Plant-parasitic nematodes on field crops in South Africa. 1. Maize

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SUMMARY

Fourteen maize fields, representative of the conditions prevailing in the main maize-producing areas of South Africa, were monitored during the 1984/85 growing season. The number of plant-parasitic nematode species present in the fields was very low but several potential pathogenic species were found. The predominant ectoparasites were *Paratrichodorus minor, Scutellonema brachyurum* and *Criconemella sphaerocephala. Pratylenchus zeae* and *Pratylenchus brachyurus* were the predominant endoparasites. In the soil, the mean numbers of plant-parasitic nematodes were low three weeks after planting but increased, on average, fivefold about eleven weeks after planting. In the roots, the mean numbers of plant-parasitic nematodes were highest three weeks after planting and decreased, on average, by almost 50 % about eleven weeks after planting. Population densities of *Longidorus pisi, S. brachyrum* and *P. brachyurus* in the soil and roots three and eleven weeks after planting 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. 1. Le maïs

Quatorze champs représentatifs des conditions de production du maïs en Afrique du Sud ont été prospectés durant la saison de culture de 1984/85. Le nombre d'espèces de nématodes phytoparasites présents dans les champs était très faible mais plusieurs espèces potentiellement pathogènes ont été déterminées. Les ectoparasites prédominants sont : *Paratrichodorus minor, Scutellonema brachyurum* et *Criconemella sphaerocephala*, et les endoparasites prédominants : *Pratylenchus zeae* et *P. brachyurus.* Trois semaines après la plantation du maïs, la population moyenne de nématodes phytoparasites dans le sol est d'un niveau faible, mais onze semaines après plantation il est multiplié par cinq. La population moyenne de nématodes parasites dans les racines est d'un assez haut niveau trois semaines après plantation; il décroît d'environ 50 % onze semaines après plantation. Les densités de population de *Longidorus pisi, S. brachyurum* et *P. brachyurus* à trois et à onze semaines après plantation sont corrélées positivement. Une corrélation positive hautement significative existe également entre le pourcentage de nématodes phytoparasites dans le sol et le nombre total de nématodes phytoparasites extraits de la rhizosphère du maïs.

In South Africa about 4,5 million ha of maize (*Zea mays* L.), which covers 45 % of the available arable land, are grown annually as a monoculture. During the last decade, Walters (1979*a,b*) and Zondagh and Van Rensburg (1983) reported on the status of plant-parasitic nematodes as pests of maize in South Africa. Although the general occurrence of some root-lesion, spiral and stubby-root nematodes was pointed out, these studies mainly dealt with the damage caused by plant-parasitic nematodes in general. Recently, Keetch and Buckley (1984) listed 36 plant-parasitic nematode species associated with maize in South Africa, but their check-list did not differentiate between common and rare species. As a result, it is unknown which are the most important plant-parasitic nematode species associated with maize in the main maize producing areas of South Africa. Such information is required 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 maize in South Africa. During the 1984/85 growing season fourteen maize fields, representative of the production conditions in the maize triangle (Fig. 1), the main maize-producing area of South Africa, were monitored.

Materials and methods

During the 1984/85 growing season, soil and root samples were collected from fourteen maize fields

