RECENT INVESTIGATIONS ON NEMATODES IN SUGARCANE FIELDS

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Abstract

Three experiments on the control of nematodes in sugarcane fields are described and results based on yield responses and nematode numbers are quoted. *Meloidogyne* practically disappeared when the grass, *Eragrostis curvula* was grown for three seasons, but increased when tomatoes and beans were grown. Yield responses to nematocides in the absence of *Meloidogyne* show that this is not the only nematode concerned. In a second experiment the sugarcane variety N50/211 responded considerably more to treatment with nematocide than did N55/805, suggesting a degree of tolerance in the latter variety. Under the conditions of this experiment chicken litter was ineffective. In a comparison of different nematocides, EDB and DBCP were more effective than Temik or Lannate but this might have been due to the high pH of soil in the experimental site.

Introduction

For more than ten years the Experiment Station has collected information on the rôle of nematodes in sugarcane fields. Evidence has accumulated to show that some of the plant-parasitic types are harmful to sugarcane and the most convincing evidence derives from the response, in the form of increased yield, which often follows nematode control.

It must be admitted that such response does not, by itself, prove the existence of a nematode problem since other pests and diseases may be controlled by nematocides and the nutrient status of the soil, especially the amount of available nitrogen, may be altered by them.

Further study of these alternative factors, however, fails to produce convincing evidence that they are, to a significant degree, involved in this response. For example, independent experiments on the control of soil micro-arthropods suggested that they were of little importance in sugarcane fields. We do not know of any root disease the control of which would make as great a difference to sugarcane yield as sometimes results from soil fumigation. In most of the soils, in which yield is significantly increased by nematocides, sugarcane does not respond in the plant crop to added nitrogen in either the nitrate or the ammonia form.

The three experiments discussed in this paper are concerned with nematode control. In the first, soil fumigation superimposed on the effects of different crop plants produced some interesting results. The grass, *Eragrostis curvula,* by practically eliminating nematodes of the genus *Meloidogyne,* made it possible to estimate the importance of these and other nematodes. In the second experiment the observation that different varieties of sugarcane may differ in the degree to which they are affected by nematocides, and presumably therefore by nematodes, was confirmed. The third experiment tested the effects of a number of different chemicals with nematocidal properties.

A disturbing result of all the experiments involving soil fumigation is the discovery that nematocide applications may be followed by significant increases in numbers of nematodes of the genus *Trichodorus.* This makes it necessary to investigate in greater detail the rôle of the genus in sugarcane yields.

Effects of previous crops and nematocide

The experiment described in this section was initiated towards the end of 1965 in order to investigate the effect of apparently resistant or susceptible plants on a mixed field population of nematodes. Half of a small field (0,16 ha) on Clansthal red sandy soil at the Central Field Station, Mount Edgecombe, was planted with the Ermelo strain of the grass, *Eragrostis curvula* Nees, while the other half was planted with tomatoes, *Lycopersicon esculentum* Mill. *Eragrostis,* which is regarded as resistant to nematodes, soon produced a full canopy, after which it required very little weeding. Being perennial, it did not have to be replanted during the three-year period which was considered necessary to ensure its full effect on the nematode population.

The tomato plant is a good host for many species of plant-parasitic nematodes, but tomatoes could not be grown in the same site for three years. When the first crop died, a second was planted but, because of diseases and the effects of nematodes built up by the first crop, did not grow well. For this reason, the site was planted with ration beans, *Phaseolus vulgaris* L., (mixed strains) after the second tomato crop. Three crops of beans were grown and, in each case, weeds which developed as the beans were drying off were allowed to remain until the next planting.

Nematode population trends were studied by screening of soil samples collected at quarterly intervals until October 1966, and then at monthly intervals until December 1968 when the field was replanted with sugarcane. Subsequently sampling at two depths — down to 228 mm and from 228 to 456 mm — was carried out at weekly intervals, soil temperatures and moisture contents being recorded at the same time. It is intended that the detailed results of these observations should form the subject of a separate paper.

