THE SUGARCANE NEMATODE PROBLEM

by J. DICK

A paper presented to this Association in 1961 summarised the results of investigations, carried out during the previous four years, on the rôle of nematodes in South African sugarcane fields.[7] This project has continued to receive attention, and the present paper is an attempt at summarising and generalising upon the results of more recent investigations. Since much of the experimental work involved has been described in Annual Reports of the Experiment Station, it is unnecessary to repeat details such as counts of nematodes and yields of cane obtained from particular nematocide trials, although a few are quoted as examples. If a single generalisation could be made at this stage, it would probably be that, despite investigations here and in other countries, the rôle of nematodes in sugarcane fields remains in many aspects a problem.

Types and status of Nematodes Concerned

Examination of soil samples from South African sugarcane fields reveals the presence of many different species of nematodes, and the task of determining which, if any, actually injure the cane plant is by no means easy. As a rule, the majority of individuals belong to the Order Rhabditida and other groups of which no member is known to be parasitic on plants. Most of these feed on decomposing organic matter or associated micro-organisms. Nematodes which attack the roots of plants may be internal parasites, such as the various species of *Meloidogyne* and *Pratylenchus*, external feeders, such as *Criconemoides*, *Xiphinema* and *Trichodorus*, or intermediate in being able to feed either externally or within the roots as do some species of *Hoplolaimus* and related genera. The plant parasites found in our cane fields, most of which have as yet been identified only to the genus, are listed in Table I.

Table I

Plant parasitic nematodes recorded from South African sugarcane fields

Soil	*Roots*
Meloidogyne javanica, larvae	*Meloidogyne javanica*
Meloidogyne incognita acrita, larvae	*Meloidogyne incognita acrita*
Hoplolaimus	*Ditylenchus*
Scutellonema	*Hoplolaimus*
Rotylenchus	*Pratylenchus*
Helicotylenchus	*Paratylenchus*
Pratylenchus	*Aphelenchoides*
Rotylenchulus, males and immature females	*Aphelenchus* (possibly feeding on fungi)
Criconemoides	
Paratylenchus	
Longidorus	
Xiphinema	
Trichodorus	

Their presence in this environment does not, of course, prove that they attack sugarcane since weeds are often present in sufficient numbers to provide them with nutriment. For species which occur in the roots of sugarcane it might appear safe to assume that they are parasitic on this plant, although the extent of their effect on it might be difficult to determine. Even in this environment, however, some saprophagous worms are usually present since the root system, especially of older cane, includes a considerable amount of dead and decomposing tissue. The improved yields which generally follow applications of nematocides to the soil of growth-failure areas suggest that nematodes have been responsible for poor growth prior to treatment. In interpreting these results, it must be remembered that most nematocides exercise some control over other organisms such as soil arthropods, molluscs, or even weeds, and that they may change the nature and amount of available plant nutrients through their action on soil micro-organisms.

Direct evidence has been obtained in some other countries by planting sugarcane in sterilised soil inoculated with more or less pure cultures of particular species. This can, unfortunately, only be done in pots and the results are qualitative rather than quantitative. Such experiments have produced evidence that the following species do affect the growth of sugarcane: *Meloidogyne incognita acrita*, *Helicotylenchus dihystera*, *Tylenchorhynchus martini*, *Pratylenchus zeae* and *Trichodorus christei*.[1-8] Our own experiments have given similar results for *Meloidogyne javanica* while circumstantial evidence casts suspicion on *Pratylenchus*, various Hoplolaimids, *Trichodorus* and, in a few localities, *Xiphinema*.

Root-knot nematodes (*Meloidogyne* spp.) are most numerous, and presumably most injurious, in sugarcane roots during early growth. Examination of samples collected at monthly intervals showed that populations in the roots attained their maximum from four to six months after planting, after which they decreased fairly rapidly (Fig. 1). Although numbers increased again in young ratoons, they did not reach the level attained in the plant cane. In at least one field, it was found that *Meloidogyne* was progressively replaced by a species of *Pratylenchus* (lesion nematode) as the cane roots became older.

In addition to saprophagous and plant parasitic nematodes, soil samples may yield specimens of predacious types which feed on small soil animals including other species of nematodes. The most noticeable of these belong to the family Mononchidae; they seldom occur in our cane field soils in sufficient numbers to be of importance in biological control of the plant parasites.

