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FURTHER INVESTIGATIONS ON THE ROLE OF PLANT-PARASITIC NEMATODES IN CROP GROWTH VARIABILITY OF GROUNDNUT IN NIGER

[A special report on research carried out during an assignment to ICRISAT Sahelian Center, Niger, in 1989].

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INTRODUCTION

Crop growth variability is an important limiting factor for crop production in the Sahel where a striking feature is the extreme variability in plant growth over very short distances. Plant growth often diminishes from very productive areas to completely barren areas over distances as short as one to two meters. Plants in the unproductive areas may eventually die. Surveys conducted by ICRISAT scientists in 1986-87 and 1988 revealed this problem to be particularly serious on groundnut (Arachis hypogaea L.) especially in the sandy soils found in all the major groundnut-producing areas of Niger. Crop growth is usually patchy in these areas. The patches which contain severely stunted and chlorotic plants with poor root and shoot growth, appear to occur at random. Poor growth also appears to be associated, though not consistently, with low lying regions in the field topography. Root systems of the poorly growing plants are under-developed, and in some cases, the root tips are swollen and necrotic. Roots are stubby and have many small bunches of lateral roots. Soil applications of high doses of pesticides (1, 3 dibromo chloro propane (DBCP), aldicarb and carbofuran) at the research farm of ICRISAT Sahelian Center, located at 13°N, 2°E near the village of Say, 45 km south of Niamey, dramatically reduced the variability in growth of the groundnut crop. Plots treated with DBCP, carbofuran and aldicarb showed vigorous plant growth whereas plants in the control plots were stunted and had severely necrosed root systems. Application of farm yard manure and fertilizers did not improve the crop growth very much. Later

on, a survey of these areas for the presence of plant-parasitic showed that Aphelenchoides sp., Ditylenchus sp., Helicotylenchus sp., Hoplolaimus pararobustus, Macroposthonia curvata, Paralongidorus sp., Scutellonema clathricaudatum, Telotylenchus indicus, and Xiphinema sp., were present in the rhizospheres of groundnut plants. S. clathricaudatum was the predominant nematode. Populations of this nematode and of Xiphinema sp. were also detected in the root samples. Population densities of plant-parasitic nematodes, particularly of S. clathricaudatum, were higher in the roots of stunted and chlorotic plants than in roots of the apparently healthy plants. Application of high dosages of pesticides significantly reduced ($P = 0.01$) the nematode populations.

A survey of many groundnut-producing regions in Niger showed that the Scutellonema spp are widespread. The survey indicated involvement of plant-parasitic nematodes in the crop growth variability problem. In 1989, investigations on the role of plant-parasitic nematodes in causing variability of groundnut growth in the Sahel were started. Some of the major objectives of these investigations were to study:

1. Relationship between nematode population densities and crop growth and yield.

2. Pathogenic effects of different population levels of plant-parasitic nematodes (mainly Scutellonema clathricaudatum) on growth of groundnut.

3. Vertical distribution of plant parasitic nematodes in

nematode infested groundnut fields.

4. Residual effects of nematicides on nematode populations.
5. Effects of different crop rotations and cropping systems on plant-parasitic nematodes.
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9. Effect of different pH levels on the incidence of crop growth variability and nematode population densities.
10. Residual effect of nematicides on groundnut and millet yield.

All these experiments are part of the trials conducted by Drs. Farid Waliyar, Principal Groundnut Pathologist and Bruno J. Ndunguru, Principal Groundnut Agronomist and Team Leader, ISC Groundnut Improvement Program. These scientists were closely associated in the investigations presented in this report.

Materials and Methods for collection of soil and root samples and for extraction of nematodes:

Collection of soil and root samples: Around 5000 soil cores and more than 1100 root samples were collected for different experiments from the research farms of ICRISAT Sahelian Center (ISC) located at 13°N, 2°E, near the village of Say, 45 km south of Niamey, Institut national de recherches agronomiques du Niger (INRAN), Maradi, Niger, ICRISAT research station, Bagauda, Nigeria, Ahmadu Bello University, Samaru, Nigeria, and Farmers' fields in Niger, Burkina Faso, Benin, and Nigeria. Soil cores were collected down to 20 cm depth. For each plot of 9 m x 4 m, 8 cores were collected using a steel shovel. Root samples were collected along with the soil samples. Roots and pods were examined for any symptoms caused by nematode infection. Nematode population densities were assessed before planting and at crop maturity.