Although it had been considered necessary to allow both the resistant and the susceptible plants three years in which to produce their full effect this was, in fact, achieved during the fist two years after which, apart from temporary fluctuations, there was little significant change in population composition. The figures in Table I represent nematodes recovered from 600 ml of soil from each site. In order to reduced the size of temporary fluctuations, counts from samples collected between December 1967 and April 1968 have been combined.

TABLE I

Nematodes in 600 ml of soil

	Under Eragrostis	Under Tomatoes/ Beans
Meloidogyne larvae	1	1 629
Hoplolaims	275	95
Other Tylenchs	60	32
Xiphinema	60	68
Trichodorus	7	14
Other Dorylaims	200	317
Rhabditids etc.	4 248	4 125
Mononchs	9	185

In the tomatoes/beans site there were large populations of *Meloidogyne,* and relatively large numbers of predaceous nematodes belonging to the family Mononchidae which might possibly have been associated with the presence of *Meloidogyne.* In the *Eragrostis* site, *Meloidogyne* had practically disappeared. Nematodes belonging to the family Hoplolaimidae were about three times as numerous as in the tomatoes/beans site but Mononchs were rare.

Investigation of the effects of nematocide treatment had not been envisaged for this field in which the arrangement of the two sites, with *Eragrostis* at one end and the tomato/bean succession at the other, would have made it difficult to interpret interactions in the response of sugarcane to previous crop and chemical treatment. Nevertheless the extreme difference in *Meloidogyne* populations between the two sites presented an opportunity of studying the importance of this genus as a pest of sugarcane. In November 1968, therefore, grass and beans were ploughed out and each site was divided into six small plots half of which, selected randomly, were treated with EDB — 4,5, applied by means of hand injectors at 224 litres per hectare. Three weeks later, all plots were planted with sugarcane of the variety N50/211.

Effect on sugarcane yield

As soon as the cane started to grow, a very marked positive response to nematocide treatment was observed, regardless of the previous crop. When the 13-month plant cane was harvested in January 1970 the response to nematocide, amounting to 32 tons cane per hectare or 3,9 tons sucrose per hectare, was statistically significant at the 1% level but no significant response due to previous crop could be demonstrated (Table II). When the anomalous results in one replication were omitted, the mean yield increment following treatment with EDB rose to 57 ± 9,6 tons cane per hectare in the site previously under tomatoes and beans.

TABLE II

Yield as 13-month plant cane

Previous crop	Nematocide treatment	Tons cane per hectare	Sucrose % cane	Tons sucrose per hectare
Tomato/bean	Nil	63	10,6	6,7
Tomato/bean	EDB	100	11,5	11,5
Eragrostis	Nil	84	10,5	8,8
Eragrostis	EDB	110	10,6	11,7

The significant response to nematocide treatment in plots from which *Meloidogyne* had practically disappeared during three years under *Eragrostis* indicated that the growth retardation in untreated plots was due either to nematodes other than *Meloidogyne* or to factors other than nematodes. The presence of nematodes of the family Hoplolaimidae, and their control by EDB, may have contributed to this response.

During the development of the first ratoon, residual responses to earlier treatments appeard in the form of greener leaves and more vigorous growth in previously fumigated plots. In addition, growth appeared to be better in the site formerly under *Eragrostis* than in the tomatoes/beans site. However, when the cane was harvested as a 13-month ratoon, in January 1971, these differences had largely disappeared.

Effect on nematode populations

Since the numbers of nematodes in soil samples collected at weekly intervals are found to fluctuate over a very wide range, the counts obtained on any one occasion after fumigation do not give a reliable assessment of the effect of nematocides. A more realistic comparison can be drawn from the population level at the first peak for each nematode being studied. Such peaks occurred between 12 and 21 weeks after treatment (Table III) and showed that fumigation had reduced populations of *Meloidogyne* and the Hoplolaims by about 80%. *Eragrostis* was more effective than fumigation against *Meloidogyne* but not against the Hoplolaims.

