Plant-parasitic nematodes on field crops in South Africa. 2. Sorghum

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SUMMARY

Eight sorghum fields, representative of the conditions prevailing in the main sorghum-producing areas of South Africa, were monitored during the 1985/86 growing season. Several potentially harmful nematode species were found. The predominant ectoparasites were *Scutellonema brachyurus, Paratrichodorus minor, Paratrophurus anomalus* and *Rotylenchus devonensis. Pratylenchus zeae, Pratylenchus penetrans* and *Pratylenchus crenatus* were the predominant endoparasites. In the soil, the average increase in the mean numbers of plant-parasitic nematodes was about one and a half times between three and eleven weeks after planting and about fourfold between three weeks after planting and harvest. In the roots, the mean numbers of plant-parasitic nematodes were as high three weeks after planting as at harvest. Between three and eleven weeks after planting the mean numbers of plant-parasitic nematodes in the roots decreased by about 25 %. Population densities of all plant-parasitic nematodes in the soil three weeks after planting and at harvest were positively correlated. A highly significant positive correlation was also found between the percentage of plant-parasitic nematodes in the soil and the total number of plant-parasitic nematodes recovered from the soil.

RÉSUMÉ

Les nématodes parasites des cultures en Afrique du Sud. 2. Le Sorgho

Huit champs représentatifs des conditions de production du sorgho en Afrique du Sud, ont été prospectés durant la saison de culture de 1985/1986. Les nématodes ectoparasites dominants sont *Scutellonema brachyurus, Paratrichodorus minor, Paratrophurus anomalus* et *Rotylenchus devonensis. Pratylenchus zeae, Pratylenchus penetrans* et *Pratylenchus crenatus* sont les nématodes endoparasites dominants. La population moyenne de nématodes phytoparasites dans le sol est multipliée par 1,5 entre trois et onze semaines après plantation et par 4 entre trois semaines après plantation et la récolte. Le taux moyen de la population de nématodes dans les racines demeure constant entre trois semaines après plantation et la récolte. Entre trois et onze semaines après plantation, le taux moyen de nématodes décroît dans les racines d'environ 25 %. Les nombres totaux de nématodes phytoparasites dans le sol trois semaines après la plantation et à la récolte sont corrélés positivement. Une corrélation positive hautement significative existe également entre le pourcentage de nématodes phytoparasites dans le sol et le nombre total de ceux extraits de la rhizosphère du sorgho.

In South Africa about 0.3 million ha of sorghum (*Sorghum bicolor* (L.) Moench) are grown annually. During the last five years, sorghum production has increased, also because of the prolonged drought in the summer-rainfall region.

The status of plant-parasitic nematodes as a limiting factor in sorghum production has received rather little attention worldwide although already three decades ago Norton (1958) reported damage caused by *Pratylenchus hexincisus* Taylor & Jenkins to sorghum (for a review see De Waele, 1984). Loss of grain and forage sorghums in the United States was estimated at 6 % (Anon., 1971). Keetch and Buckley (1984) listed ten plant-parasitic nematode species associated with sorghum in South Africa but their check-list did not differentiate between common and rare species. The nematode genera which are known to cause sorghum yield losses (e.g. *Meloidogyne, Pratylenchus, Xiphinema*) are abundant in South African agricultural soils but the most important plant-parasitic nematode species associated with sorghum in the main sorghum-producing areas are unknown. Such information is, however, needed to initiate specific pathogenicity experiments under controlled conditions.

This paper presents the results of a study to identify the predominant plant-parasitic nematode species on sorghum in South Africa.

Materials and methods

During the 1985/86 growing season, soil and root samples were collected from eight sorghum fields throughout the sorghum-producing areas of South

Africa (Fig. 1) three, five and eleven weeks after planting and at harvest.

The properties of the soil, together with the rainfall, cultivar planted and yield of the eight sorghum fields are given in Table 1. Soil properties and agronomic practices of the selected sorghum fields represent the prevailing production conditions. On all fields sorghum had been grown in monoculture under dryland conditions for at least two consecutive years. Fields were planted between 21st October and 30th December 1985. Minimum tillage was applied at farms 1, 2, 5, 8 and 15; conventional tillage (plough) at the other farms.

Soil texture was determined by a rapid hydrometer method based on Day's (1965) modification of Bouyoucos' (1951) technique. Soil type was determined according to the triangular textural diagram (Hodgson, 1974). All fields were naturally infested with nematodes.

In each sorghum field, soil and roots from fifteen sorghum plants were collected along the diagonal of a 0.25 ha plot and combined. The soil nematodes were extracted from five 200 ml subsamples by a modified decanting and sieving method (Flegg, 1967) using 710 µm and 45 µm sieves, followed by the sugar centrifugal-flotation method (Jenkins, 1964). The root nematodes were extracted from five 5g subsamples by the sugar centrifugal-flotation method (Coolen &

