Studies on the relationship between nematodes and sugarcane in South and West Africa : Plant cane

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Summary

In West Africa the loss in yield of the sugarcane plant crop caused by nematodes is due largely to a decrease in the number of stalks while in South Africa, it is due more to a reduction in length of stalks. To explain this difference, studies were made of the growth of sugarcane and associated changes in numbers of plant-parasitic nematodes in nematicide trials in the two localities. In both trials large numbers of endoparasites invaded the sett roots during the period when tillering was suppressed in untreated plots but the rate of invasion was much greater in West Africa. In South Africa, a marked difference in length of stalks between nematicide-treated and untreated plots was associated with an increase in the population densities of *Xiphinema elongatum* and *X. vanderlindei*, the dominant ectoparasites. In West Africa however, where the cane was irrigated, there was only a small difference in length of cane between treated and untreated plots, despite the presence of large numbers of *Meloidogyne* and *Pratylenchus* in the shoot roots. *Helicotylenchus dihystera* was the dominant ectoparasite in West Africa. Possible reasons for the differences in the reaction of sugarcane to nematode control in South and West Africa are presented.

Résumé

Étude des relations entre nématodes et canne à sucre en Afrique du Sud et de l'Ouest : canne plantée

En Afrique de l'Ouest, les dégâts occasionnés aux cannes à sucre par les nématodes résultent essentiellement d'une diminution du nombre de tiges, alors qu'en Afrique du Sud ils proviennent plutôt d'une réduction de la longueur des tiges. Pour expliquer cette différence la croissance des cannes à sucre, et l'évolution des populations de nématodes phytoparasites qui y sont associés, ont été comparées dans deux essais nématicides installés dans chaque région. Dans les parcelles non traitées de ces essais, le tallage est réduit pendant une période où de grandes quantités de nématodes endoparasites envahissent les racines de bouture; le taux d'invasion est toutefois beaucoup plus fort en Afrique de l'Ouest. En Afrique du Sud, la grande différence que l'on observe dans les longueurs de tige entre les parcelles traitées et les parcelles témoins était associée avec une augmentation de la densité de population de *Xiphinema elongatum* et *X. vanderlindei*, nématodes ectoparasites dominants. Dans les mêmes circonstances en Afrique de l'Ouest, on n'observe qu'une légère différence dans les longueurs des cannes et ceci malgré la présence de nombreux *Meloidogyne* et *Pratylenchus* dans les racines de tige; *Helicotylenchus dihystera* est dans cette région l'espèce ectoparasite dominante. Quelques causes susceptibles d'expliquer les différences observées dans la réaction de la canne à sucre au contrôle des nématodes en Afrique du Sud et de l'Ouest sont évoquées.

The control of plant-feeding nematodes can result in a considerable increase in yield of sugarcane growing on sandy soils. Data from several nematicide trials on plant cane in South and West Africa show that there is a notable difference in the manner by which the yield is increased in the two localities. In eight trials in West Africa treatment with a nematicide increased stalk population by an average of 46 % compared with an increase of 20 % in 21 trials in South Africa. Stalk length was increased by an average of 21 % in West Africa and by 35 % in South Africa (Moberly, Harris & Millard, 1974; Cadet & Merny, 1978; unpublished data from ORSTOM, Ivory Coast; and from SA Sugar Association Experiment Station). Thus, whilst in West Africa the higher yields are due largely to an increase in the number of stalks, in South Africa they result more from an increase in the length of the stalks. This difference is independent of the sugarcane varieties used in the field trials. Nematodes have little or no effect on stalk diameter in either locality (Cadet & Merny 1978; Thompson, 1983).

Using data from three nematicide trials on sandy soil in West Africa, Cadet, Quénéhervé and Merny (1982) concluded that the reduction in the number of stalks in untreated plots resulted from nematode damage to the sett roots of the sugarcane during the early period of tiller emergence. A trial carried out in South Africa to investigate the relationship between nematodes and the roots of sugarcane revealed certain differences compared with the situation in West Africa. In this paper we report the results of the South African trial and one of the West African trials and attempt to explain the difference between the response of sugarcane to nematode damage in the two localities. Apart from lower nematode densities in the roots of the cane, the selected West African trial is similar to the other two trials referred to by Cadet, Quénéhervé and Merny (1982).

It should be noted that : *i)* the results and observations here reported do not constitute a single experiment performed in two localities; rather they constitute two experiments each conducted separately but with the same aim; *ii)* due to differences in climate, agricultural conditions, sugarcane varieties etc., the comparisons made suggest only indications of the factors responsible for the differences between South and West Africa; *iii)* nevertheless the authors are convinced that a common paper affords more to the reader than two separate publications on the same subject.

Material and methods

Details of the two trial sites and experimental methods are given in Table 1. The high rate of application of the nematicide in the South African trial was to ensure good nematode control. For farm management reasons this trial was harvested at 10.1 months, whereas sugarcane in this area is usually harvested at approximately 18 months. Mass of cane and sucrose and the number and length of the stalks were recorded at harvest. The number of stalks and, in South Africa, the length of stalks were monitored at intervals during the growth of the crop.