TABLE III

Effect of previous crop and treatment on numbers of nematodes

Treatment	Meloidogyne		Hoplolaims		Trichodorus	
	No.*	Weeks†	No.*	Weeks†	No.*	Weeks†
B fumigated	60	20	2	22	241	17
B untreated	287	19	10	12	4	19
G fumigated	8	20	6	18	111	21
G untreated	25	20	41	20	2	20

B — Cane planted after tomatoes and beans
G — Cane planted after Eragrostis curvula
* — Peak number recovered from 60 ml soil
† — Time in weeks from treatment to peak

For *Tricodorus*, counts revealed a startling increase in fumigated plots which was consistent throughout the trial and confirmed previous observations. In spite of periodic fluctuations, higher number of *Trichodorus* persisted in fumigated plots until after the plant cane harvest. This phenomenon is possibly associated with the production by sugarcane in treated plots of a healthy root system on which *Trichodorus* can thrive, but reduced competition by other nematodes, and suppression of biological control agents may also be involved.

It now becomes important to know to what extent infestation by nematodes of the genus *Trichodorus* can affect the growth of sugarcane. If they significantly reduced yield, the long-term effect of fumigation may be to intensify rather than to alleviate the problem. This factor is now being investigated by means of tests in which sterilised soil is inoculated with cultures of *Trichodorus*. The fact that, in the field experiment described here, there was a positive yield response to fumigation in spite of increased populations of *Trichodorus* would suggest either that these nematodes affect sugarcane only during the first few weeks of its growth or that they do not constitute a serious pest of sugarcane.

Effects of chicken litter, soil fumigant and variety of sugarcane

In comparing the effects of nematocides on different varieties of sugarcane, it was assumed that a variety which responded to soil fumigation could be regarded as susceptible to nematodes while one which did not respond was probably either resistant or tolerant. In an exploratory trial, planted at the Central Field Station in September 1967 and harvested in July 1969, evidence was obtained that sugarcane varieties did, in fact, differ significantly in their response to nematocide treatment. Twenty varieties were tested in fumigated and untreated soil in 16 randomised blocks in which single stools of sugarcane were used as plots. Largely on account of the smallness of the plots the experimental error was high (35,6% of the mean) and the experiment described in this section was therefore designed primarily to obtain a more accurate comparison between two varieties selected from the extremes of the range of apparent susceptibility. The varieties chosen were N50/211 which had responded very significantly to soil fumigation and N55/805 which had not responded.

When included as a treatment in an agronomic trial at the Central Field Station in 1967 chicken litter, a by-product of the poultry industry, caused more tillers and greener foliage to be produced during the development of a sugarcane crop. At harvest, however, yield increases were disappointing. Chicken litter was included in the experiment described in this section in an attempt at determining to what extent the apparent response might have been due to the control of nematodes.

The experiment, based on a 2^3 factorial design with four replications, was planted at the Central Field Station in October 1969. Nematode populations at the start of the investigation were not particularly high but sugarcane in an adjacent field with similar populations had responded significantly to nematocide treatment. Varieties and treatments were as shown in Table IV, soil fumigation with EDB-4,5, at 224 litres per hectare, being carried out by means of hand injectors, and chicken litter being applied, at 6,7 tons per hectare, in the furrow before planting.

TABLE IV

Experimental treatments and varieties

N50/211	X Soil fumigated	X Chicken litter
N55/805	Soil not fumigated	No chicken litter

Effect on sugarcane

At intervals during the development of the crop attempts were made to assess growth differences between treatments by using two criteria, namely numbers of stalks in the middle row of each plot and mean height of a random sample of stalks. Figures obtained in June 1970, seven months after planting, are shown in Table V. For each criterion and for both varieties the treatments can be arranged in descending order as follows:

Fumigated, without litter
Fumigated, with litter
Not fumigated, with litter
Not fumigated, without litter.

TABLE V

Prelimary assessments, June 1970

Treatment	Stalks per row		Mean height of stalks, mm	
	N50/211	N55/805	N50/211	N55/805
Fumigated, no litter	182	205	860	730
Fumigated, chicken litter	168	202	700	570
Not, fumigated, chicken litter	167	185	640	560
Not fumigated, no litter	143	166	600	340

When the cane was harvested as a 15-month plant crop in January 1971 the yield, in tons cane per hectare, showed a significant response (at 1%) to soil fumigation. The yield increase in N50/211, amounting to 19 tons cane per hectare, was significantly greater than that in N55/805, confirming the result of the preliminary trial. Harvesting took place at a period of low and variable sucrose and the figures for estimated recoverable sucrose per hectare, while still showing a significant response to fumigation, do not show differences in response between the varieties.