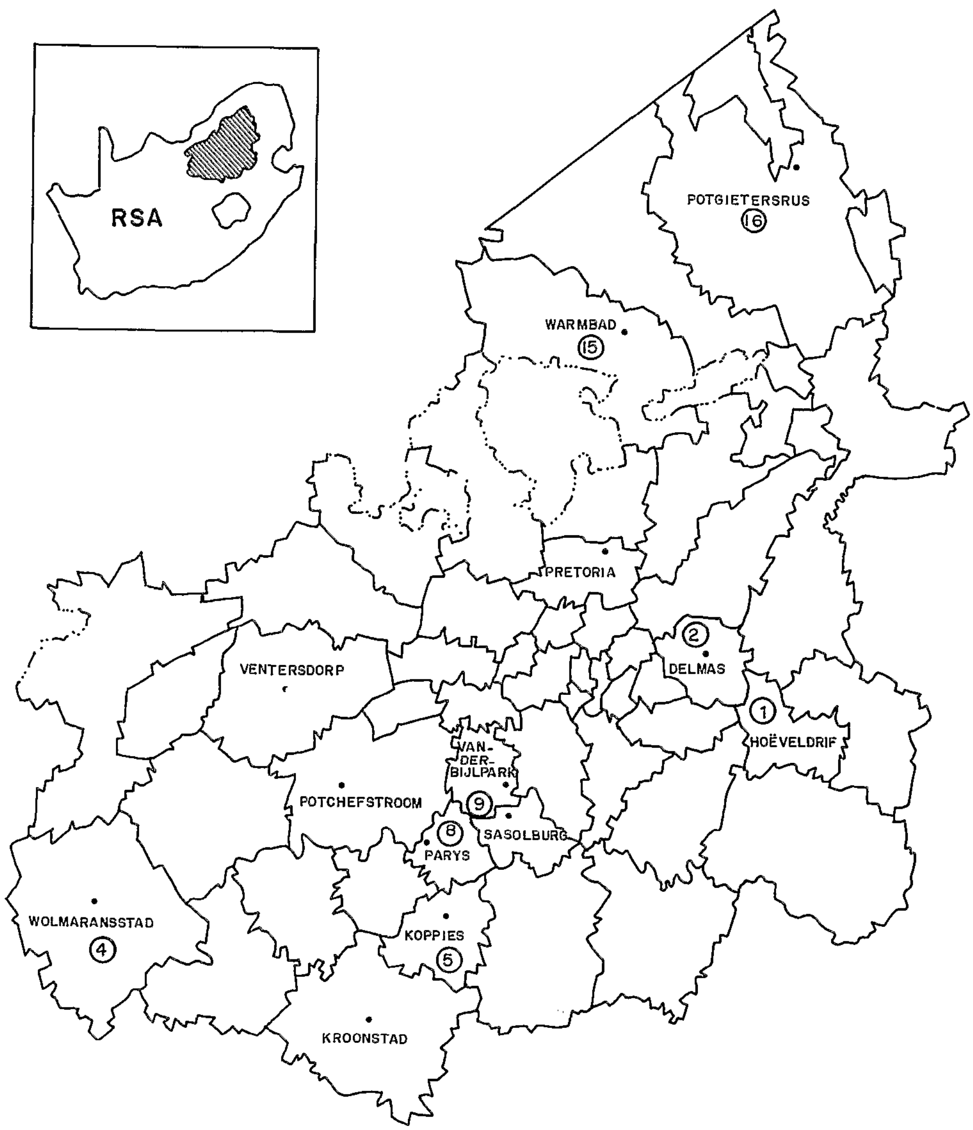

Fig. 1. Sites in South Africa where nematode populations were monitored during the 1985/86 growing season.

Table 1

Main soil properties, rainfall, cultivar planted and yield of eight sorghum fields monitored during 1985/1986, South Africa.

Farm no.	*District*	*Soil form*[1]	*Soil* *% sand*	*texture*[2] *% loam*	*% clay*	*Soil type*[3]	*Rainfall*[4] *(mm)*	*Cultivar*	*Yield* *(ton/ha)*
1	Nigel	Valsrivier	74	12	14	SL	417	PNR 8469	3.8
2	Nigel	Sterkspruit	64	10	26	SCL	303	NK 283	1.1
4	Wolmaransstad	Hutton	87	11	2	S	178	NK 300	1.34
5	Koppies	Arcadia	62	22	16	SL	260	NK 283	0.5
8	Parys	Arcadia	71	11	18	SL	177	BC 34	0.6
9	Parys	Arcadia	72	15	13	SL	166	PNR 8469	0.95
15	Warmbad	Clovelly	70	16	14	SL	217	NK 283	0.4
16	Potgietersrus	Shortlands	65	23	12	SL	391	PNR 8468	3.0

1. Soil form according to MacVicar *et al.* (1977)
2. Soil texture as determined by the Bouyoucos' hydrometer method (Bouyoucos, 1951; Day, 1965)
3. Soil type (S : sand; LS : loamy sand; SL : sandy loam; SCL : sandy clay loam)
4. Rainfall from one week before planting onwards until 11 weeks after planting

Table 2

Frequency of occurrence, mean population density and prominence value (PV) of the pre-dominant plant-parasitic nematodes recovered from soil and sorghum roots in eight sorghum fields, South Africa, 3, 5, 11 weeks after planting and at harvest *(PV = population density × √frequency of occurrence/10)*