The density of the endoparasites in the roots of cane in West Africa was estimated as the number per g dry mass, while in South Africa it was estimated as the number per 10 g fresh mass. The dry to fresh mass ratio of the sett and shoot roots of sugarcane varieties NCo 376 and NCo 382, up to the age of 14 weeks, varies from 1 : 4.8 to 1 : 9.6 (Spaull, unpubl. data); for cane older than 14 weeks the ratio is not known. We have therefore not attempted to convert the data in the text figures to a common base. However it can safely be assumed that the South African nematode populations expressed per g dry root mass would be smaller than those expressed per 10 g fresh root mass.

Results

The plant-feeding nematodes recovered from soil and roots at the two localities are listed in Table 2. For brevity, we refer mainly to endoparasites and ectoparasites. With a few exceptions, referred to in the text, changes in numbers of these two groups largely reflect those of the component genera.

Population dynamics of endoparasitic nematodes

Sett roots

In both South and West Africa the greatest density of endoparasites was recorded in the sett roots. In untreated plots the pattern of change in numbers was the same, that is, following a sharp increase the populations reached a maximum and then declined (Fig. 1 a, b). In West Africa this event took place over a period of about three months, with a maximum density at between one and two months and coincided with the growth of the sett roots; the greatest mass of sett roots occurred one month after planting and within four months they had practically disappeared. In South Africa the rise and fall in the density of nematodes in the sett roots occurred over a period of seven months with a maximum density at five months. Sett root mass was greatest 6 weeks after planting and the roots only disappeared five months later. Thus the density of the endoparasites in the sett roots in South Africa continued to increase even though the root system was dying back. The endoparasites were dominated by *Meloidogyne* in West Africa and by *Pratylenchus* in South Africa (Tab. 3).

At both localities the nematicide treatment gave good control of the endoparasitic nematodes in the sett roots (Figs 1, 2).

Shoot roots

In West Africa the number of nematodes in the shoot roots increased progressively until the seventh month after which no further samples were taken (Fig. 2). In South Africa the density of the nematode populations in untreated plots increased to a maximum four to six months after planting and either remained at about that level or decreased until harvest (Fig. 2). The nematicide treatment gave excellent control of the nematodes in the shoot roots in South Africa but was less satisfactory in West Africa (Figs 1, 2).

Population dynamics of ectoparasitic nematodes

In West Africa the ectoparasites were dominated by *Helicotylenchus dihystera* (Tab. 4). The population density of this species increased rapidly during the first three months after planting and was still at a high level 4 months later (Fig. 3).

In South Africa the ectoparasites were mainly represented by species of *Xiphinema* and the trichodorids, *Trichodorus* and *Paratrichodorus* (Tab. 4). The density of the trichodorids remained at a low level until sometime after the seventh month, after which there was a marked increase (Fig. 3). The density of *Xiphinema*, however, increased in the fourth month and remained at a relatively high level until after harvest (Fig. 3).

For the first two months there was only a small difference between the number of ectoparasites recove-

Table 1
Characteristics of trial sites and methods

Locality	*South Africa*	*West Africa*
Location of trial	Zululand, South Africa	Banfora, Upper-Volta
Soil texture :		
Clay %	2.7	3.0
Silt %	2.3	6.0
Sand %	95.0	91.0
pH	5.9	4.8
Rainfall + irrigation	630 + 0 mm	804 + 800 mm
Duration of crop	10.1 months (Oct.-Aug.)	10.2 months (May-Mar)
Sugarcane variety	NCo 382	NCo 376
Treatments	Untreated control and 9.88 kg aldicarb/ha in the furrow at planting followed by 4.9 kg/ha over the row 33 & 60 days after planting	Untreated control and 4.0 kg aldicarb/ha in the furrow at planting
Trial design	Randomised blocks with six replicates	Randomised blocks with six replicates
Number and length of rows per plot	15 × 10 m	6 × 11.11 m
Row spacing	0.85 m	1.5 m
Samples for nematode analysis	Sett roots, shoot roots and soil	Sett roots, shoot roots and soil
No. of subsamples per plot :		
Soil	20	2
Roots	From 9 setts each with 1-6 nodes	From 2 setts each with 3 nodes
Time of sampling	0, 3, 6, 10, 14, 19, 27 and 45 weeks after planting	0, 4, 8, 12 and 26 weeks after planting
Method for extracting nematodes :		
Soil	Combination of Flegg's (1967) technique and Spaull & Braithwaite's (1979) decanting plus sieving plus Baermann tray method	Seinhorst's (1962) elutriator
Roots	Coolen & d'Herde's (1972) maceration plus centrifugal sugar flotation	Seinhorst's (1950) mistifier