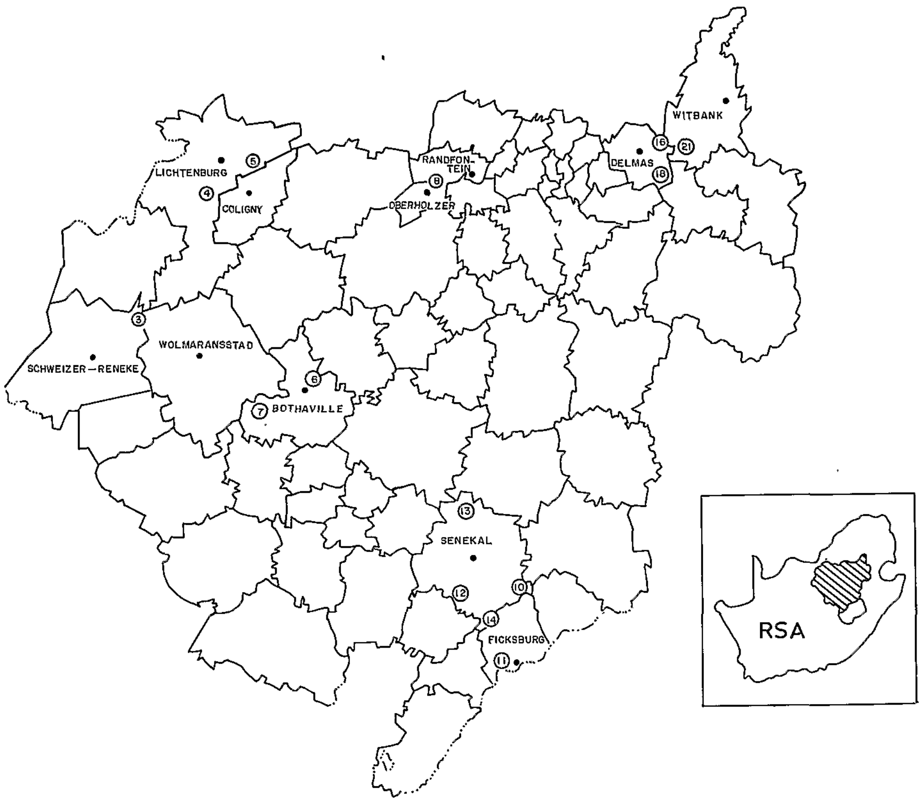

Fig. 1. Sites in the maize triangle, South Africa, where nematode populations were monitored during the 1984/85 growing season.

throughout the maize triangle (Fig. 1) three, five and eleven weeks after planting.

The properties of the soil, together with the rainfall, cultivar planted and yield of the fourteen maize fields are given in Table 1. Soil properties and agronomic practices of the selected maize fields represent the prevailing production conditions in the maize triangle. On all fields maize had been grown in monoculture under dryland conditions for several years. Fields were planted between 8th October and 6th December 1984. Minimum tillage was applied at farms 8 and 12; conventional tillage (plough) at farms 5, 10, 11 and 14; deep rip at the other farms. Planting density varied between 14 000 and 34 000 plants/ha; row spacing between 0.9 and 2.4 m. All fields are situated between 1 300 and 1 800 m altitude.

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 maize field soil and roots from 15 maize 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 5 g subsamples by the sugar centrifugal-flotation method (Coolen & 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 microscope and expressed either as the number of nematodes per 100 ml soil or per 5 g roots. For species identification plant-parasitic nematodes were transferred to anhydrous glycerin (De Grisse, 1969) and mounted on slides, by means of the paraffinring method.

Prominence values *(PV = population density × $\sqrt{}$ frequency of occurrence/10)* and correlation coefficients were calculated for plant-parasitic nematode population densities three, five and eleven weeks after planting (soil and roots) and between the percentage of plant-parasitic nematodes in the soil and the total number of plant-

Table 1

Main soil properties, rainfall, cultivar planted and yield of the fourteen maize fields monitored during 1984/85 in the maize triangle, South Africa.

Farm No.	*District*	*Soil Form (1)*	*Soil Texture (2)*			*Soil type (3)*	*Rainfall (4) (mm)*	*Cultivar*	*Yield (ton/ha)*
			% sand	*% loam*	*% clay*				
3	Migdol	Hutton	90	5	5	S	116	CG 4705	1.2
4	Lichtenburg	Avalon	90	6	4	S	227	PNR 473	3.3
5	Coligny	Hutton	88	9	3	S	44	SNK 2147	0.5
6	Bothaville	Clovelly	94	2	4	S	250	Asgrow 475	5.1
7	Bothaville	Avalon	97	2	1	S	130	PNR 473	3.9
8	Oberholzer	Hutton	84	8	8	LS	262	PNR 394	1.8
10	Senekal	Clovelly	80	15	5	LS	165	PNR 496	1.2
11	Ficksburg	Clovelly	82	13	5	LS	267	PNR 496	3.3
12	Marquard	Clovelly	75	17	8	SL	331	Asgrow 1750	4.7
13	Senekal	Westley	82	12	6	LS	248	PNR 473	2.5
14	Senekal	Westley	85	11	4	LS	307	SSM 35	1.3
16	Delmas	Hutton	91	5	24	S	237	PNR 4627	3.5
18	Balfour	Rensburg	66	10	4	SCL	412	PNR 394	1.9
21	Delmas	Hutton	90	6	4	S	—	—	—