	Frequency of occurrence (%)	*Mean population density* (Nematodes/100 ml soil or 5g roots)				Coeff. correl.		*Prominence value*			
		3 wks	5 wks	11 wks	harvest	3 and 11 wks	3 wks and harvest	3 wks	5 wks	11 wks	harvest
SOIL											
Paratrichodorus minor	25	1	3	225	13	—	—	0.5	1.5	112.5	11.5
Longidorus pisi	50	2	2	15	12	—	—	1.4	1.4	10.6	8.5
Scutellonema brachyurus	37.5	9	173	77	543	—	—	5.5	105.9	47.2	332.5
Paratrophurus anomalus	50	12	14	12	74	—	—	8.5	9.9	8.5	52.3
Rotylenchus devonensis	25	45	90	60	18	—	—	22.5	45.0	34.5	9.0
Rotylenchulus parvus	87.5	153	54	218	504	+ 0.163 n.s.	+ 0.172 n.s.	143.1	50.0	203.9	471.4
Pratylenchus spp.	87.5	12	12	13	108	— 0.126 n.s.	+ 0.255 n.s.	11.2	11.2	12.2	101.0
All plant-parasitic nematodes	100	195	165	323	809	+ 0.440 n.s.	+ 0.775*	195	165	323	809
ROOTS											
Pratylenchus zeae	100	1 098	713	790	682	+ 0.325 n.s.	— 0.710 n.s.	1 098	713	790	682
Pratylenchus penetrans	87.5	620	298	348	357	+ 0.113 n.s.	+ 0.385 n.s.	579.9	278.8	325.5	333.9
Pratylenchus crenatus	62.5	100	237	259	408	— 0.396 n.s.	— 0.191 n.s.	79	187.4	204.8	322.6
Pratylenchus brachyurus	12.5	300	0	0	0	—	—	106	0	0	0
Rotylenchulus parvus	100	45	28	33	19	+ 0.613 n.s.	+ 0.320 n.s.	45	28	33	19
Meloidogyne spp.	25	5	3	13	0	—	—	2.5	1.5	6.5	0
Spiral nematodes	100	9	48	21	609	—	—	9	48	21	609
All plant-parasitic nematodes	100	1 768	1 146	1 280	1 878	+ 0.262 n.s.	— 0.437 n.s.	1 768	1 146	1 280	1 878

* Significant at $P < 0.01$; n.s. = not significant.

D'Herde, 1972). The extracted nematodes were killed and fixed in hot 4 % formalin. Nematode population levels were determined in a counting dish under a stereoscopic micoscope and expressed either as the number of nematodes per 100 ml soil or per 5g roots. For species identification, plant-parasitic nematodes were transferred to anhydrous glycerin (De Grisse, 1969) and mounted on slides by the paraffin-ring method.

Prominence values *(P.V. = population density × √frequency of occurrence/10)* and correlation coefficients were calculated for plant-parasitic nematode population densities in soil and roots three and eleven weeks after planting and at harvest. The relationship between the percentage of plant-parasitic nematodes in the soil and the total number of plant-parasitic nematodes in the soil was also calculated (percentage plant-parasitic nematodes in the soil : *freeliving + plant-parasitic nematodes in the soil plant/parasitic nematodes in the soil × 100)*.

Results

The predominant ectoparasites were *Scutellonema brachyurus* (Steiner) Andrássy, *Paratrophurus anomalus* Kleynhans & Heyns, *Rotylenchus devonensis* van den Berg and *Paratrichodorus minor* (Colbran) Siddiqi. Predominant endoparasites were *Pratylenchus zeae* Graham, *Pratylenchus penetrans* Cobb and *Pratylenchus crenatus* Loof. *Longidorus pisi* Edward, Misra & Singh occurred in four sorghum fields but its population density remained low (mean density : 12 individuals/100 ml soil). *Rotylenchulus parvus* (Williams) Sher was present in most sorghum fields but the high populations in the soil (mean density : 227 individuals/100 ml soil) were not matched by high populations in the roots (mean density : 31 individuals/5g roots). *Pratylenchus brachyurus* (Godfrey) Filipjev & Schuurmans Stekhoven and larvae of *Meloidogyne* spp. were present in only one and two sorghum fields respectively.

Mean density of the larvae of *Meloidogyne* spp. was six individuals/5g roots (Tab. 2).