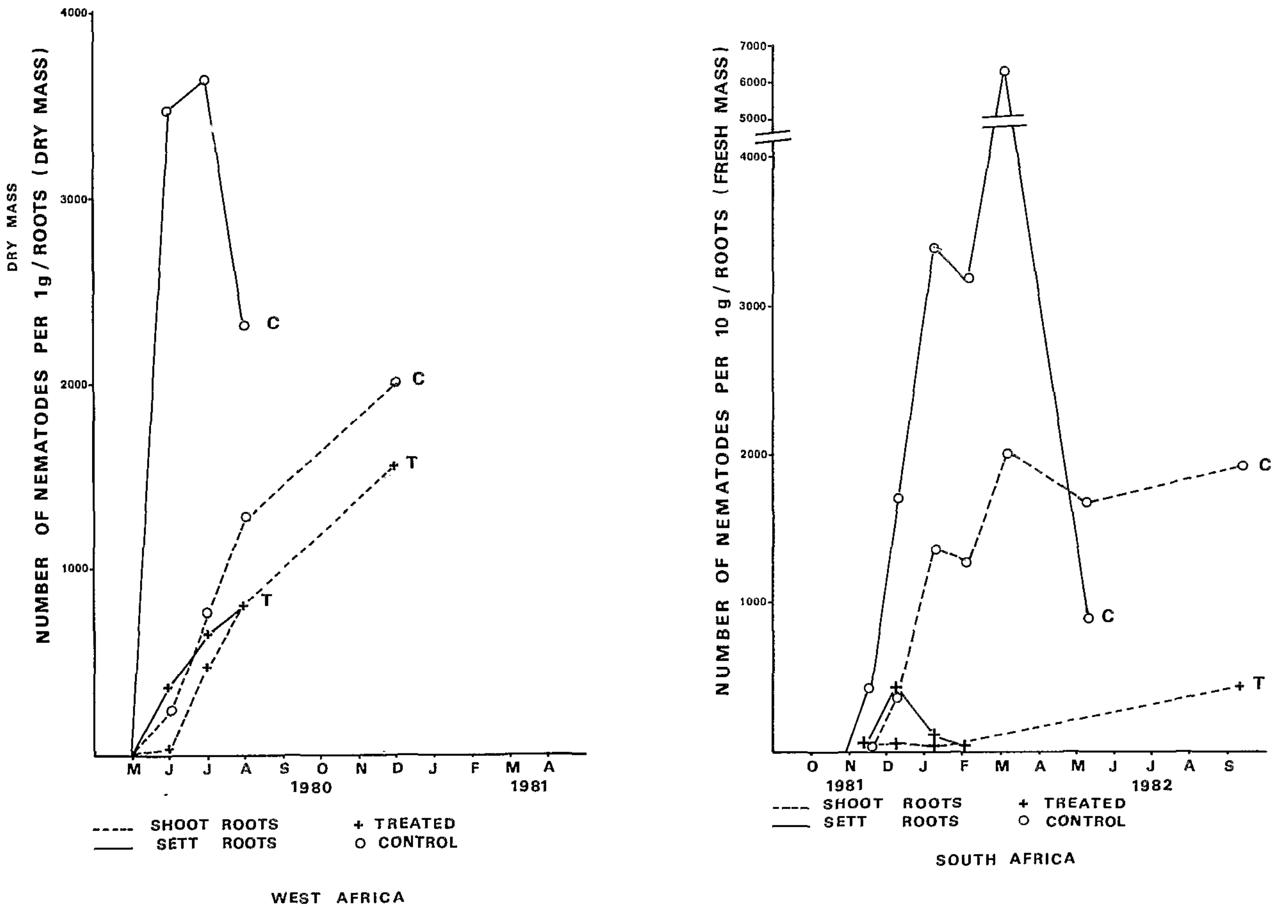


Fig. 1. Changes in numbers of endoparasitic nematodes in sett and shoot roots of sugarcane in plots treated with a nematicide (T) and in untreated plots (C) in South and West Africa.

Table 2

Species of nematodes recovered from the two trial sites

South Africa	*West Africa*
	Endoparasites
Hoplolaimus pararobustus	*Heterodera sacchari*
Meloidogyne incognita	*Hoplolaimus pararobustus*
M. javanica	*Meloidogyne incognita*
Pratylenchus zeae	*Pratylenchus zeae*
	Ectoparasites
Criconemella sp.	*Criconemella* sp.
Helicotylenchus sp.	*Helicotylenchus dihystera*
Histotylenchus sp.	*Hemicycliophora (sensu lato)* sp.
Paralongidorus sp.	*Paratylenchus aquaticus*
Paratrichodorus sp.	*Scutellonema clathricaudatum*
Trichodorus sp.	*Telotylenchus ventralis*
Tylenchorhynchus sp.	*Trichodorus* sp.
Xiphinema elongatum	*Tylenchorhynchus* sp.
X. vanderlindei	*Xiphinema* sp.