(1) Soil form according to MacVicar *et al.* (1977).
(2) Soil texture as determined by the Bouyoucos (1951) hydrometer method (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.

parasitic nematodes in the soil (percentage plant-parasitic nematodes in the soil = freeliving + plant parasitic nematodes in the soil/plant parasitic nematodes in the soil × 100).

Results

The number of plant-parasitic nematode species present in the fourteen maize fields monitored was very low (Tab. 2). The predominant ectoparasites were *Paratrichodorus minor* (Colbran) Siddiqi, *Scutellonema brachyurum* (Steiner) Andrássy and *Criconemella sphaerocephala* (Taylor) Luc & Raski. *Rotylenchulus parvus* (Williams) sher also occurred in most maize fields but the high population levels in the soil (72 individuals/100 ml soil) were not matched by high populations in the roots (29 individuals/5 g roots). *Longidorus pisi* Edward, Misra & Singh was also present in many maize fields but its population density in the soil usually remained low (maximum 33 individuals/100 ml soil), hence the low prominence value. *Helicotylenchus dihystera* (Cobb) Sher was present in only one maize field but in rather high numbers (31-67 individuals/100 ml soil). The predominant endoparasites were *Pratylenchus zeae* Graham and *Pratylenchus brachyurus* (Godfrey) Filipjev & Schuurmans Stekhoven. *Pratylenchus penetrans* Cobb and *Meloidogyne* spp. [a mixture of predominantly *M. incognita* (Kofoid & White) Chitwood plus some *M. javanica* (Treub) Chitwood] were present in only two densities usually increased considerably during the growing season reaching 375 and 594 individuals/5 g roots respectively, hence the rather high prominence values.

Other plant-parasitic nematode species found in the soil in very low numbers were : *Telotylenchus avaricus* Kleynhans (farm 7), *Tylenchorhynchus brevilineatus* Williams (farms 8 and 12), *Scutellonema africanum* Smit (farm 5), *Helicotylenchus digonicus* Sher (farms 8 and 21) and *Xiphinema vanderlindei* Heyns (farm 7).

Mixed populations of *P. zeae* and *P. brachyurus* were present in seven fields while *P. zeae* occurred alone in five fields and *P. brachyurus* alone in one field. *P. zeae* usually outnumbered *P. brachyurus* when both species were present in the same field.

The population development of plant-parasitic nematodes between three and eleven weeks after planting differed from field to field and many different patterns were observed (Fig. 2 A-N). On average, population levels of plant-parasitic nematodes in the soil were low three weeks after planting but increased fivefold towards eleven weeks after planting (Tab. 2). In nine fields plant-parasitic nematode numbers in the roots were lower creased continuously while in five fields the popu-

Table 2

Frequency of occurrence, mean population density and prominence value (PV) of the predominant plant-parasitic nematodes recovered from soil and maize roots in fourteen maize fields in the maize triangle, South Africa, 3, 5 and 11 weeks after planting
(PV = population density $\sqrt{\text{frequency of occurrence}/10}$)