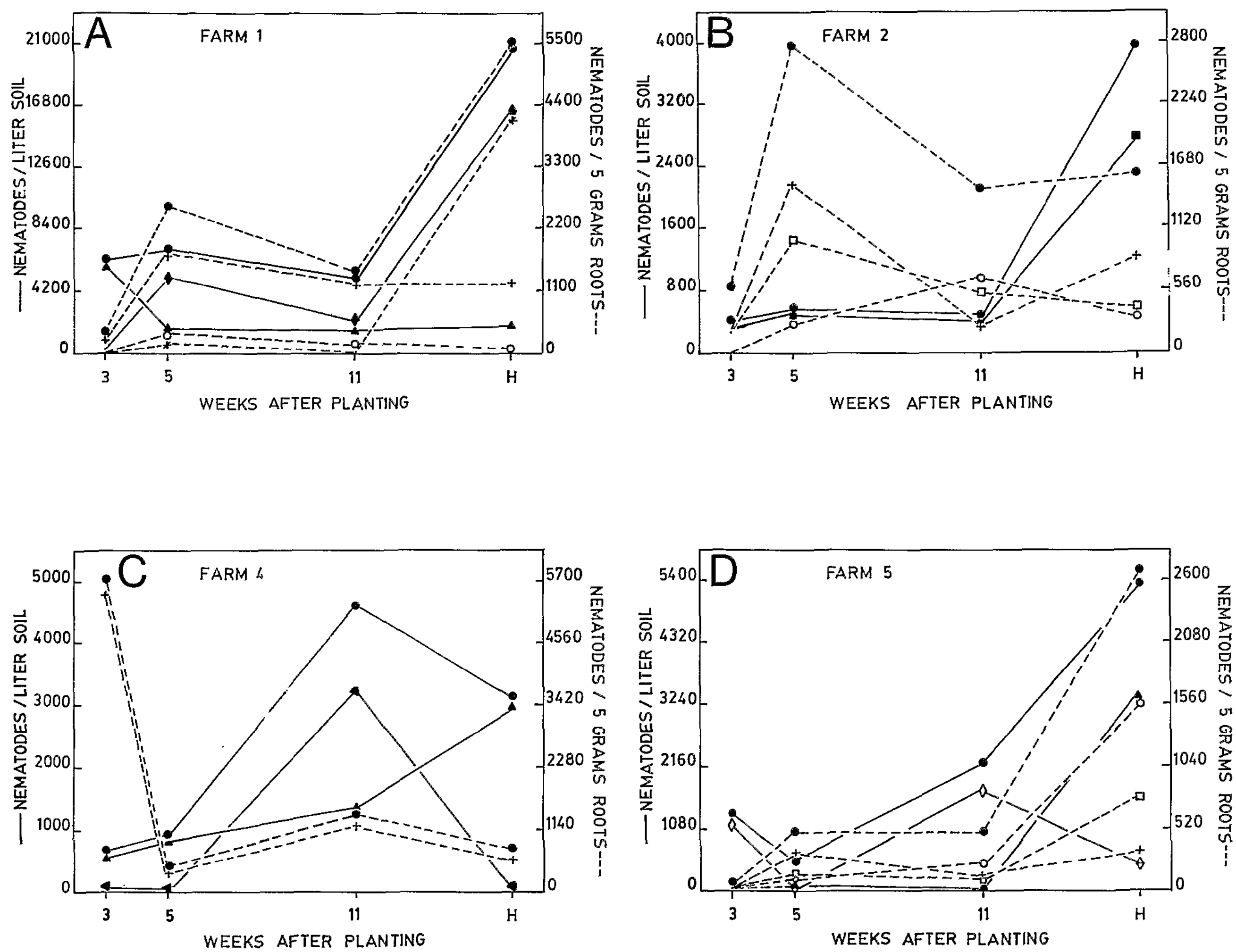

Fig. 2 (A-D). Seasonal population fluctuations of plant-parasitic nematodes in rhizosphere and roots of sorghum plants in eight sorghum fields, South Africa. Numbers of nematodes per dm³ soil or 5g roots.