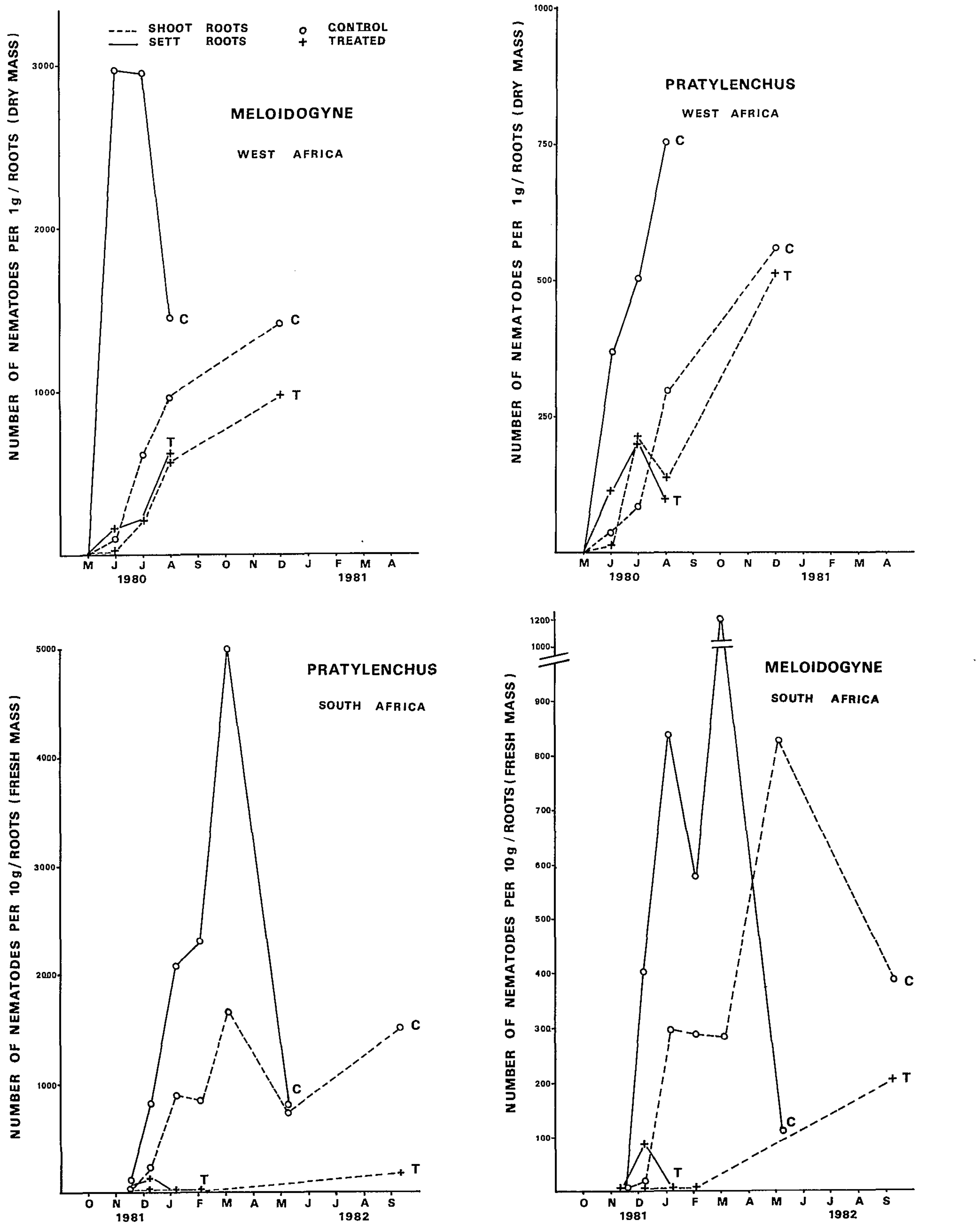


Fig. 2. Changes in numbers of *Meloidogyne* and *Pratylenchus* in sett and shoot roots of sugarcane in plots treated with a nematicide (T) and in untreated plots (C) in South and West Africa.

Table 3

Numerical composition of the endoparasitic nematode fauna and the frequency of occurrence of the component genera

	South Africa				*West Africa*			
	Sett roots		*Shoot roots*		*Sett roots*		*Shoot roots*	
	Percent of total number of endoparasites	*Percent frequency of occurrence in root sample*	*Percent of total number of endoparasites*	*Percent frequency of occurrence in root sample*	*Percent of total number of endoparasites*	*Percent frequency of occurrence in root sample*	*Percent of total number of endoparasites*	*Percent frequency of occurrence in root sample*
Pratylenchus	62.2	100	67.0	100	19.0	79	19.5	76
Hoplolaimus	21.9	100	11.0	97	1.6	46	0.8	35
Meloidogyne	15.9	97	22.0	97	76.3	87	67.9	85
Heterodera	0	0	0	0	3.1	29	11.8	36

Table 4

Numerical composition of the ectoparasitic nematode fauna and frequency of occurrence of the component genera