Association with organisms causing disease

Certain virus diseases of plants have been shown to be transmitted by nematodes, all known vectors being members of the Order Dorylaimida. At present no instance of this type of transmission is known for sugarcane although Martin *et al.* (1960) attempted to transmit ratoon stunting and chlorotic streak by this means.[9]

Synergistic association between nematodes and parasitic micro-organisms, including fungi and bacteria, has been demonstrated in a number of host plants. Up to the present, no such association has been proved to occur in sugarcane, although a suspected interaction between nematodes and root-rot fungi has been investigated in Hawaii. In Natal, Roth found a fungus, *Mortierella* sp., in sugarcane roots in which infestation by *Meloidogyne javanica* had produced typical nodules. Possible association between these two organisms was investigated by planting sugarcane cuttings in replicated pots of sterilised soil, untreated or after the addition of pure cultures of *Meloidogyne*, of the fungus, or of both. After five months, when cane in some of the pots had begun to be root-bound, the shoots which had been produced were cut and weighed Statistical analysis of the results (Table II) indicated a highly significant reduction in growth due to the nematodes. The fungus had produced no observable effect and there was no significant intereaction. Examination of the roots showed that nodules occurred only in pots inoculated with nematodes; they were not produced in the presence of the fungus alone. The co-existence of these two organisms in the same roots appears to be fortuitous.

Table II

Nematode-Fungus Trial

Total weight in grams of six replicates

	Control	Nematode	Total
No Fungus	2509	1744	4253
Fungus (waxed)*	2620	1653	4273
Fungus	2612	1495	4107
Total	7741	4892	12633

*The ends of cuttings were coated with wax to prevent direct infection by the fungus.

Tests with Nematocides

In Natal, twelve field trials involving soil fumigation have now been completed. In most cases the fumigant used was EDB, since this was the material most readily available at the start of investigations, but the few trials using DBCP and D-D gave no evidence that results with these were significantly different. Early tests indicated that 40 gallons per acre of a solution containing 2.25 pounds per gallon, or 20 gallons per acre of one containing 4.5 pounds per gallon of EDB were approximately the correct amounts to apply, and most subsequent trials were carried out at these rates, which correspond to 90 pounds of active ingredient per acre.

Even at rates of application high enough to be completely uneconomic, nematocides cannot entirely eliminate plant parasitic nematodes from the soil, although treatment generally reduces their numbers very significantly. In our trials, mortalities have varied from less than 60 per cent to about 90 per cent. Reproduction by survivors leads to recrudescence, so that populations eventually equal or exceed those in untreated plots. The time required for this to happen varies considerably, ranging from under a year to over two years in our experiments. In Australia, intervals as short as six months have been recorded.[10] The tendency of populations in fumigated plots eventually to exceed those in untreated plots is thought to be due to the vigorous root system which develops in treated soil. This may provide conditions which encourage rapid increase of nematodes. It may also account for the phenomenon of residual yield responses in ratoons which often occur even when nematode populations have completely recovered during the life of the plant cane crop.

In the twelve field trials which we have carried out, mean yield differences between untreated and fumigated plots have varied from nil to 21 tons cane per acre, with a general average of 9 tons. In four trials the yield increases were statistically significant at the one per cent level and in another four at the five per cent level. In seven trials which were harvested as first ratoons mean differences between treated and untreated plots varied from nil to 13 tons cane per acre, with a general average of about 6 tons. Three of these trials showed statistically significant residual effects resulting from fumigation which was applied before planting.

On account of the high cost of the chemicals used, the difficulty of applying them effectively and the somewhat variable results obtained in experiments, it has not been possible to recommend soil fumigation of sugarcane fields with confidence that the results will be economically profitable. Consequently, here as in other countries, commercial application of soil fumigants has been negligible.

Combined Treatments

It has often been in cane growing in poor, sandy fields that symptoms attributed to the presence of nematodes have been noticed. This is particularly true of infestation by *Meloidogyne* spp. Although soil fumigation in such fields usually leads to significant increases in yield, crop responses may be limited by the nature of the soil. Several trials have therefore been carried out to discover whether the presence of fertilizers and soil ameliorants might enable the plant to take greater advantage of the period, following soil fumigation, when nematodes are least numerous. Materials tested in this way have included inorganic fertilisers at various levels, magnesium sulphate, molasses, compost and filtercake. Some of these, notably fertilizers and filtercake, led to significant crop increases on their own, but no significant interaction between these and the effects of fumigation was demonstrated. In two trials on Nkwali Flats, Illovo, significant reductions in numbers of parasitic worms followed applications of filtercake (Table III) but in other trials yield responses to this material may have been due to its value as a plant food.

