenchus						
Preplant	0	0	0	0	3	2	3	0	1	1	2	1
30 wks post-plant	4	1	3	30	7	18	13	1	22	14	48	66
						Hoplolaims						
Preplant	1	0	1	9	10	5	18	3	2	8	4	7
30 wks post-plant	7	1	0	52	8	19	40	4	22	29	37	83
						Saprozoic nematodes						
Preplant	7	187	50	275	295	435	470	380	330	590	350	325

Pratylenchus and nematodes in the sub-family Hoplolaiminae (Hoplolaims). Low numbers of *Longidorus, Dolichodorus, Tylenchorhynchus* and *Rotylenchulus* were occasionally extracted from soil around the roots. Their distribution was patchy and their numbers low. Female *Rotylenchulus* were not observed on the roots.

Table 2 shows the number of nematodes extracted at 2 sampling times. The preplant sampling was done 18 days after the EDB and Di-Trapex treatments. The post-plant sampling was done 30 weeks after planting.

Although numbers of nematodes extracted were generally low, preplant treatments 2, 4 and 5 appear to have lowered their numbers, in particular the saprozoic nematodes and also *Xiphinema, Trichodorus*, Hoplolaims and probably *Pratylenchus*. From the results of the post-plant sampling this effect seemed to include *Meloidogyne*, (the numbers of which were assessed by larval counts only) and possibly *Criconemoides*. At the second sampling the effects of the fumigants appeared to be persistent for *Xiphinema, Meloidogyne, Pratylenchus* and Hoplolaims. An increase in numbers of *Trichodorus*, in relation to other plant-parasitic nematodes, is generally associated with the use of the fumigant nematicides. This occurred in treatment 4 and 5 and not in treatment 2, in which it was however, found to have occurred in a later sampling assessment.

The systemic nematicides aldicarb and oxamyl were associated with lower numbers of *Meloidogyne* larvae, and metmercapturon and oxamyl with lower numbers of *Pratylenchus*.

Table 3 shows the totalled results of extractions from soil and root samples taken from control and oxamyl foliar treated plots (treatment 6). The figures strongly suggest a lowering in numbers of both endo- and ecto-parasitic nematodes by oxamyl, indicating a downward translocation into the roots of a nematicidal concentration of the chemical.

TABLE 3

Nematodes extracted from 400 cc soil and 24 g root samples taken from control and oxamyl foliar-treated plots

	Soil		Roots	
	Treated	Control	Treated	Control
Meloidogyne larvae	10	84	6	109
Pratylenchus	0	56	10	94
Criconemoides	12	35		
Xiphinema	9	42		
Trichodorus	6	25		
Hoplolaims	5	23		

On deep sandy soils sugarcane roots may develop down to 5 m or more. Field investigations by the author showed the presence often in large numbers of certain genera of nematodes, known to be damaging to sugarcane, at depths of at least 3 m. Since it is impractical in field trials to sample so deeply, it becomes necessary to interpret results by using root and soil samples taken at relatively shallow levels. This is not entirely satisfactory but where a crop has responded to treatment an early comparison of its roots with those from an untreated area indicated a reduction in injury by nematodes.

Experiment 2: Residual and post-plant treatment effects of nematicides

Materials and methods

Since it is known that nematicide application particularly to the soil, can offer partial protection for a limited period only, it becomes necessary to establish the effect on the subsequent ratoons of a crop which has responded well in its plant crop stage. In addition it becomes necessary to know whether a growing or ratooning crop will respond to nematicide treatment. To investigate the above effects, it was decided to ratoon the sugarcane in a plant crop experiment where a number of nematicides had been applied by various methods (Harris[1]).

By restricting the randomization so as to have equal representation of treatments in the original replication, 24 plots in which the growth had not been significantly different from the control treatments, were selected for ratoon treatment. Two levels of aldicarb, applied 3 weeks after harvesting, and replicated 8 times, were used as follows:

1. Control.
2. Aldicarb 10% granules placed and covered in a trench on either side of the cane row, approximately 15 cm from its centre and 5-11 cm deep.
   Rate: 56 kg/ha (3,9 g/m trench).
3. Placed as for treatment 2.
   Rate: 28 kg/ha.

The remaining 40 plots were ratooned without treatment so as to measure residual effects of the original plant crop treatment (replicated 4 times). The treatments and responses in the plant crop were as follows:

1 and 2. Double set of controls.