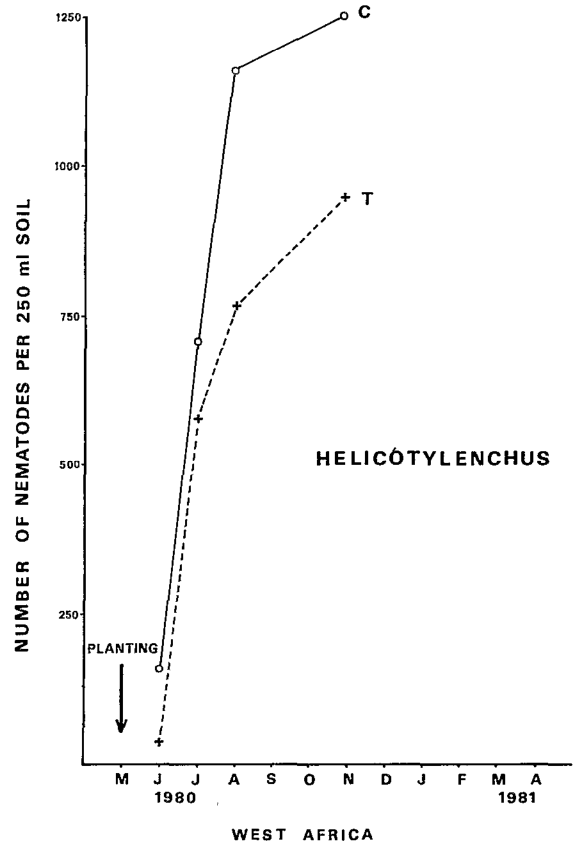
	South Africa		*West Africa*	
	Percent of total number of ectoparasites	*Percent frequency of occurrence in soil samples*	*Percent of total number of ectoparasites*	*Percent frequency of occurrence in soil samples*
Helicotylenchus	12.9	73	83.5	98
Xiphinema	58.8	100	6.6	61
Trichodorids	21.8	98	< 1	< 10
Histotylenchus	2.8	58	0	0
Paralongidorus	2.0	65	0	0
Telotylenchus	0	0	2.5	24
Tylenchorhynchus	1.7	33	1.2	< 10
Scutellonema	0	0	6.2	35
Criconemella	< 1	< 10	< 1	< 10
Hemicycliophora	0	0	< 1	< 10
Paratylenchus	0	0	< 1	< 10

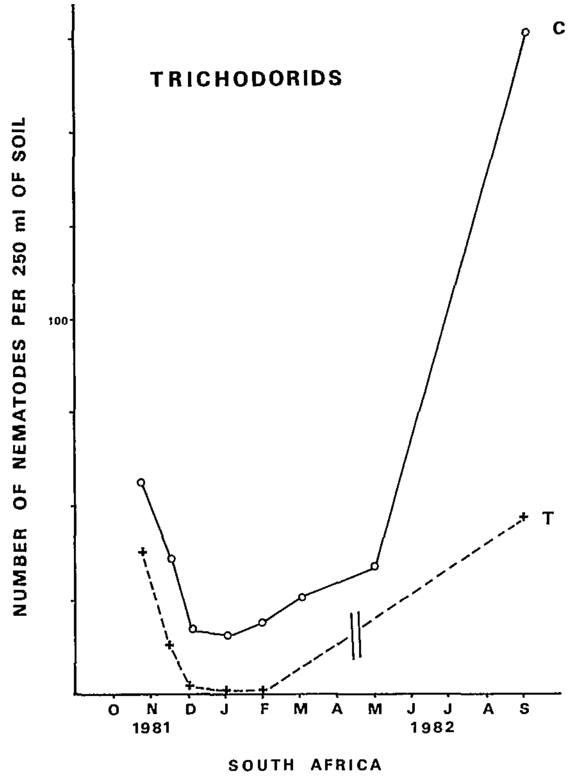
red from treated and control plots both in South and West Africa. Thereafter, especially in South Africa, populations in the control plots increased compared with those treated with nematicide.

Changes in the number of stalks

The patterns of change in the number of stalks (primary shoots plus tillers) in South and West Africa are shown in Figure 4. For the first month after planting the stalk population in West Africa was composed of primary shoots, with 21 % fewer shoots in the control plots than in the treated plots (Tab. 5). Primary and secondary tillers appeared six to eight weeks after planting with 82 % fewer tillers being produced in control plots than in plots treated with nematicide during the main period of tiller development (Tab. 5). This difference in tiller population was established by the second month and thus coincided with the period when tillers first appeared above ground.

In South Africa, before the development of tillers, there were 25 % fewer primary shoots in control plots than in treated plots. Primary tillers appeared ten weeks





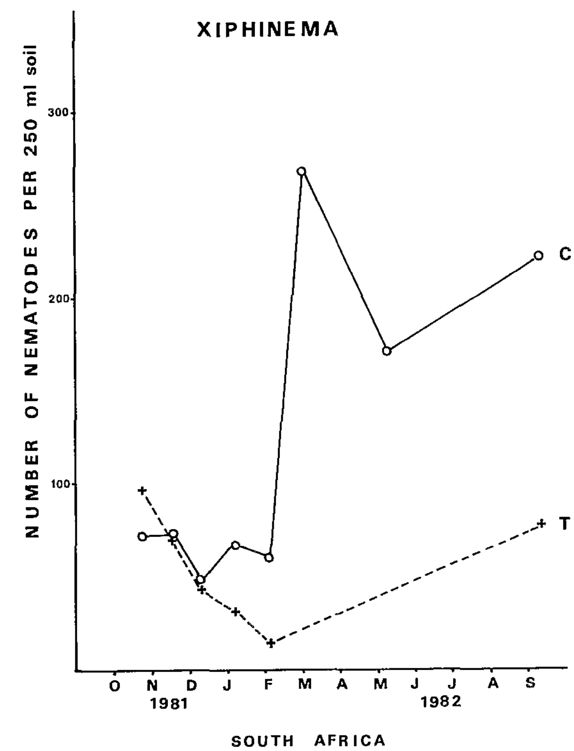


Fig. 3. Changes in numbers of ectoparasitic nematodes in plots treated with a nematicide (T) and in untreated plots (C) in South and West Africa.

after planting and only a few secondaries had developed by fourteen weeks. Forty-three percent fewer tillers developed in control plots than in treated plots during the main period of tiller development (Tab. 5). This difference in tiller population was established by the third month, that is, soon after tillers first appeared above ground. In both South and West Africa the maximum stalk population in control plots was attained one month later than in treated plots (Fig. 4).