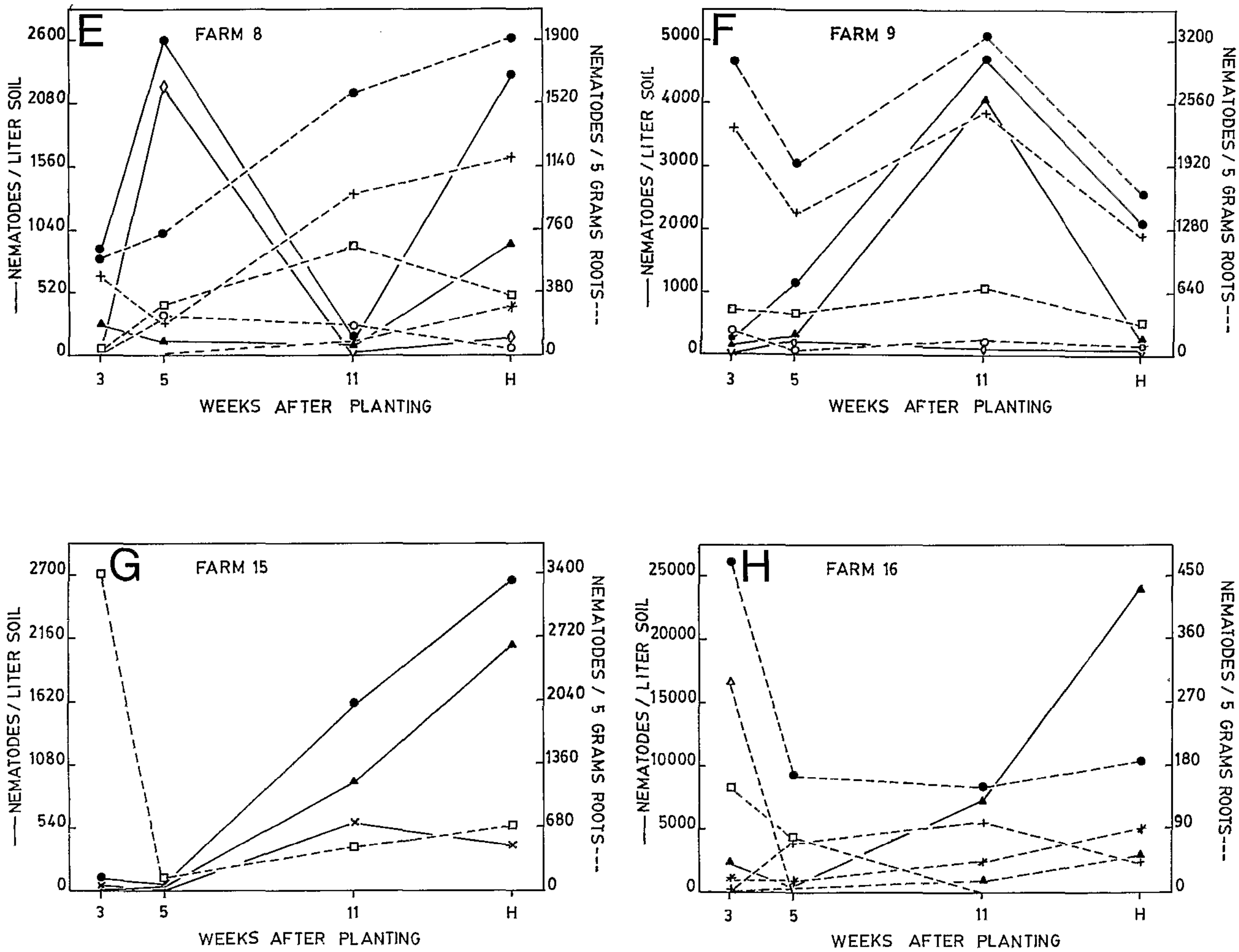

Fig. 2 (E-H). Same as Fig. 2 (A-D).

Total numbers of plant-parasitic nematodes in the soil (— ●) and in the roots (... ●); *Scutellonema brachyurus* (♦); *Paratrophurus anomalus* (■); *Rotylenchus devonensis* (◊); *Paratrichodorus minor* (◄); *Pratylenchus zeae* (+); *Pratylenchus penetrans* (□); *Pratylenchus crenatus* (O); *Longidorus pisi* (×); *Rotylenchulus parvus* (▲); *Pratylenchus brachyurus* (△); spiral nematodes (*).

In the roots, the very low numbers of *Pratylenchus* spp. usually occurred in mixed populations (Tab. 3). A monospecific population of *P. zeae* was present in only one field. *P. zeae* usually outnumbered the other *Pratylenchus* spp. present although in two fields *P. penetrans* and *P. crenatus* outnumbered *P. zeae.*

The population development of plant-parasitic nematodes between three weeks after planting and harvest varied from field to field and several different patterns were observed (Fig. 2 A-H).

In general, populations of plant-parasitic nematodes in the soil were low three weeks after planting but increased one and a half times eleven weeks after planting and about fourfold at harvest.

In five fields, plant-parasitic nematode populations in the soil increased sharply towards harvest (Fig. 2 A, B, C, D, G & H). In two fields the plant-parasitic nematode numbers in the soil were highest eleven weeks after planting (Fig. 2 C & F) while in one field populations fluctuated throughout the growing season (Fig. 2 E). The end result, however, was always a higher population in the soil at harvest than three weeks after planting.

In the roots, the mean numbers of plant-parasitic nematodes were, generally, as high three weeks after planting as at harvest. Between three and eleven weeks after planting the mean plant-parasitic nematode population density in the roots decreased, on average, by about 25 %.

Low initial plant-parasitic nematode populations in the roots three weeks after planting always resulted in

Table 3

Occurrence of mixed populations of *Pratylenchus* spp. recovered from sorghum roots in eight sorghum fields (mean density during the growing season/5g roots)

Farm no.	P. zeae	P. penetrans	P. crenatus	P. brachyurus
1	1 117	53	104	0
2	705	536	307	0
4	1 938	0	0	0
5	189	263	468	0
8	711	354	95	0
9	1 852	463	115	0
15	7	1 117	0	0
16	54	56	0	76

high populations at harvest (Fig. 2 A, B, D & E) and vice versa (Fig. 2 C, F, G & H).

Neither the increase nor the decrease of the plant-parasitic nematode populations in the roots were usually continuous. In three fields, plant-parasitic nematode populations stabilised between five weeks after planting and harvest after a decrease between three and five weeks after planting (Fig. 2 C, G & H).

The population densities of all plant-parasitic nematodes in the soil three weeks after planting were postively correlated ($P < 0.01$) with their population densities at harvest (Tab. 2). The percentage of plant-parasitic nematodes present in the soil was positively correlated ($P < 0.001$) with the total number of plant-parasitic nematodes recovered from the soil (Fig. 3).

Many of the predominant parasitic nematodes (expect *P. zeae* and *P. penetrans*) found during the present study of sorghum in South Africa have never before been associated with this crop. This is especially surprising since *S. brachyurus* and *P. minor* are polyphagous, cosmopolitan species (Siddiqi, 1974; Heyns, 1975). From host plant studies in the USA, Kraus-Schmidt and Lewis (1979) even considered sorghum a non-host for *S. brachyurus*. In this study *S. brachyurus* was found to be primarily a root ectoparasite which invaded the deeper cortical layers of sorghum. In one field (farm 1) 4 135 individuals/5g roots were present at harvest.

Previous reports that sorghum was a good host for *P. zeae* (Endo, 1959; Ayoub, 1961; Bee-Rodriguez & Ayala, 1977*b*) were confirmed.

In the past the known occurrence of *P. anomalus*, *R. devonensis*, *P. penetrans* and *P. crenatus* in South Africa was limited to a few localities and host plants (Van den Berg, 1971, 1976; Kleynhans & Heyns, 1983) but this study indicates that these species are much more widespread in local agricultural soils. The presence of *L. pisi* in 50 % of the sorghum fields sampled was also surprising. This species has a world-wide distribution (Heyns *et al.*, 1984) and is common in South Africa (Jacobs & Heyns, 1982) but has never been reported from sorghum. Populations were low but this could be the result of the extraction technique which is known to be unsuitable for longidorids (Coolen & D'Herde, 1977). In reality population levels could have been five to ten times higher.