Extraction of nematodes from soil and root samples:

Thoroughly mixed 100 cm^3 soil samples were processed for each plot by suspending the soil samples in water, pouring them through nested sieves (850 and 45 um pore) and placing the residues from the 45 um pore sieve on double layers of tissue paper supported on a wire mesh immersed in water in 9 cm diameter petridishes. After 48 hrs, the water in the petridish was examined for the presence of plant-parasitic nematodes. Roots (1 to 5 g) were cut into lengths of 1-cm or less, and nematodes were extracted by placing the root pieces on a tissue paper supported on a wire mesh immersed in water in 9 cm diameter

petridish and incubating them for 36 hrs or more. Soil samples were analyzed for acidity, available aluminium, total nitrogen, phosphorus, organic matter (%) and for pH by Dr. A. Bationo, Principal Soil Chemist (IFDC), ISC.

Relationship between nematode population densities and crop growth and yield of groundnut:

A field at ISC that exhibited severe crop growth variability in 1988 was selected for studying the relationship, if any, between the population densities of plant-parasitic nematode and crop growth variability and growth and yield of groundnut. In order to have different levels of population densities of plant-parasitic nematodes in different plots, some plots were irrigated during the hot summer months in April 1989 and May 1989 so that the dormant nematodes in anhydrobiotic stage might be activated and exposed to unfavorable summer fallow conditions. In some plots, carbendazim and carbofuran 5 G were applied at the time of sowing. The different irrigation treatments and chemical treatments are described in Table 1.

Groundnut cultivar 55-437, a spanish type, was used in this study. Different treatments were 1. irrigation in April (three irrigations), 2. irrigation in April (three) and in May (four irrigations), 3. irrigation in April (one) and in May (four), 4. irrigation in April (one) and in May (one), 5. application of Bavistin (fungicide) at the time of planting, 6. application of carbofuran 5 G (a broad spectrum pesticide) at the time of planting, and 7. control. These treatments were replicated four times. Plot size was 16 m^2 (8 rows of 4 m length) and treatments were arranged in a randomized block design. Plots were treated with 40 kg P_2O_5 ha^{-1} at land preparation and 400 kg ha^{-1} gypsum as top dressing was applied at the pegging stage. The crop was

sown on 10 June 1989, harvested at normal maturity, and haulm and pod yields were recorded.

Soil samples were collected at the time of sowing, four times during the crop growth, and at crop harvest. Root samples were collected three times during the crop growth. Samples were collected from plants showing poor growth and from plants exhibiting good growth from the same plots to compare the nematode infection levels in stunted and apparently healthy plants. Crop growth in every plot was scored on a 1-9 scale (1 = uniform growth, 9 = highly variable crop growth).

Pot experiments: Soil samples were collected in bulk from plots having different densities of Scutellonema clathricaudatum. These plots represented four soil densities, 1.3, 0.5, 0.2 and 0.1 individuals of S. clathricaudatum per cm^3 of soil. Some soil samples were autoclaved to obtain a zero nematode population level. All the soil samples containing different population densities of nematodes were also analyzed for available aluminium, nitrogen, phosphorus, for organic matter, and for pH. Soil containing different levels of S. clathricaudatum was placed in 15 cm diameter plastic pots and two seeds of the groundnut variety 55-437 were sown in each pot. These pots were then buried in the field soil with their necks slightly (about 3 cm) above the ground in a fallow land. The pots were irrigated regularly, and plant growth was monitored regularly. Dry shoot weight, leaf weight, leaf area and pod number were recorded at harvest some 45 days after germination.

Soil samples in bulk were also collected from an area of crop showing very stunted growth, and from an area with apparently very healthy crop growth. Nematode population densities were estimated in both these soils. A portion of each soil (around 30 kg) was autoclaved. The soil from poor, and the good growth areas, and the autoclaved samples were placed in 15 cm diameter plastic pots. In four pots for each of these soils, carbofuran 5G was applied at the rate of 8 kg a.i. ha^{-1} and seeds of cv. 55-437 were sown the next day. Plant growth was monitored regularly and plants were harvested 50 days after germination and data on plant growth recorded.