3. EDB 2,25 (in hydrocarbon diluent) applied overall 3 weeks before planting by tractor-mounted tine injector.
   Rate: 450 l/ha.
   Response: 7 tons cane/ha.
4. EDB 2,25 applied 3 weeks before planting by tractor-mounted single tine injector. Applied along a line where the planting furrows were drawn 18 days later.
   Rate: 339 l/ha.
   Response: 13 tons/ha.
5. 1,3 — dichloropropene and 1,2 — dichloropropane ('D-D') applied as for treatment 4.
   Rate: 225 l/ha.
   Response: 30 tons/ha.
6. 'D-D' applied 3 weeks pre-plant by single tine injector into the base of the drawn planting furrow.
   Rate: 225 l/ha.
   Response: 30 tons/ha.
7. 1,2—dibromo—3—chloropropane (DBCP80EC) applied as for treatment 4.
   Rate: 23 l/ha.
   Response: Nil.
8. DBCP80EC applied as for treatment 6 at planting.
   Rate: 23 l/ha.
   Response: 11 tons/ha.
9. Aldicarb 10% granules applied in furrow at planting.
   Rate: 56 kg/ha (7,8 g/m).
   Response: 66 tons/ha.
10. Aldicarb 10% granules applied as for treatment 9.
   Rate: 28 kg/ha (3,9 g/m)
   Response: 48 tons/ha.

The first ratoon crop of this experiment was harvested on 24th October, 1972, 379 days after harvesting of the plant crop.

Results

(*a*) *Post-plant treatment effects*

In Table 4, taking a mean yield of 115 tons/ha for the aldicarb treatments, a mean response of 23 tons/ha is encouraging as it indicates that nematicide treatment of the ratooning plant may become feasible even when applying a relatively low quantity of the chemical. However, in two observational trials, where attempts have been made to improve the growth of ratoon cane when using a number of nematicides including aldicarb, results have not been as encouraging. These results should therefore be treated with caution until more become available.

TABLE 4
Final yield results of first ratoon (post-plant treatment)

Treatment	Tons cane/ha	Response Tons cane/ha	Tons ERS/ha
1. Control	92		13,3
2. Aldicarb 56 kg/ha	112	20	15,5
3. Aldicarb 28 kg/ha	119	27	16,8
L.S.D. (0,05)	15,4		1,88
(0,01)	21,4		2,61
C.V.	13,4%		11,6%

The erratic and smaller growth responses resulting from ratoon nematicide application were probably partly caused by the presence of large quantities of undecomposed root material protecting endoparasitic nematodes from the chemical. In addition, by binding a certain amount of the chemical, it could have rendered it incapable of further movement at concentrations high enough to reduce nematode attack satisfactorily. It is possible also that nematodes may have caused some phytotoxicity from which the plant did not fully recover despite the relative scarcity of nematodes after treatment.

(*b*) *Residual effects*

Table 5 shows that there was relatively high variability (cv 20,9%) in this experiment and a great deal of confidence should not be placed in the results.

The 21 ton residual response in treatment 4 is fairly large (P<0,05), but taking into consideration the excellent responses to both levels of aldicarb applied in the plant crop, it becomes difficult to explain why an 18 ton residual response was achieved with aldicarb at the high level and no response to aldicarb at the low rate. This result could indicate that in order to achieve a longer period of protection from nematodes, quantities of aldicarb greater than 28 kg/ha would have to be applied. Of the remaining treatments tested only EDB and 'D-D' applied before planting along the furrow line appeared to cause residual responses. This was presumably due to treating the soil along the line of the furrow before it was drawn, and not only the soil below the furrow base after the furrow had been drawn for planting.

The relatively low and often absent residual responses were almost certainly due to the re-invasion of the roots and root zone by harmful nematodes which took place before the second crop was harvested.

The total response in both crops was higher for both aldicarb treatments than for the other nematicides.

TABLE 5

Final yield results of first ratoon (residual effects)

No.	Treatment	Tons cane/ha	Response tons cane/ha	Total response plant + ratoon tons cane/ha
1	Control	89		
2	Control	84		
3	EDB overall	89	Nil	7
4	EDB furrow line	110	21	34
5	'D-D' furrow line	100	11	41
6	'D-D' in-furrow	89	Nil	30
7	DBCP furrow line	79	Nil	Nil
8	DBCP in-furrow	89	Nil	11
9	Aldicarb 56 kg	107	18	84
10	Aldicarb 28 kg	87	Nil	48
	L.S.D. (0,05)	18,3		
	(0,01)	24,8		
	C.V.	20,9%		

Experiment 3: Aldicarb rates

Materials and methods

Aldicarb when used under certain conditions has proved to be a satisfactory nematicide (Harris[1]). The following experiment was designed to find effective and optimum rates at which it should be applied in the furrow at planting. A latin square (5×5) design was used. Plots were 12 m long by 5 rows 1,2 m apart. The trial was planted on 11th November, 1971, when the soil moisture and temperature at 23 cm depth were 9% and 21°C respectively. Treatments were as follows:

1. Control.
2. Aldicarb 10% granules at 6,7 g/m in the planting furrow.
   Rate: 56 kg/ha.
3. 4. 5. as for treatment 2.
   Rate: 28 kg/ha.
   14 kg/ha.
   7 kg/ha respectively.