Several *Meloidogyne* spp. and *P. brachyurus* occur in South Africa and are considered serious pests of many

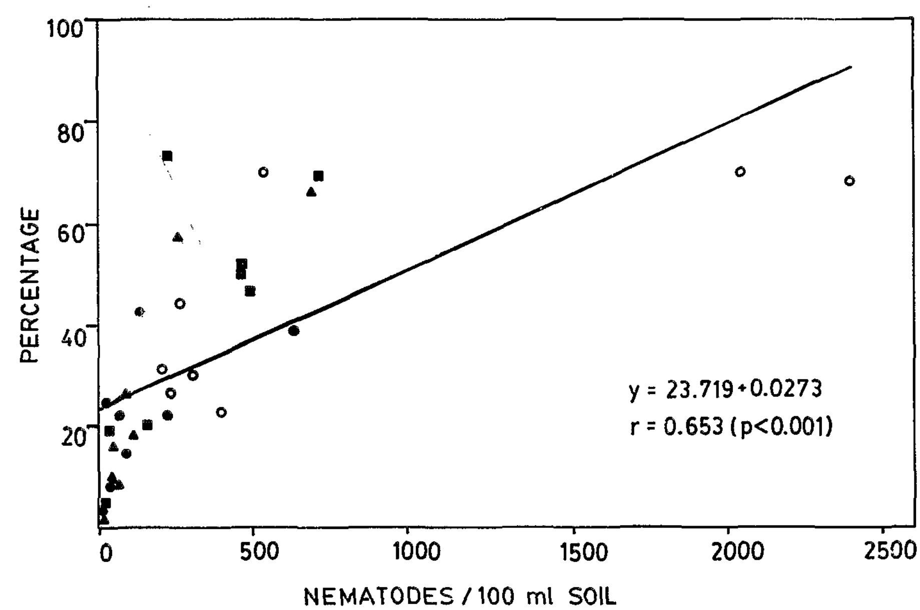

Fig. 3. Relationship between the percentage of plant-parasitic nematodes in the soil and the total number of plant-parasitic nematodes in the soil 3 (●), 5 (▲), 11 (■) weeks after planting and at harvest (○).

crops (Keetch & Heyns, 1982) but on sorghum these nematodes occurred infrequently and in low numbers. Sorghum is a good host for several *Meloidogyne* spp. (Aytan & Dickerson, 1969; Birchfield, 1983) so that its use for crop rotation in fields infested with *Meloidogyne incognita* (Kofoid & White) Chitwood has been discouraged in the USA (Carter & Nieto, 1975). On the other hand, resistance of sorghum genotypes to *Meloidogyne* spp. and *P. brachyurus* has been reported (Whitehead, Ledger & Kariuki, 1963; Sharma & De S. Medeiros, 1982).

Sorghum apparently is also a good host for *Rotylenchulus parvus*. However, population densities of *R. parvus* in sorghum roots remained low while its prominence values in the soil were high compared with the other plant-parasitic nematode species present (Tab. 2). De Waele and Jordaan (1988) report a similar situation for *R. parvus* in maize. The growth of sorghum is not affected by high soil populations of *R. parvus* because no feeding takes place before the nematodes enter the roots (Dasgupta & Raski, 1968). The same authors also point out that *R. parvus* has the potential to develop into an important agricultural pest.

S. brachyurus, P. minor and *P. zeae* were also among the predominant parasitic nematodes associated with maize in South Africa (De Waele & Jordaan, 1988). The pathogenicity of those plant-parasitic nematodes most commonly associated with sorghum in South Africa has never been studied. However, many of them are known to be potential pathogens on other crops and their influence on sorghum will have to be established.

P. zeae at 500 and 1 500 nematodes per 15-cm-diameter pot suppressed plant growth of sorghum and induced root necrosis (Bee-Rodriguez & Ayala, 1977*a;* Cuarezma-Teran & Trevathan, 1985).

Damage to sorghum induced by hoplolaimids, root-knot nematodes, trichodorids and longidorids has been reported (Orr, 1967; Lamberti, 1969; Dasgupta, Nand & Seshadri, 1970; Chevres-Roman, Gross & Sasser, 1971; Marks & Elliot, 1973; Ediz & Dickerson, 1976; Smolik, 1977; Orr & Morey, 1978).

The observation that *P. zeae* usually outnumbers other *Pratylenchus* species when present in mixed populations leads to the conclusion that *P. zeae* dominates not only *P. brachyurus* (Olowe & Corbett, 1976; De Waele & Jordaan, 1988) but also *P. penetrans* and *P. crenatus*. One possible cause for this is the shorter life cycle of *P. zeae* which is on maize three weeks at 30 to 35° (Olowe & Corbett, 1976) compared with 35 days at 28° on peas (Dickerson, 1961) and 35 days at 21° on potatoes and onions (Wong & Perria, 1968).

In moist soil which is allowed to dry out, *S. brachyurus* and *P. penetrans* exhibit anhydrobiosis (Demeure, Freckman & Van Gundy, 1979*a*, 1979*b;* Townshend, 1984). De Waele & Jordaan (1988), suggest that the predominant plant-parasitic nematodes of maize display the same mechanism. Anhydrobiosis may also occur in those plant-parasitic nematodes associated with sorghum in South Africa which would explain how these organisms are able to survive almost six months of drought between growing seasons.

The different population development patterns observed between three weeks after planting and harvest could be the result of many interactions. It will therefore be difficult to forecast the population development of sorghum nematodes at the beginning of the growing season.