Table III

Nematodes in root samples, 12 months after treatment

Filtercake rate	No Fumigant	EDB	Total
Nil	1852	1631	3483
20 tons/acre	1237	736	1973
40 tons/acre	905	750	1655
Total	3994	3117	7111

Other Chemicals

In addition to standard soil fumigants, several other chemicals have been tested for nematocidal properties, both in the laboratory and in the field. In pot tests, tomatoes were used as indicator plants and the numbers of nodules produced on their roots by *Meloidogyne* spp. were used to assess the results. A calcium polysulphide preparation was effective in pot tests but, possibly on account of method of application, did not improve the yield of sugarcane in the field. Similarly, calcium cyanimide, which has been recommended for nematode control on some other crops, was effective in pot tests but did not influence nematode populations or cane yield in field trials in which EDB led to highly significant results. Ammonium hydroxide, in several pot tests, caused very significant reduction in numbers of nodules and noticeably stimulated the development of tomato plants. Urea, at equivalent nitrogen rates produced a similar but less noticeable effect (Table IV). Although it has

Table IV

Mean number of nodules on 4 tomato roots

	Ammonium Hydroxide	Urea
400 lb. N.	2.0	15.5
200 lb. N.	16.7	67.1
Nil	98.8	105.1

not yet been possible to plant field trials with the specific object of testing the effect of different forms of nitrogen on nematode populations, advantage has been taken of an offer by a fertiliser company to place soil samples from a field trial, in which anhydrous and aqueous ammonia were included as treatments, at our disposal for nematode diagnosis. In these samples (Table V) counts varied so considerably that no statistical significance was found but, especially for *Meloidogyne*, the totals showed differences suggesting that further investigation might be justified.

Table V

Numbers of nematodes in soil samples six months after treatment

	Meloidogyne	Pratylenchus	Hoplolaimidae
Control	191	173	32
Limestone Ammonium Nitrate	165	150	69
Sulphate of Ammonia	215	263	55
Urea	172	282	37
Anhydrous Ammonia	31	224	43
Aqueous Ammonia	50	99	45

Resistant cover crops

Another form of nematode control which has been attempted involves the cultivation of resistant cover crops. Up to the present, only one species has been investigated under our conditions, namely the Ermelo strain of *Eragrostis curvula*. A small trial plot of this grass was planted on a field near Empangeni, where heavy infestations especially of *Meloidogyne* and *Pratylenchus* had been observed. After four years, parasitic nematodes had practically disappeared from this plot and the grass was ploughed out and sugarcane replanted. As this was not a replicated trial, valid yield comparisons could not be made but, when inspected about a year later, the cane appeared considerably better grown than that in surrounding fields. The main disadvantage of this type of control measure is the lengthy period during which the field is out of cane production. It is unlikely to be adopted commercially under normal conditions.

Nematode — Variety Trials

In two trials, the reactions of different varieties of sugarcane to nematodes has been investigated by planting them in fumigated and untreated plots. It was reasoned that varieties which did not respond to treatment might be assumed to be resistant or, at least, tolerant. On the other hand, those which responded to the greatest degree would presumably prove to be the most susceptible. Results obtained for the plant cane crop in these trials are given in Tables VI and VII. Both showed differences due to fumigation and to variety. The interaction between these factors was not statistically significant and ranking

Table VI

Tons cane per acre

	EDB	Nil	Ratio
N:Co 293	54.36	38.71	1.40
N:Co 382	60.29	41.57	1.45
Co 331	40.88	25.01	1.63
N:Co 292	51.68	30.50	1.69
N:Co 339	56.42	32.66	1.73
N.50/211	56.63	32.33	1.75
N:Co 376	56.85	32.23	1.76
N:Co 334	50.92	24.37	2.09

of the varieties in these trials in order of apparent tolerance would therefore not be justified. However, N:Co.382, which shows a small ratio between treated and untreated plots, gives reasonably good crops in infested sandy soils while some varieties, at the other end of the list, do not. Without doubt, investigations along these lines should continue, since the discovery and cultivation of tolerant variety would be a far more satisfactory solution to the nematode problem than treatment with nematocides.