Soil samples were also analyzed for available aluminium, total nitrogen, phosphorus, organic matter (%), and for pH.

Results

Population densities of plant-parasitic nematodes: Populations of S. clathricaudatum, Xiphinema parasetariae, Telotylenchus indicus and a Paralongidorus sp. were present in the soil at the time of sowing. Nematode population densities did not differ significantly in different plots (Table 1). Irrigations during the summer fallow did not appear to affect the nematode population. S. clathricaudatum was the predominant nematode and Paralongidorus sp. was present in very low numbers at the time of sowing. During the crop growth period, nematode population densities were lowest in carbofuran-treated plots. Differences in S. clathricaudatum populations were evident in late July. Plots that were treated with carbendazim at the time of sowing had the highest number of plant-parasitic nematodes ($P = 0.05$).

Soil populations of S. clathricaudatum decreased gradually during the crop growth period while population densities in roots increased. Population density of X. parasetariae in soil was low at the time of sowing and thereafter increased gradually, the highest population density being recorded in the month of August (66 days after sowing) (Table 2). I. indicus population density did not differ significantly in different treatments, however, the soil population decreased significantly during crop growth (Table 3, 4).

Population densities of plant-parasitic nematodes in the roots: All the plots, irrespective of the treatments had some stunted plants and apparently healthy and vigorous plants. For example, carbofuran-treated plots had almost uniform growth and there were only a few randomly distributed stunted plants whereas in other treatments there were many stunted plants and some apparently healthy plants. Five stunted plants and their neighboring apparently healthy plants were randomly selected, gently uprooted from each plot, and population densities of S. clathricaudatum were assessed in July and August. In addition root samples were collected randomly (irrespective of plant growth) from each plot in June, July, August and September and S. clathricaudatum population densities were estimated. Stunted plants always had higher than average numbers of S. clathricaudatum irrespective of treatment (Table 5, 6). The nematode population was up to three times higher in the stunted plants than in the apparently healthy plants, and the nematode population increased during the crop

growth. When root samples were collected at random, the differences in treatments were evident 45 days after sowing.

Pot experiments: Growth of 55-437 was significantly less ($P = 0.05$) in pots having the infestation level of 1.3 S. clathricaudatum cm^{-3} of soil at sowing time (pH (in H_2O) = 4.8 and $Al^{3+} + H^+$ was 0.35 meq. 100 g^{-1} soil) and plant growth in the pots containing 0.5 S. clathricaudatum cm^{-3} of soil was not different from that in the autoclaved soil (no S. clathricaudatum and $Al^{3+} + H^+$ = 0.14 meq 100 g^{-1} soil). The plant growth was significantly ($P = 0.05$) reduced in pots having very low population of S. clathricaudatum (0.1 nematode cm^{-3} of soil and higher $Al^{3+} + H^+$ = 0.55 meq 100 g^{-1} soil) (Table 7).

Soil samples collected from areas with good and with poor growth differed in $Al^{3+} + H^+$ (0.34 meq 100 g^{-1} soil) or less in good patch and 0.51 meq 100 g^{-1} soil in bad patch). Application of carbofuran 5G at the rate of 8 kg a.i. ha^{-1} in pots containing soil from good growth areas, did not result in significantly ($P = 0.05$) more vigorous plant growth, however, addition of carbofuran 5G to the pots containing soil from poor growth areas lead to significant increase ($P = 0.05$) in plant growth. Application of carbofuran 5G to the autoclaved soil dramatically improved plant growth (Table 8). These results indicated that at a sowing time population density of 1.3 S. clathricaudatum cm^{-3} causes reduced and stunted growth of groundnut. $Al^{3+} + H^+$ of 0.36 or more also resulted in poor and stunted growth. Application of carbofuran 5G, even in autoclaved soil, resulted in very vigorous crop growth indicating that this chemical affects the plant growth not

only by controlling the harmful biotic factors (nematodes, insects etc.) but it probably also affects availability of some nutrients and microelements. Application of carbofuran in soil containing 0.8 nematodes cm^{-3} of soil (Al^{3+} + H^{+} 0.34) did not improve the plant growth but it significantly (P = 0.05) affected the plant growth in soil with higher Al + H^{+} (0.51) and lower 0.1 nematode cm^{-3} of soil.