The cane from the experiment was harvested 452 days after planting. The results are shown in Figure 1.

Results

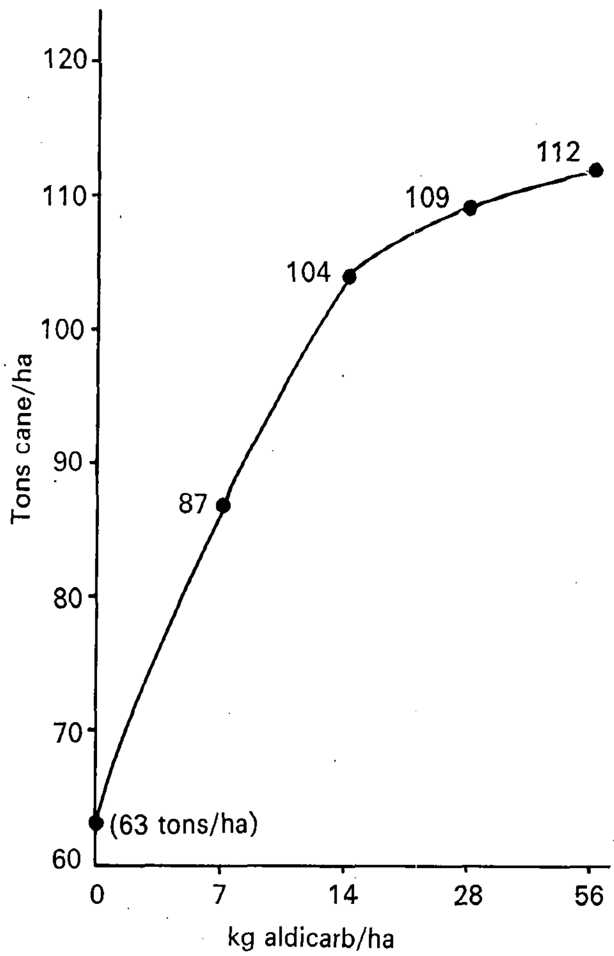

FIGURE 1: Growth responses to 4 rates of aldicarb.

(*a*) *Effects on yield*

Figure 1 shows that a highly satisfactory growth response was achieved where as little as 0,7 kg (active) of aldicarb was applied per hectare. The response was nearly linear up to the 14 kg rate, above which the curve became less steep and tended to level off at about the 56 kg/ha rate, above which it seems that comparatively little extra growth would have been obtained. The optimum rate appears to be between 14 and 56 kg/ha. This rate may, however, require adjustment when taking into consideration the results shown in Table 5, where a higher rate resulted in a greater residual response and presumably a longer-lasting effect.

As the experiment progressed it became most noticeable that the growth in the 14 kg and, in particular, in the 7 kg treatments, was sparse and uneven compared with that in the 28 and 56 kg/ha treatments.

(*b*) *Effects on nematodes*

Soil and root samples were taken 10 weeks after planting in the same way as described for the screening trial. The results are listed in Table 6 for completeness. The numbers of nematodes extracted were comparatively small and with the possible exception of *Meloidogyne* there are no strong indications of lowered numbers.

TABLE 6

Total numbers of plant-parasitic nematodes extracted from 500 cc and 30 g soil and root samples respectively

Treatments	Soil				
	Control	7 kg	14 kg	28 kg	56 kg
Meloidogyne larvae	14	2	2	2	5
Pratylenchus	11	7	7	11	3
Criconemoides	35	32	73	34	26
Hoplolaims	10	40	25	21	10
Xiphinema	0	1	11	6	0
Trichodorus	4	16	12	27	5
Tylenchorhynchus	1	0	1	1	4
Rotylenchulus	26	1	2	0	3
			Roots		
Meloidogyne larvae	1	0	0	0	0
Pratylenchus	4	17	12	4	2

Conclusions

These experiments, as others have done, have indicated the severity of the nematode problem. It was shown that certain nematicides applied to the plant crop can increase sugarcane yields substantially. Aldicarb nematicide which is being successfully used in the sugar industry was shown to cause very satisfactory growth responses when applied at rates below 6,7 g/m which is the quantity currently being recommended.

Residual growth responses and responses due to ratoon application of nematicides were obtained. Such responses, although not as large as those which can be obtained in a plant crop, could have a major influence on the economics of nematicide treatment.

REFERENCES

1. Harris, R. H. G., 1972. Effects of nematicides and methods of applying them on field grown sugarcane. Proc. S. Afr. Sug. Technol. Ass. 46 : 226-229.
2. Jenkins, W. R., 1964. A rapid centrifugal-flotation technique for separating nematodes from soil. Pl. Dis. Reprt 48: 692.
3. Thompson, L. S. and Willis, C. B., 1970. Effect of nematicides on root lesion nematodes and forage legume yields. Can. J. Pl. Sci. 50 : 577-581.