	Frequency of occurrence %	*Mean population density*				*Prominence value*		
		Nematodes/100 ml soil or 5 g roots			*Coeff. correl. 3 and 11 wks*			
		3 wks	*5 wks*	*11 wks*		*3 wks*	*5 wks*	*11 wks*
SOIL								
Paratrichodorus minor	100.0	9	6	52	+ 0.150 n.s.	9.0	6.0	52.0
Longidorus pisi	64.3	2	3	9	+ 0.890**	1.6	2.4	7.2
Criconemella sphaerocephala	50.0	4	11	42	+ 0.793 n.s.	2.8	7.8	29.7
Scutellonema brachyurum	78.6	24	27	70	+ 0.854***	21.3	23.9	62.1
Rotylenchulus parvus	78.6	14	9	72	— 0.160 n.s.	12.4	8.0	63.8
Pratylenchus spp.	92.9	2	2	6	+ 0.438 n.s.	1.9	1.9	5.8
All plant-parasitic nematodes	100.0	47	49	201	+ 0.644*	47.0	49.0	201.0
ROOTS								
Pratylenchus zeae	92.9	2 098	2 316	863	+ 0.529 n.s.	2 022.1	2 232	831.8
Pratylenchus brachyurus	57.1	1 451	600	1 196	+ 0.932***	1 096.4	453.4	903.8
Pratylenchus penetrans	14.3	107	286	302	—	40.5	108.2	114.2
Rotylenchulus parvus	92.9	18	9	29	+ 0.471 n.s.	17.4	8.7	28.0
Meloidogyne spp.	28.6	2	1	155	—	1.1	0.5	82.9
Scutellonema brachyurum	78.6	25	78	28	—	22.2	69.2	24.8
All plant-parasitic nematodes	100.0	2 831	2 607	1 621	+ 0.745**	2 831	2 607	1 621

(Significant at $P < 0.01^{*}$; $P < 0.05^{**}$; $P < 0.001^{***}$; n.s. = not significant.)

lation levels first decreased before increasing later in the growing season (Fig. 2 A-N). The end result, however, was always a higher population level eleven weeks after planting than at three weeks after planting.

In the roots, the mean numbers of plant-parasitic nematodes were on average highest three weeks after planting and then decreased by almost 50 % towards eleven weeks after planting (Tab. 2). In nine fields, plant-parasitic nematode numbers in the roots were lower eleven weeks after planting than three weeks after planting. The decrease was continuous in only two fields (Fig. 2 D & K). In five fields, population levels initially increased before decreasing later in the growing season (Fig. 2 A, E, H, J & N) while in two fields the population levels first decreased before increasing later in the growing season (Fig. 2 B & F). In five fields, plant-parasitic nematode populations in the roots were higher eleven weeks after planting than three weeks after planting. The increase was continuous in only one field (Fig. 2 C); in two fields the population levels increased first before decreasing later in the growing season (Fig. 2 G & L) while in two fields the population levels decreased first before increasing later in the growing season (Fig. 2 I & M).

The population densities of *L. pisi*, *S. brachyurum*, and *P. brachyurus* in the soil and roots three weeks after planting were positively correlated ($P < 0.05$) with their population densities at 11 weeks after planting (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).

Discussion

The results of the present study confirm that *P. zeae*, *P. brachyurus* and *P. minor* are among the most common parasitic nematodes associated with maize in South Africa. Maize has been reported as a good host for these three species (Christie, 1959; Ayala, Allen & Noffsinger, 1970; Corbett, 1976; Fortuner, 1976) and all are widely distributed in South Africa (Van den Berg, 1971; Vermeulen & Heyns, 1983, 1985). *P. zeae* usually outnumbered *P. brachyurus* when both species occurred together and this reinforces the suggestion by Olowe and Corbett (1976) that *P. zeae*, although less pathogenic than *P. brachyurus*, dominates *P. brachyurus* in maize roots because of its shorter life cycle, faster reproductive