Effect of different treatments on crop growth, haulm weight and pod yield:

Crop growth in the field experiment: Variability in crop growth in some plots was noticed from the early seedling stage. One-week-old seedlings were yellowish, stunted and weak. These seedlings continued to grow poorly and their root systems were poorly developed, sparse, with very few nodules. Roots were brittle and appeared to be almost inactive. In many other plots crop growth was uniform for the initial two to three weeks after germination. Plants were vigorous, green and apparently healthy, however, after three weeks, variability in crop growth was evident in some rows and it increased gradually. Leaves were chlorotic and plants were stunted. Root systems of these plants were less well developed than the healthy-looking plants. In some cases root tips were slightly swollen and necrotic. Lateral roots were branched and stubby.

Analysis of soil samples from some of these plots indicated that these plots differed mainly in Al^{3+} + H^{+} concentration, and

in population densities of plant-parasitic nematodes. $Al^{3+} + H^{+}$ was high (more than 0.35 meq 100 g^{-1} soil) in the plots wherein crop growth variability was observed from the very beginning of crop emergence, and it was comparatively low in other plots where crop growth variability was evident after three weeks. In these plots, population densities of Scutellonema clathricaudatum and Xiphinema parasetariae were greater than in other plots (Table 9).

Haulm weight and pod yields were significantly improved in the plots treated with carbofuran 5G at the time of sowing. Number of plants per plot did not differ significantly between different treatments (Table 10).

Table 1. Population densities of plant-parasitic nematodes at the time of sowing, ICRISAT, Sadore, 1989.

Treatment	Nematode population densities 100 cm^{-3} soil*			
	SC	XP	TI	TOT
Irrigation 1[a]	89.1	9.9	17.4	141.6
Irrigation 2	50.1	15.2	9.1	92.9
Irrigation 3	87.1	11.9	3.3	117.2
Irrigation 4	36.3	15.2	1.8	87.3
Carbendazim	120.2	25.7	1.8	167.9
Carbofuran 5G	102.3	11.0	3.9	132.4
Control	44.7	12.9	3.3	65.9
LSD (P=0.05)	NS	NS	NS	NS

Irrigation 1 Three irrigations in April
Irrigation 2 Three irrigations in April and four in May
Irrigation 3 One irrigation in April and three in May
Irrigation 4 One irrigation in April and one in May

SC = Scutellonema clathricaudatum; XP = Xiphinema parasetariae;
TI = Telotylenchus indicus; TOT = Sum of all parasitic nematode populations

Data were $\log_{x+1}$ transformed for analysis.

Table 2. Changes in population densities of plant-parasitic nematodes in soil during the crop growth period of groundnut (cv. 55-437).

Sampling date	Nematode population densities 100 cm^{-3} soil			
	SC	XP	TI	TOT
11 June 1989	69.2 (1.84)	4.2 (0.62)	13.8 (1.14)	109.6 (2.04)
6 July 1989	52.5 (1.72)	10.5 (1.02)	9.8 (0.99)	102.3 (2.01)
21 July 1989	28.8 (1.46)	19.5 (1.29)	12.6 (0.41)	56.2 (1.75)
22 August 1989	26.3 (1.42)	31.6 (1.50)	10.5 (1.02)	97.7 (1.99)
22 September 1989	21.9 (1.34)	20.9 (1.32)	4.7 (0.67)	72.1 (1.86)
LSD (P = 0.05)	(0.238)	(0.309)	(0.299)	(0.212)

SC = Scutellonema clathricaudatum; XP = Xiphinema parasetariae;
TI = Telotylenchus indicus; TOT = Sum of all parasitic nematode populations

Figures in parentheses are log x+1 transformed values.

Table 3. Effects of different presowing treatments on the population densities of plant-parasitic nematodes.