The correlation coefficients between mean nematode population densities three weeks after planting and harvest (Tab. 2) indicate that root-lesion nematodes leave decaying sorghum roots as soon as they are physiologically mature.

In sorghum planted after 15th November, large populations of plant parasitic nematodes were observed three weeks after planting (Fig. 2 C, F, G & H). However, it is unclear if prolonged exposure to high moisture levels in the soil induced quiescent *Pratylenchus* populations to resume activity, even in the absence of growing sorghum roots.

Large populations of ecto- and endoparasitic nematodes also occurred in soils with more than 15 % clay (Fig. 2 B, D & E). This suggests that sorghum grown in clay soils can also be attacked by nematodes.

The percentage of plant-parasitic nematodes present in the rhizosphere of sorghum can be used to indicate the potential for nematode infestation since this parameter was positively correlated with the total number of plant-parasitic nematodes present around the roots.

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REFERENCES

ANONYMOUS (1971). Estimated crop losses due to plant parasitic nematodes in the United States. *J. Nematol., spec. Public.*, 1 : 7 p.

AYOUB, S. M. (1961). *Pratylenchus zeae* found on corn, milo and three suspected new hosts in California. *Pl. Dis. Reptr*, 45 : 940.

AYATAN, S. & DICKERSON, O. J. (1969). *Meloidogyne naasi* on sorghum in Kansas. *Pl. Dis. Reptr*, 53 : 737.

BEE-RODRIGUEZ, D. & AYALA, A. (1977*a*). Interaction of *Pratylenchus zeae* with four soil fungi on sorghum. *J. Agric. Univ. P. Rico*, 61 : 501-506.

BEE-RODRIGUEZ, D. & AYALA, A. (1977*b*). Nematodes associated with sorghum in Puerto Rico. *Nematropica*, 7 : 16-20.

BIRCHFIELD, W. (1983). Wheat and grain sorghum varietal reaction to *Meloidogyne incognita* and *Rotylenchulus reniformis*. *Pl. Dis. Reptr*, 67 : 41-42.

BOUYOUCOS, G. J. (1951). Recalibration of the hydrometer method for making mechanical analysis of soil. *Agron. J.*, 23 : 434-438.

CHEVRES-ROMAN, R., GROSS, H. D. & SASSER, J. N. (1971). The influence of selected nematode species and number of consecutive plantings of corn and sorghum on forage production, chemical composition of plant and soil, and water use efficiency. *Nematropica*, 1 : 40-41.

CARTER, W. W. & NIETO, S. (1975). Population development of *Meloidogyne incognita* as influenced by crop rotation and fallow. *Pl. Dis. Reptr*, 59 : 402-403.

COOLEN, W. A. & D'HERDE, C. J. (1972). *A method for the quantitative extraction of nematodes from plant tissues*. Ministr. Agric., Belgium : 77 p.

COOLEN, W. A. & D'HERDE, C. J. (1977). Extraction de *Longidorus* et *Xiphinema* spp. du sol par centrifugation en utilisant de la silice colloïdale. *Nematol. medit.*, 5 : 195-206.

CUAREZMA-TERAN, J. A. & TREVATHAN, L. E. (1985). Effects of *Pratylenchus zeae* and *Quinisulcius acutus* alone and in combination on sorghum. *J. Nematol.*, 17 : 169-174.

DASGUPTA, D. R., NAND, S. & SESHADRI, A. R. (1970). Culturing, embryology and life history studies on the lance nematode, *Hoplolaimus indicus*. *Nematologica*, 16 : 235-248.

DASGUPTA, D. R. & RASKI, D. J. (1968). The biology of *Rotylenchulus parvus*. *Nematologica*, 14 : 429-440.

DAY, P. R. (1965). Particle fractioning and particle size analysis. In : Black, C. E., Evans, D. D., White, J. L., Ensminger, L. A., & Clark, F. E. (Eds). *Methods of Soil Analysis*. Am. Soc. Agron. : 547-567.

DE GRISSE, A. T. (1969). Redescription ou modification de quelques techniques utilisées dans l'étude des nématodes phytoparasitaires. *Meded. Rijksfac. LandbWet. Gent*, 34 : 351-359.

DEMEURE, Y., FRECKMAN, D. W. & VAN GUNDY, S. (1979*a*). *In vitro* response of four species of nematodes to desiccation and discussion of this and related phenomena. *Revue Nématol.*, 2 : 203-210.

DEMEURE, Y., FRECKMAN, D. W. & VAN GUNDY, S. (1979*b*). Anhydrobiotic coiling of nematodes in soil. *J. Nematol.*, 11 : 189-195.

DE WAELE, D. (1984). *Planten-parasitaire nematoden van sorghum en giersten*. Thesis, Univ. Gent, Belgium, 130 p.

DE WAELE, D. & JORDAAN, E. M. (1988). Plant-parasitic nematodes on field crops in South Africa. 1. Maize. *Revue Nématol.*, 11 : 65-74.

DICKERSON, O. J. (1961). Pathogenicity, life cycle, and morphology of certain *Pratylenchus* spp. on potato. *Diss. Abstr.*, 22 : 700.

EDIZ, S.A. & DICKERSON, O. J. (1976). Life cycle, pathogenicity, histopathology and host range of race 5 of the barley root-knot nematode. *J. Nematol.*, 8 : 228-232.

ENDO, H. Y. (1959). Responses of root-lesion nematodes, *Pratylenchus brachyurus* and *P. zeae*, to various plants and soil types. *Phytopathology*, 49 : 417-421.