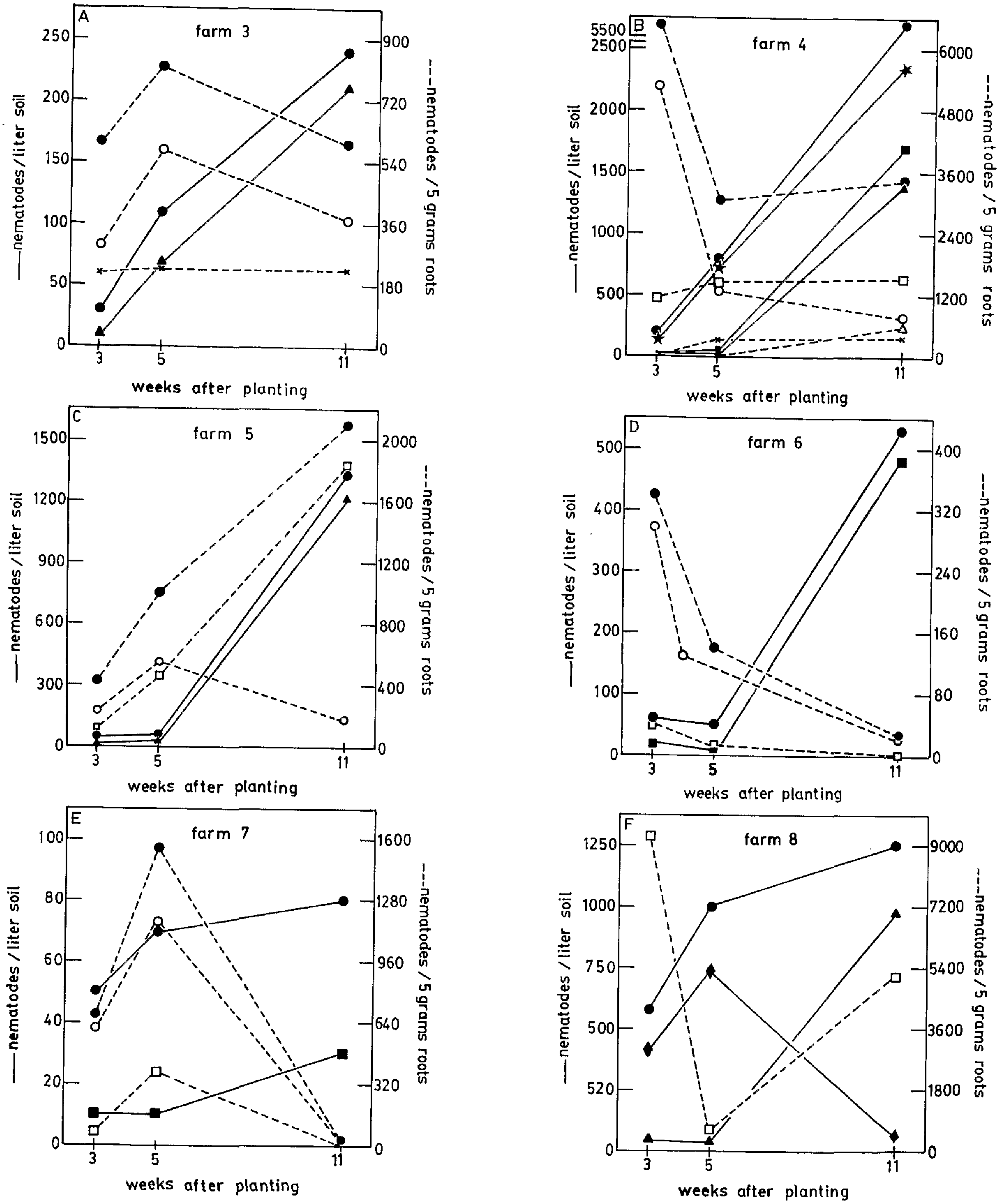

Fig. 2 A-F. Seasonal population fluctuations of plant-parasitic nematodes in rhizosphere and roots of maize plants in fourteen maize fields, maize triangle, South Africa. Numbers of nematodes/dm^3 soil or 5 g roots. Each point represents the mean of five observations.

Total number of plant-parasitic nematodes in the soil (———●) and in the roots (........●); *Paratrichodorus minor* (■), *Scutellonema brachyurum* (♦); *Criconemella sphaerocephala* (★); *Pratylenchus zeae* (○); *Pratylenchus brachyurus* (□); *Longidorus pisi* (◇); *Helicotylenchus dihystera* (+); *Meloidogyne* spp. (△); *Pratylenchus penetrans* (×); *Rotylenchulus parvus* (▲).