For both tons cane per hectare and tons ERS per hectare chicken litter reduced the yield of N55/805, but not of N50/211. The disappointing results obtained from this treatment appear to have been associated with the severe drought which occurred between February and April 1970 since cane in chicken litter showed symptoms of moisture stress, in the form of wilted and scorched foliage, at an earlier stage and more severely than did the rest of the cane. Perhaps for the same reasons, fumigation did not significantly increase the yield in chicken litter plots although it did so in plots without litter.

Although the total weight of cane produced by the two varieties did not differ significantly, the higher sucrose content of N55/805 led to a significantly better figure for tons ERS per hectare in this variety. Results are summarised in Table VI.

TABLE VI

Yield of 15-month plant cane

	Tons cane per hectare		Tons ERS per hectare	
	No EDB	EDB	No EDB	EDB
N50/211	120	139	6,4	8,0
N55/805	131	133	7,8	9,6
No litter	123	142	7,3	9,9
Litter	128	130	7,0	7,6
	No litter	Litter	No litter	Litter
N50/211	128	131	7,7	6,7
N55/805	136	127	9,5	8,0

TABLE VII

Mean numbers of nematodes in 60 ml soil during nine months after treatment

	Variety N50/211			
	EDB		No EDB	
	Litter	No litter	Litter	No litter
Meloidogyne larvae	5	15	59	43
Hoplolaims	4	4	27	30
Other Tylenchs	3	11	20	17
Trichodorus	67	47	13	2
Saprobiotic nematodes	2 395	283	766	273

	Variety N55/805			
	EDB		No EDB	
	Litter	No litter	Litter	No litter
Meloidogyne larvae	4	7	57	18
Hoplolaims	2	8	9	15
Other Tylenchs	5	24	7	20
Trichodorus	66	75	10	3
Saprobiotic nematodes	849	312	1 436	236

	Variety and treatment means					
	Litter	No litter	EDB	No EDB	N50/211	N55/805
Meloidogyne	31	21	8	44	31	22
Hoplolaims	11	14	5	20	16	9
Other Tylenchs	9	18	11	16	13	14
Trichodorus	39	32	64	7	32	39
Saprobiotic	1 362	276	960	678	929	708

Effect on nematodes

On account of the difficulty of handling the large number of samples involved, nematode assessments were made only at quarterly intervals. To minimise the effect of periodic fluctuations, the results of the first three such assessments were posted to obtain the figures shown in Table VII. It should be noted that these figures do not show, in the customary sense, mortalities due to treatment since populations had started to recover before collection of the last set of samples. Nevertheless, for *Meloidogyne* and the Hoplolaims, which were the only Tylenchida present in sufficiently large numbers to be considered separately, fumigation caused decreases amounting to 85% and 80% respectively. On the other hand, as in a number of previous experiments, fumigation led to an increase in the numbers of *Trichodorus*. The only noticeable effect of chicken litter was to increase the numbers of saprobiotic nematodes, a result which could have been predicted since these nematodes thrive in the presence of decomposing organic matter. Predators belonging to the family Mononchidae were scarce and their numbers did not increase with those of the saprobiotic nematodes, although such an increase has been observed in other experiments.

Comparison of different nematocides

In a considerable number of experiments in South African sugarcane fields, particularly in areas where the soil is sandy, significant yield increases have followed soil fumigation with the standard nematocide, EDB (ethylene dibromide). However, some anxiety has been caused by the fact that treatment with EDB often results in increased populations of nematodes belonging to the genus *Trichodorus* which are suspected of being harmful to sugarcane. A field experiment was therefore carried out to investigate possible effects on sugarcane yield and on *Trichodorus* populations of a number of toxicants. These included the relatively newly developed nematocides Temik (U.S.21149) and Lannate (methomyl) and the insecticides Thimet (phorate) and Basudin (diazinon) for which some nematocidal properties are claimed. As yet we have few results comparing the effects of the different standard nematocides and, for this reason DBCP (dibromochloropropane) was included for comparison with EDB. Finally filter cake was included since this material is thought to affect nematode populations by encouraging biological control. In earlier trials significant yield increases, as well as decreases in numbers of plant parasitic nematodes, had resulted from filter cake applied in the planting furrow at 90 tons per hectare.