Changes in stalk length

Stalk length was not measured in West Africa until the cane was harvested because previous work had shown that the difference in length between treated and untreated cane which is visible during the first few months of growth largely disappears before harvest (Cadet & Merny, 1978; Cadet, 1979). In South Africa however, the small difference in stalk length which was apparent soon after planting, became pronounced in the fourth month and steadily increased until harvest (Fig. 5). The rate of elongation of the cane was considerably greater in West Africa than in South Africa. For example, two months after planting the stalks in the control plots had reached an estimated length of 500 mm

Table 5

Effect of nematicide treatment on tiller emergence of sugarcane in South Africa and West Africa (Number of shoots and tillers per hectare × 10^{-3})

West Africa

Treatment	*Number of stalks at 1 month (June) when only primary shoots above ground* (a)	*Number of stalks at 2 months (July) when primary and secondary tillers appeared above ground* (b)	*Therefore, number of primary and secondary tillers* (b — a) *(Assuming that no more primary shoots appeared)*	*Number of tillers in control plots as a percentage of those in the nematicide treated plots*
Control	39.75	56.00	16.25	17.7
Nematicide	50.25	142.25	92.00	

South Africa

Treatment	*Number of stalks at 6 weeks (December) when only primary shoots above ground* (a)	*Number of stalks at 10 weeks (January) when primary tillers appeared above ground* (b)	*Therefore, number of primary tillers* (b — a) *(Assuming that no more primary shoots appeared)*	*Number of tillers in control plots as a percentage of those in the nematicide treated plots*
Control	55.7	118.1	62.4	56.7
Nematicide	74.8	184.8	110.0	

in West Africa but only 100 mm in South Africa. After four months the corresponding lengths were 1 100 and 300 mm.

EFFECT OF NEMATICIDE TREATMENT ON THE SUGARCANE

Treatment with a nematicide greatly increased the mass of cane and sucrose per hectare at both localities (Tab. 6). In West Africa this improved production resulted from an increase in stalk population and, to a lesser extent, from an increase in stalk length whereas in South Africa the reverse was true (Tab. 6).

Discussion

Within each trial it is possible to compare and relate the patterns of change in the nematode populations with the patterns of change in the development of the sugarcane crop. In so doing, we attempt to deduce the probable rôles played by the ectoparasites and endoparasites in reducing the yield of sugarcane. Comparisons between the two trials are made merely to indicate those factors that might explain the differences in the response of cane to treatment with nematicide in South and West Africa.

EFFECT OF NEMATODES ON THE NUMBER OF STALKS

Ectoparasites

The difference between the stalk population in nematicide-treated and untreated plots was established within two months in West Africa and within three months in South Africa (Fig. 4). In West Africa there was little difference between the number of ectoparasites in treated and untreated plots during the first two months (Fig. 3). It is therefore unlikely that they had any influence on stalk population.

In South Africa, where the ectoparasitic fauna was dominated by species of *Xiphinema* and trichodorids, symptoms of damage normally associated with these nematodes (Christie, 1959; Apt & Koike, 1962; Cohn,