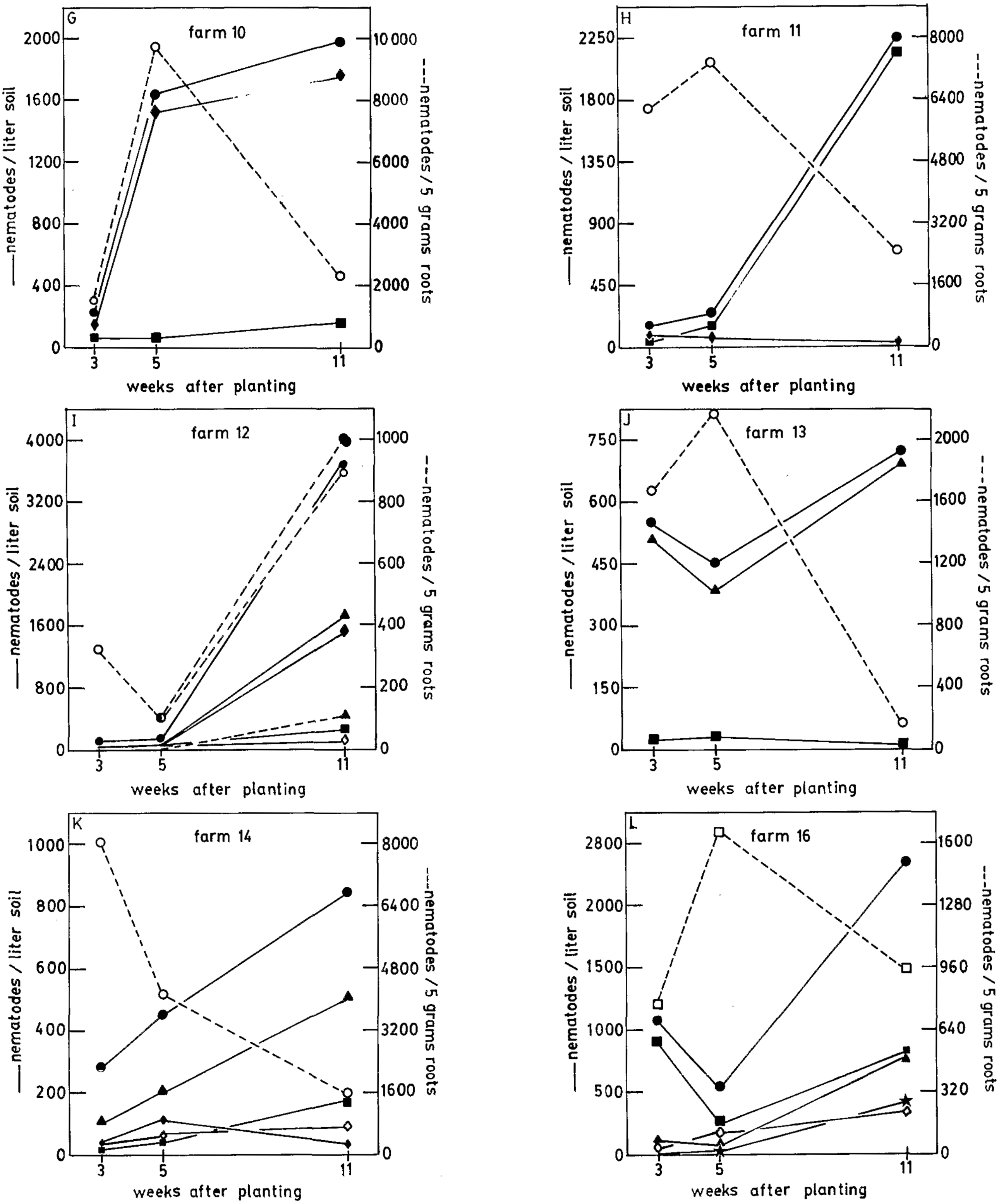

Fig. 2 G-L. See above.