FLEGG, J. J. M. (1967). Extraction of *Xiphinema* and *Longidorus* species from soil by a modification of Cobb's decanting and sieving technique. *Ann. appl. Biol.*, 60 : 429-437.

HEYNS, J. (1975). *Paratrichodorus minor*. *C. I. H. Descript. Pl.-paras. Nematodes*, Set 5, No. 69 : 4 p.

HEYNS, J., JACOBS, P. J. F., LOOTS, G. C. & TIEDT, L. (1984). On the occurrence of unknown objects in the prerectum of *Longidorus pisi* Edward, Misra & Singh, 1964 (Nematoda : Longidoridae). *Phytophylactica*, 16 : 167-169.

HODGSON, J. M. (1974). *Soil Survey Field Handbook*. Harpenden, England, Rothamsted exp. Statn, Soil Surv. techn. Monogr., No. 5, 99 p.

JACOBS, P. J. F. & HEYNS, J. (1982). *Longidorus* species from sugar cane in Natal (Nematoda : Longidoridae). *Phytophylactica*, 14 : 195-204.

JENKINS, W. R. (1964). A rapid centrifugal-flotation method for separating nematodes from soil. *Pl. Dis. Reptr*, 48 : 692.

KEETCH, D. P. & BUCKLEY, N. H. (1984). A check-list of the plant-parasitic nematodes of Southern Africa. *Tech. Commun. Dep. Agric. Fish. Republ. S. Afr.*, No. 195, 213 p.

KEETCH, D. P. & HEYNS, J. (Eds). (1982). Nematology in Southern Africa. *Sci. Bull. Dep. Agric. Fish. Repub. S. Afr.*, No. 400, 170 p.

KLEYNHANS, K. P. N. & HEYNS, J. (1983). New species of *Amplimerlinius Siddiqi*, 1976 and *Paratrophurus* Arias, 1970 from South Africa (Nematoda : Hoplolaimidae). *Phytophylactica*, 15 : 57-62.

KRAUS-SCHMIDT, H. & LEWIS, S.A. (1979). *Scutellonema brachyurus* : host plants and pathogenicity on cotton. *Pl. Dis. Reptr*, 63 : 688-691.

LAMBERTI, F. (1969). Pathogenicity of *Longidorus africanus* on selected field crops. *Pl. Dis. Reptr*, 53 : 421-424.

MACVICAR, C. N., DE VILLIERS, J. M., LOXTON, R. F., VERSTER, E., LAMBRECHTS, J. J. N., MERRYWEATHER, F. R., LE ROUX, J., VAN ROOYEN, T. H. & HARMSE, H. J. VON M. (1977). Soil classification. A binomial system for South Africa. *Sci. Bull. Dep. Agric. Tech. Serv. Repub. S. Afr.*, No. 390, 152 p.

MARKS, C. F. & ELLIOT, J. M. (1973). Damage to flue-cured tobacco by the needle nematode *Longidorus elongatus*. *Can. J. Plant Sci.*, 53 : 689-692.

NORTON, D. C. (1958). The association of *Pratylenchus hexincisus* with charcoal rot of sorghum. *Phytopathology*, 48 : 355-358.

OLOWE, T. & CORBETT, D. C. M. (1976). Aspects of the biology of *Pratylenchus brachyurus* and *P. zeae*. *Nematologica*, 22 : 202-211.

ORR, C. C. (1967). Observations on cotton root-knot nematode in grain sorghum in West Texas. *Pl. Dis. Reptr*, 51 : 29.

ORR, C. C. & MOREY, E. D. (1978). Anatomical response of grain sorghum roots to *Meloidogyne incognita acrita*. *J. Nematol.*, 10 : 48-53.

SHARMA, R. D. & DE S. MEDEIROS, A. C. (1982). Reacoes de alguns genotipos de sorgo sacarino aos nematoides, *Meloidogyne javanica* e *Pratylenchus brachyurus*. *Pesq. Agropec. brasil.*, 17 : 697-701.

SIDDIQI, M. R. (1974). *Scutellonema brachyurus*. *C.I.H. Descript. Pl.-parasit. Nematodes*, Set 4, No. 54, 3 p.

SMOLIK, J. D. (1977). Effects of *Trichodorus allius* and *Tylenchorhynchus nudus* on growth of sorghum. *Pl. Dis. Reptr,* 61 : 855-858.

TOWNSHEND, J. L. (1984). Anhydrobiosis in *Pratylenchus penetrans. J. Nematol.,* 16 : 282-289.

VAN DEN BERG, E. (1971). The root-lesion nematodes of South Africa (genus *Pratylenchus,* family Hoplolaimidae). *Tech. Commun. Dep. agric. techn. Serv. Repub. S. Afr.,* No. 99, 13 p.

VAN DEN BERG, E. (1976). Some species of Tylenchoidea (Nematoda) from South Africa, with descriptions of two new species. *Phytophylactica,* 8 : 55-64.

WHITEHEAD, A. G., LEDGER, M. A. & KARIUKI, L. (1963). Plant Nematology. *Rec. Res. E. Afr. Agric. For. Res. Org.,* Year 1962 : 54-56.

WONG, K. Y. & FERRIS, J. M. (1968). Factors influencing the populationfluctuation of *Pratylenchus penetrans* in soil. III Host plant species. *Phytopathology,* 58 : 662-665.

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