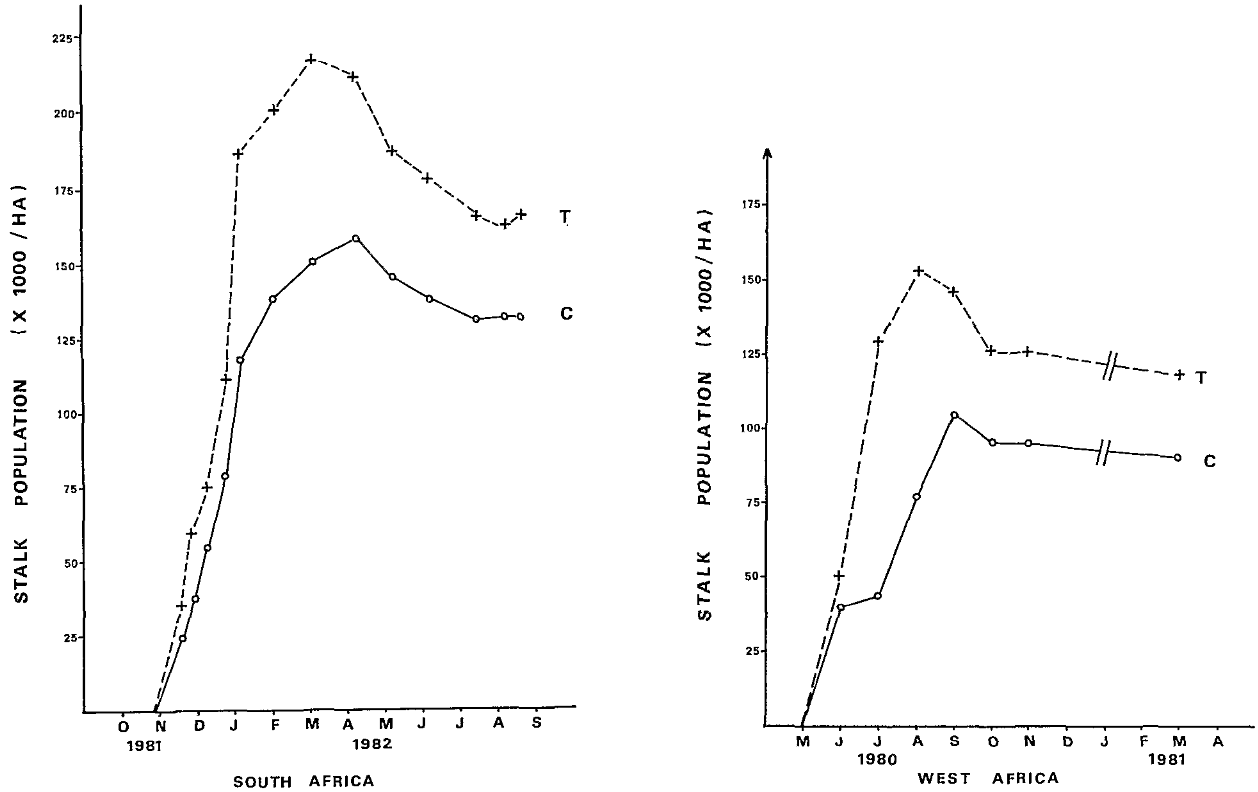


Fig. 4. Changes in the sugarcane stalk populations in plots treated with a nematicide (T) and in untreated plots (C) in South and West Africa.

Table 6

Yield data from the two trials

	South Africa			*West Africa*		
	Control	*Nematicide*	*Percent increase*	*Control*	*Nematicide*	*Percent increase*
Cane (t/ha)	21*	80	281	45.6	84.4	85
Sucrose (t/ha)	2.4	8.8	267	4.5	8.7	93
Stalk length (m)	0.73	1.65	126	1.42	1.71	20
Stalk population $\times 10^{-3}$/ha	135	166	23	87	128	47

* The differences between the control and nematicide treated plots are all significant at the 1 % level except stalk length in West Africa which is significant at the 5 % level.

1975) were observed on the shoot roots of untreated cane three months after planting. Such symptoms were rarely observed on sett roots. Damage to shoot roots by ectoparasitic nematodes may therefore have contributed to the difference in stalk population between treated and untreated plots in South Africa.

Endoparasites in shoot roots

It is unlikely that the endoparasites in the shoot roots had much effect on stalk population because in neither South nor West Africa were increasing densities of nematodes in these roots associated with a suppression

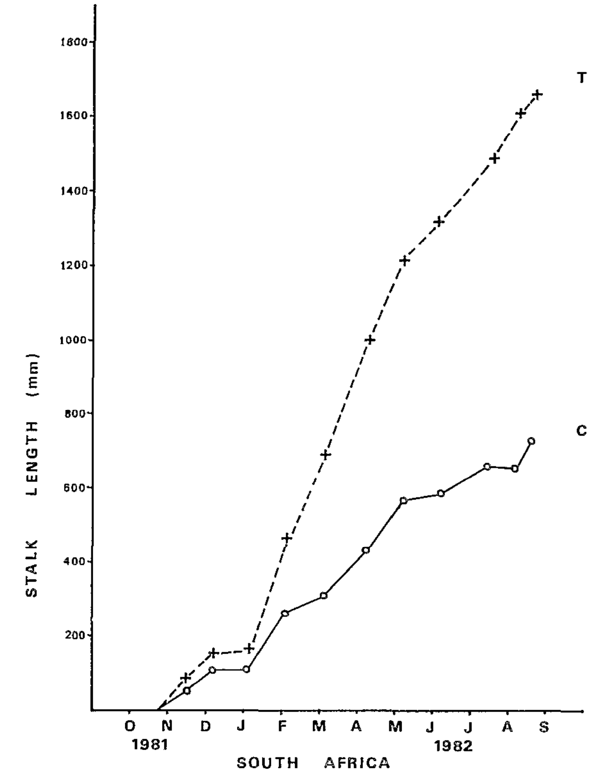


Fig. 5. Changes in sugarcane stalk length in South Africa in plots treated with a nematicide (T) and in untreated plots (C).

of tillering, for example, during the period January to March in South Africa or July to September in West Africa (Figs 1, 4).