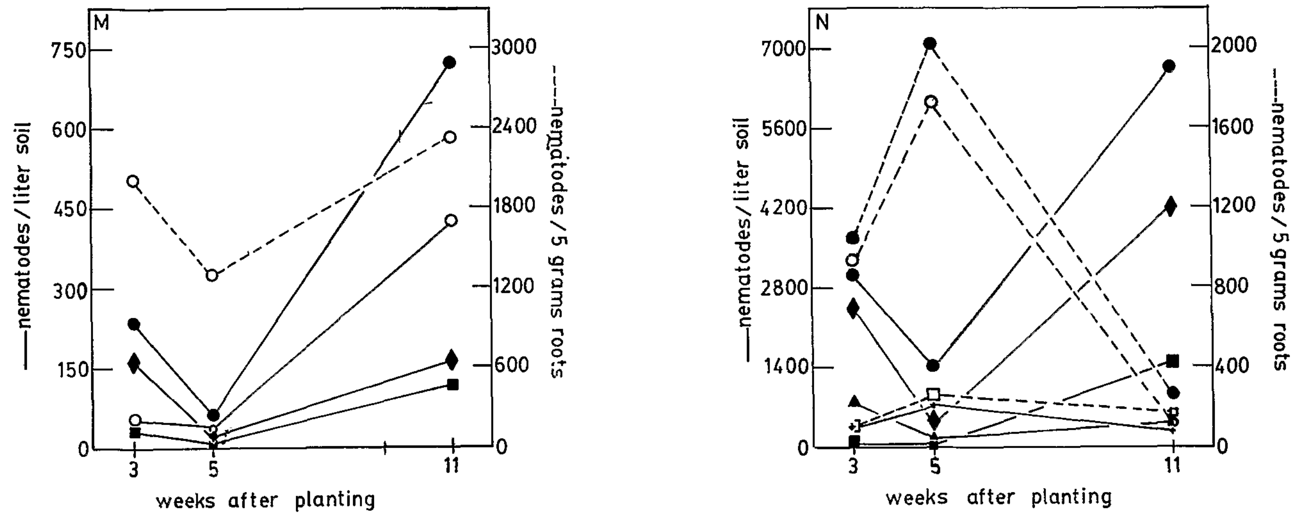

Fig. 2 M-N. See above.

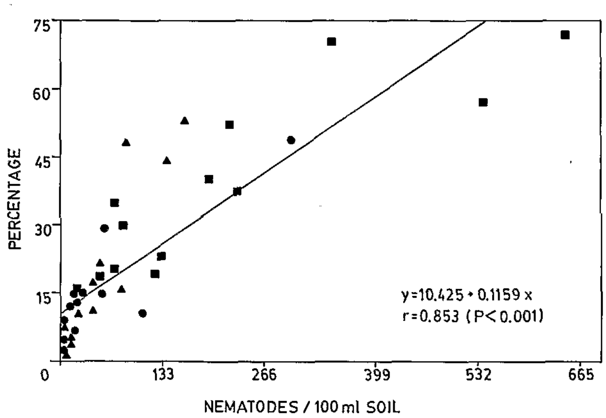

Fig. 3. Relationship between the percentage of plant-parasitic nematodes in the soil and the total number of plant-parasitic nematodes in the soil 3 (●), 5 (▲) and 11 (■) weeks after planting.

rate and higher tolerance for a wider range of temperatures.

The widespread occurrence of *S. brachyurum* on maize, though reported by Walters (1979*a*), is surprising. Worldwide, this species has been associated with numerous host plants (Sher, 1963; Siddiqi, 1974) but rarely with maize. From host range studies in the USA Kraus-Schmidt and Lewis (1979) even reported that cereals (maize, sorghum and small grains) did not favour the reproduction of *S. brachyurum* and these crops were considered non-hosts.

S. brachyurum, primarily a root ectoparasite, may become endoparasitic by invading the deeper cortical layers. At farm 21, about 600 individuals/5 g roots were present five weeks after planting.

C. sphaerocephala occurred in 50 % of the maize fields sampled, but population levels usually remained very low. This ectoparasite has been reported from maize (Kinloch, 1974; Volvas & Inserra, 1976; Van den Berg, 1980) but its pathogenicity has received little attention.