Table VII

Tons cane per acre

	DBCP	Nil	Ratio
N:Co 293	69.3	60.1	1.15
N.50/211	63.7	54.7	1.16
N.51/168	38.0	38.0	1.00
N.52/219	55.7	46.9	1.19
N.10	56.0	36.5	1.53
N.51/539	40.8	22.1	1.85

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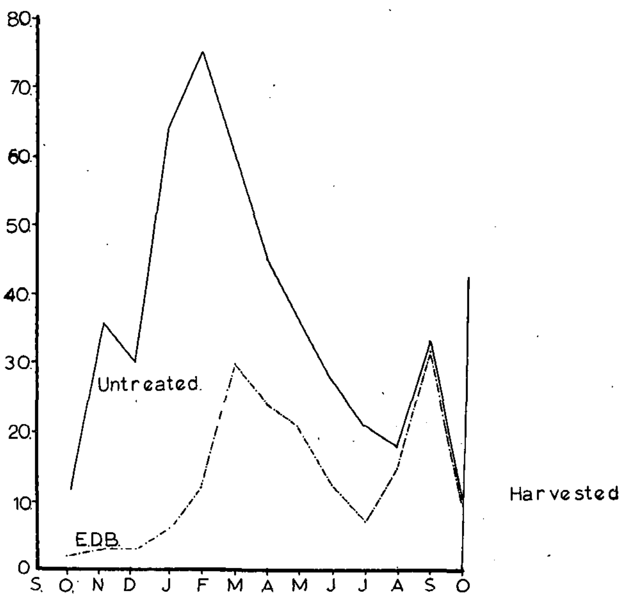
Monthly Counts Of Eelworms In Cane Roots.
Figures represent means of 12 subsamples



Summary

The nematodes known to occur in South African sugarcane fields are listed and their status discussed. Experiments have shown that *Meloidogyne javanica* can affect cane growth, but other species are probably involved as well. The possible association between nematodes and organisms causing disease is mentioned and an instance is quoted in which no interaction between *Meloidogyne javanica* and a fungus, *Mortierella* sp., could be found. Results of trials with nematocides are summarised. Although highly significant responses are often shown, sometimes in ratoons as well as plant cane, the economic value of soil fumigation is still in doubt. Attempts at increasing responses to fumigation by applications of fertilizers and soil ameliorants gave inconclusive results, although filter cake produced some effect on nematode populations. Among other materials tested, ammonia gave results suggesting that further investigations would be justified. *Eragrostis curvula*, as a cover crop, succeeded in controlling an infestation consisting mainly of *Meloidogyne* and *Pratylenchus* but was too slow to be of practical value. Variety trials gave results in which, although interaction between fumigation and variety was not statistically significant, differences in behaviour suggested that continued investigation should be undertaken.

Reference

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Mr. du Toit (in the chair): Referring to Table III, I am surprised that EDB did not have more effect on the nematodes.

Dr. Dick: These figures were from counts a year after treatment, and nematode populations had probably recovered from the effects of fumigation. It does look as though the response to filter cake has been more persistent.

Mr. Gilfillan: Dr. Dick said there are difficulties in applying fumigants to the soil but I do not see why. For example, liquid ammonia can be applied in the field.

We have recently applied fumigants to the soil at a cost of R10 per acre and an increased yield of 5 tons per acre.

He also says the application of fumigants might stop the nitrification process in the soil but surely increased fertilization will overcome this?

Dr. Dick: What was meant by difficulty was not merely the mechanical problem of getting the nematocides into the soil. For the best results, soil temperature, moisture status and tilth must satisfy somewhat circumscribed requirements.

Inhibition of nitrification is not mentioned in the paper. The action on micro-organisms is quoted merely to demonstrate that nematode control is not the only effect of nematocides.

Mr. R. A. Wood: The fumigant will affect the total amount of nitrogen that is mineralised probably due to a partial sterilisation effect on certain micro-organisms in the soil. It has been clearly shown where fumigants have been used on tobacco in Rhodesia that nitrification in the soil was reduced.

In sandy soils the ammonium form of nitrogen is retained longer than the nitrate form and a larger response on the soil can be expected.

Mr. Johnson: In a trial carried out at Hippo Valley using methyl-bromide a definite suppression of nitrification occurred with a reduction in germination and cane yield. The nematocides, as such, had no effect on cane yield.

It is all rather confusing and I think Dr. Dick is right when he says that until we know which of these nematocides affect the cane roots adversely we cannot make much progress.

Mr. Aucock: Does Mr. Gilfillan's price of R10 per acre include chemicals and application?

Mr. Gilfillan: It was for chemicals only—for one gallon of active ingredient.