Endoparasites in sett roots

The population dynamics of endoparasitic nematodes in the sett roots were similar in the two trials, that is, there was an increase in numbers followed by a decline and, although the increase took place much more rapidly in West Africa, in both localities it preceded or coincided with the period during which tillering was suppressed in the control plots (Figs 1, 4). *Pratylenchus zeae* and *Meloidogyne javanica* and/or *M. incognita* constituted more than 75 % of the endoparasites feeding on the sett roots in South and West Africa. All are known pathogens of sugarcane (Apt & Koike, 1962 b; Khan, 1963; Anon., 1980). Growth of cane shoots is impaired if the sett roots are damaged (Bonazzi, 1928). Assuming that a poorly developed shoot would produce fewer tillers, it seems likely that, as suggested previously for cane in West Africa (Cadet, Quénéhervé & Merny, 1982) tiller development was suppressed in both trials by endoparasitic nematodes in the sett roots.

That the suppression of tillering was much greater in West Africa may possibly be explained by the much greater rate of invasion of the sett roots by the endoparasites (Fig. 1). This rapid rate of invasion probably had a substantial effect on root development and may therefore have inhibited tillering to a greater extent than did the slower invasion of these roots observed in South Africa.

In the month preceding the appearance of tillers there were, in both localities, approximately 25 % fewer primary shoots in the control plots than in plots treated with nematicide. This may have resulted from a delay in the emergence of some of the shoots following extensive nematode damage to the sett roots and the subsequent mortality of these shoots when they were unable to compete successfully with those that had developed more rapidly. However, if early damage to the sett roots was more extensive in West Africa, mortality of primary shoots might have been expected to be somewhat greater than in South Africa. That this did not occur suggests that some other factor limited development of some of the primary shoots in South Africa.

Ten nematicide trials in West Africa gave similar results to the West African trial reported here (Cadet, unpubl. data). In five of these trials *Meloidogyne* was the dominant nematode in the sett roots while in the other five trials *Pratylenchus* predominated. The large difference in stalk population response between South and West Africa is therefore not likely to be due to a difference in composition of the endoparasitic fauna within the sett roots (Tab. 3).

EFFECT OF NEMATODES ON STALK LENGTH

Since damage to sett roots can limit shoot growth (Bonazzi, 1928), it seems probable that the large numbers of endoparasitic nematodes in these roots were responsible for the check in stalk elongation that was observed in control plots during the first three months in both South and West Africa. In West Africa, although the endoparasites in the shoot roots and the ectoparasites in the soil increased markedly during the subsequent growth of the crop (Figs 1, 2, 3) they appeared to have had little or no further influence on stalk length. This contrasts with the situation in South Africa where an increase in the numbers of ectoparasites and of *Meloidogyne* was associated with a progressive increase in the difference between the length of cane in nematicide treated and untreated plots (Figs 2, 3, 5). We suggest that this difference in response may be explained as follows.

South Africa

Symptoms of severe damage by nematodes were observed on the shoot roots of cane in untreated plots in South Africa, that is, fine lateral roots, which were abundant on the shoot roots of cane from nematicide treated plots, were largely absent, and those that were present were stunted, coarse and brittle. Such damage would be expected to limit the plants' ability to take up water; certainly, symptoms of drought, observed in untreated cane, were not apparent in cane treated with nematicide. Since stalk elongation in sugarcane is particularly sensitive to drought stress (Chang *et al.*, 1965; Koehler *et al.*, 1982) we conclude that the shorter stalks of untreated cane in South Africa were due to restricted uptake of water resulting from root damage by nematodes. The symptoms of damage were similar to those caused by some species of *Xiphinema* and by trichodorids (Christie, 1959; Apt & Koike, 1962a; Cohn, 1975). Since *Xiphinema* and trichodorids were the dominant ectoparasites in South Africa (Tab. 4), we further conclude that it was these nematodes, rather than the endoparasites, that were the pathogens primarily responsible for the root damage.

West Africa

Symptoms of nematode damage were also observed on the shoot roots of cane in West Africa. That this damage had little or no effect on stalk length may possibly have been because the cane in West Africa was irrigated. Thus even though the functioning of the root system may have been impaired there was probably sufficient available soil moisture for the plants to maintain almost normal stalk elongation. *Helicotylenchus dihystera*, the dominant ectoparasite in West Africa, is perhaps less pathogenic to sugarcane than *Xiphinema elongatum* and *X. vanderlindei*, the dominant ectoparasites in South Africa. This would further explain the absence of a marked response in stalk length in West Africa. An alternative explanation for the absence of such a response is that the nematicide treatment in West Africa may not have given sufficient control of the nematodes feeding on the shoot roots (Figs 1, 2 3) and stalk elongation of treated cane was therefore little better than that of cane in untreated plots. But this is not supported by data from another trial in West Africa where a fumigant nematicide gave very good control of nematodes in the shoot roots but did not increase stalk length (Cadet & Merny, 1978). However, relating yield of cane to the amount of irrigation water and/or rainfall suggests that some factor limited water use in the treated plots in West Africa so that the yield was less than the potential. In the control plots yields were comparable, 2.8 and 3.3 tons cane/ha/100 mm water in West Africa and South Africa respectively. Yield of cane treated with a nematicide was, however, relatively much lower in West Africa, viz 5.3 compared with 12.7 tons cane/ha/100 mm water. The reason for this is not known.

We emphasize that the explanations given for the differences in reaction of sugarcane to plant-parasitic nematodes in South and West Africa are tentative and that they apply only to the plant crop and not to ratoon cane.

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