The presence of *L. pisi* in most maize fields and of *H. dihystera* in only one maize field is also suprising. Both ectoparasites are distributed worldwide (Sher, 1966; Siddiqi, 1972; Heyns *et al.*, 1984) and common in South Africa (Van den Berg & Heyns, 1975; Jacobs & Heyns, 1982) but *L. pisi* has rarely been reported from maize while Rao and Swarup (1975) found that maize was an excellent host for *H. dihystera.*
dihystera.

The high frequency of *R. parvus* in the maize roots supports previous findings that maize is a good host (Shepherd, 1977; Furstenberg & Heyns, 1978; Van den Berg, 1978). However, it is unclear why the population densities of this nematode in the maize roots remained rather low while its prominence values in the soil were high compared with the other plant-parasitic nematode species. The growth of maize is not affected by high populations of *R. parvus* in the soil because no feeding takes place before the nematodes enter the plant roots (Dasgupta & Raski, 1968). However, these workers have pointed out that *R. parvus* has a high potential for developing into an important agricultural pest.

M. incognita, M. javanica and *P. penetrans* occurred infrequently. Both *Meloidogyne* species are considered serious pests on many crops in South Africa (Keetch & Heyns, 1982); resistance of maize genotypes to species of *Meloidogyne* has been reported in the literature (Baldwin & Barker, 1970*a,b*). *P. penetrans* is an important pest in Europe (Loof, 1978) but not in South Africa. This species probably prefers cooler climatological conditions (Loof, 1978).

The pathogenicity of the plant-parasitic nematodes most commonly associated with maize in South Africa has never been studied. However, many of them are potential pathogens and their influence on maize growth will have to be established. In the present study, *P. minor* populations in excess of 1 500 individuals/dm^3 soil were found in several maize fields. Johnson and Chalfant (1973) and Johnson (1975) obtained good crop responses and increased maize yields after the nematicidal treatment of *P. minor*(and *H. dihystera*). *S. brachyurum* has been considered a relatively unimportant nematode in agricultural soils but this has been based on experimental monospecific population studies (Ruehle, 1973; Kraus-Schmidt & Lewis, 1979). Interactions with other plant-parasitic nematode species under field conditions may affect the pathogenicity of this species (Kraus-Schmidt & Lewis, 1981). Damage to potato root tissues induced by *S. brachyurum* was recently reported (Schuerger & McClure, 1983).

The low population levels of *L. pisi* in the present study could have been the result of the sugar centrifugal-flotation method which is known to be unsuitable for longidorids (Coolen & D'Herde, 1977). In reality, population levels could have been five to ten times higher. On cotton and Jew's mallow, the stunting of shoots and poor root development have been associated with low numbers of *L. pisi* (Aboul-Eid, 1972; Yassin, 1974). In the USA, *L. breviannulatus* Norton & Hoffman injured maize roots with as few as 10 individuals/100 ml soil (Malek *et al.*, 1980).

When moist soil is allowed to dry out slowly *S. brachyurum* (and *H. dihystera*) are able to enter anhydrobiosis (Demeure, Freckman & Van Gundy, 1979*a,b*). Anhydrobiosis also occurs with *P. thornei* Sher and Allen (Glazer & Orion, 1983) and *P. penetrans* (Townshend, 1984). It is possible that the same mechanism enables *P. zeae* and *P. brachyurus* in South Africa to survive almost six months of drought between the two maize-growing seasons and to return to full activity at the start of the rainy season when the maize seeds germinate.

Many factors such as soil texture, rainfall, maize cultivar and agronomic practices and their complex interactions could have been responsible for the different population development patterns observed between three and eleven weeks after planting. The data presented illustrate how difficult it is to forecast the population development of maize nematodes at the beginning of the growing season.

No correlation between the observed population development patterns and single environmental or agronomic factor was found. The high numbers of plant-parasitic nematodes present in the sandy clay loam soil of farm 18 (24 % clay) suggests that maize grown on clay soils can also be attacked by nematodes.

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

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