The experiment was established at the Central Field Station, using a random block design with six replications, and sugarcane of the variety N50/211 was planted at the end of October 1969. Treatments and rates of application were:

EDB-4,5 at 224 litres per hectare

DBCP (Fumagon EC), 112 litres in 336 litres water per hectare

Temik, 10% granules at 56 kilograms per hectare

Lannate, 90% wettable at 6,2 kilograms per hectare

Thimet, 10% granules at 56 kilograms per hectare

Basudin, 5% granules at 224 kilograms per hectare

Filter cake, at 90 tons per hectare

Effect on sugarcane

As in the experiment described above, preliminary assessment of the results was made by counting and measuring samples of cane stalks. Figures obtained in June 1970 (Table VIII) showed that, seven months after planting, plots treated with EDB had produced more and taller stalks than had any of the others, with most of these intermediate between EDB and the untreated control.

TABLE VIII

Preliminary assessment, June 1970

Treatment	Stalks per row	Mean height of stalks mm
EDB	189	970
DBCP	162	900
Temik	166	860
Lannate	162	790
Filter cake	169	790
Thimet	144	740
Basudin	143	740
Control	146	730

TABLE IX

Yield of 15-month plant cane

	Tons cane per hectare	Tons ERS per hectare
EDB	138	10,1
DBCP	133	10,1
Temik	125	9,4
Lannate	114	9,2
Filter cake	116	7,0
Thimet	124	7,1
Basudin	114	7,0
Control	127	8,5

When the cane was harvested as a 15-month plant crop in January 1971 the results (Table IX) showed no significant differences between the control and any of the treatments, although it was still possible to draw comparisons between treatments. On a basis of tons cane per hectare, EDB and DBCP were better than filter cake, Basudin and Lannate, with Temik and Thimet intermediate. For tons ERS per hectare EDB and DBCP were highly significantly better (at 1%), while Temik and Lannate were significantly better (at 5%) than filter cake, Basudin and Thimet.

The disappointing result for filter cake which, in other trials has been found to produce significant yield increases associated with decreased populations of plant-parasitic nematodes, might have been due to the severe drought experienced between February and April 1970. Wilting and scorching of leaves appeared earlier and in a more severe form in filter cake plots than in the rest of the experiment.

Temik was not as effective here as in a number of trials in other parts of the sugar belt. It is likely that this might be the result of the high pH shown by soils at the Central Field Station since there is now evidence that Temik may be inactivated in alkaline soils.

Effect on nematodes

For the sake of completeness, nematode counts are appended (Table X). These were derived by pooling and averaging assessments from samples collected during the first nine months after planting. Differences between untreated and treated plots are small but numbers of *Trichodorus* have increased in plots treated with either EDB or DBCP. The other toxicants have not produced this effect.

TABLE X

Mean numbers of nematodes in 60 ml soil during nine months after treatment

	Control	EDB	DBCP	Temik
Meloidogyne larvae	17	19	24	11
Hoplolaims	19	3	6	8
Pratylenchus	4	2	4	1
Other Tylenchs	31	19	7	10
Trichodorus	7	63	58	5
Xiphinema	3	0	0	1
Saprobiotic nematodes	341	224	255	195
	Lannate	**Thimet**	**Basudin**	**Filtercake**
Meloidogyne larvae	11	25	10	11
Hoplolaims	15	13	33	10
Pratylenchus	0	2	3	2
Other Tylenchs	11	13	14	8
Trichodorus	6	4	3	7
Xiphinema	1	2	1	2
Saprobiotic nematodes	176	209	242	748

Discussion

Mr. Crookes: At Chirundu DD was the commercially used nematocide and proved superior to EDB and DBCP so is there any reason why it was not used in these experiments?

On control crops methyl bromide was regarded as the nearest to 100% effective in killing nematodes, being much more effective in all respects than EDB and yet it also was not used in these experiments.

We used to apply 45 gallons of DD per acre, then irrigate, and we got striking results in the plant cane crop. Unfortunately there was a very poor residual effect in the ratoons which made the treatment very costly.

Dr. Dick: We did an initial trial with DD, EDB and DBCP and there was little to choose between them. The reason for using EDB for most of the trials was that when we started it was the only one readily available.

Other trials carried out since with DD have not shown it to be any better than the others under our conditions.

DD has one disadvantage in that it has a very corrosive effect on the machinery used to apply it.

We do not use methyl bromide because it is hardly a practical treatment in the field and it is very expensive. We use it as a routine treatment for soils in pot tests.

The response to ratoons in about 20 experiments we carried out indicated that there was an increase of about 5 tons per acre in the first ratoon crop compared with 15 tons in the plant crop. One experiment that went to the second ratoon had an apparent increase of 2 tons.

Mr. Harris: Preliminary results from a recent field trial do indicate that DD is slightly better than the others. I think an application of 26, not 45, gallons per acre is sufficient and this puts it on a par with EDB as regards cost.

Mr. Carnegie: Some of the papers read appear to give the impression that nematodes are merely an irritating factor and are responsible for spoiling experiments. However, there are many nematodes, all acting in different ways, and they are a very important factor in cane growth.

Filter cake is mentioned in this paper—what do the authors feel about fresh filter cake and filter cake that has degenerated?

Dr. Dick: Decomposition of organic matter in the soil leads to an increase in micro-organisms, including bacteria. There is a group of nematodes called saprobionts that feeds on the bacteria associated with decomposition.

In using filter cake, the first stage in control is the production of micro-organisms and then the development of harmless nematodes to feed on them. They would encourage the development of predacious nematodes and also various fungus diseases which could then attack the parasites.

Fresh filter cake, having more organic matter left to decompose, would lead to more saprobiotic nematodes, and probably also to more effective biological control.

Mr. Harris: We carried out a pot trial based on the reasoning just expounded by Dr. Dick and the results, which are being analysed at present, give the following nematode counts.

The count of total plant parasites, for fresh filter cake, old filter cake and no filter cake are 300, 1 000 and 3 000 respectively, showing a drastic reduction of plant parasitic nematodes.

We also took count of the saprobiont nematodes and the figures were 23 000, 8 000 and 4 000 for fresh filter cake, old filter cake and no filter cake respectively. The relative figures for predacious nematodes were 20, 40 and 300.

Mr. Boyce: Dr. Dick said that the average response to fumigants on plant crops has been 12 to 14 tons of cane per acre. Would he expect the same response to Temik?

Mr. Harris: We have had a good initial response to Temik but it faded so we cannot at this stage recommend it.

A trial we are carrying out at Tongaat using Temik has given a very big initial response but it may fade after 12 months.

Dr. Cleasby (in the chair): There was a suggestion that deep plougring might have an effect, among others, on the nematode population.

Mr. Harris: In deep ploughing experiments on the sands at CFS there were unexpected responses, possibly due to nematode control.

Mr. Moberly: The increase in deep ploughing on the sands was far smaller than that obtained from EDB so for economic reasons we would be in favour of EDB.

Dr. Dick: In one trial, in order to try and achieve complete control, the whole area was treated at foot intervals using a hand injector with a coverage of 40 gallons per acre of dilute EDB. In the same trial the furrow only was treated, using about a quarter of the amount. Furrow only gave about 60% of the response of the overall treatment so the economics of this could still be investigated.

Mr. Boyce: Regarding Temik, in one experiment at Tongaat the response was 30 tons per hectare plant crop but no residual response. In an observation experiment the response was about 16 tons of cane per hectare.

Large areas have been planted with Temik, and adjacent areas without it, and the response is 36 tons of cane per hectare.

Dr. Cleasby: The advantage of Temik is that it is a powder and can be applied in the furrow in a systemic manner.

Mr. Harris: Tongaat has been using 50 pounds of Temik per acre and our trial of 25 pounds per acre is giving results that are as good.

Dr. Dick: When Temik is used, is there the same increase in counts of *Trichodorus* as there is with EDB?

Mr. Harris: Counts have been done using after Temik and there was not a build-up of *Trichodorus*.