Treatment	Nematode population densities 100 cm^{-3} soil SC	XP	TOT
Irrigations during April and May 1989	35.5 (1.55)	15.8 (1.20)	89.1 (1.95)
Carbendazim	66.1 (1.82)	16.2 (1.21)	131.8 (2.12)
Carbofuran 5G (10 kg a.i. ha^{-1})	18.6 (1.27)	6.2 (0.79)	43.6 (1.64)
Control	39.8 (1.60)	18.2 (1.26)	87.1 (1.94)
LSD (P = 0.05)	(0.268)	(0.251)	(0.187)

SC = Scutellonema clathricaudatum; XP = Xiphinema parasetariae;
TOT = Sum of all parasitic nematode populations

Figures in parentheses are log x+1 transformed values.

Table 4. Effects of different presowing treatments on populations plant-parasitic nematodes, ICRISAT Sadore, Niger.

Treatment	Nematode population densities 100 cm^{-3} soil			
	SC	XP	TI	TOT
Irrigation 1	56.8 (1.75)	21.9 (1.34)	7.6 (0.88)	109.6 (2.04)
Irrigation 2	44.5 (1.65)	14.1 (1.15)	6.3 (0.80)	91.2 (1.95)
Irrigation 3	26.6 (1.43)	17.0 (1.23)	6.3 (0.80)	93.3 (1.97)
Irrigation 4	23.5 (1.37)	12.0 (1.08)	8.5 (0.93)	72.4 (1.86)
No irrigation + Carbendazim	66.4 (1.82)	16.2 (1.21)	12.6 (1.10)	131.8 (2.12)
No irrigation + carbofuran 5G	18.8 (1.27)	6.2 (0.79)	4.6 (0.66)	43.6 (1.64)
Control (no irrigation and no chemical)	40.1 (1.60)	18.2 (1.26)	5.6 (0.75)	87.1 (1.94)
LSD (P = 0.05)	(0.343)	(0.314)	NS	(0.248)
CV	9.9	17.5		7.1

SC = Scutellonema clathricaudatum; XP = Xiphinema parasetariae;
TI = Telotylenchus indicus; TOT = Sum of all parasitic nematode populations

Figures in parentheses are log x+1 transformed values.

Table 5. Scutellonema clathricaudatum population densities in roots of stunted and apparently healthy plants.

Treatment	Nematode population g^{-1} root		
	Stunted plant	Apparently healthy plant	Mean population
Irrigation 1	18.7 (1.27)	7.8 (0.99)	12.0 (1.08)
Irrigation 2	33.4 (1.52)	7.4 (0.87)	16.2 (1.21)
Irrigation 3	21.9 (1.34)	9.2 (0.96)	32.3 (1.51)
Irrigation 4	20.4 (1.31)	9.3 (0.97)	13.8 (1.14)
Carbendazim	23.4 (1.37)	9.4 (0.97)	14.8 (1.17)
Carbofuran 5G	4.4 (0.64)	4.3 (0.64)	4.3 (0.64)
Control	18.7 (1.27)	6.1 (0.78)	10.7 (1.03)
LSD (P=0.05)	(0.39)	NS	(0.24)

Figures in parentheses are log x+1 values.

Table 6. *Scutellonema clathricaudatum* population in roots of stunted and apparently healthy plants at different dates.

Plant growth	Nematode population g^{-1} root		
	Date 1 (August)	Date 2 (September)	Mean population
Stunted plant	15.7 (1.19)	19.9 (1.30)	17.8 (1.25)
Apparently healthy plant	4.9 (0.69)	11.3 (1.05)	7.4 (0.87)
LSD (P=0.05)		(0.30)	(0.31)
Mean	8.7 (0.94)	15.1 (1.18)	
LSD (P=0.05)		(0.13)	

Table 7. Relationship between population densities of Scutellonema clathricaudatum, aluminium levels in soil and growth of groundnut cv. 88-437 in pot experiments, ICRISAT, Sadore, 1988.

Nematode population density cm^{-3} soil	Al + H^+	pH (H_2O)	pH (kcl)	Organic matter (%)	N total (ppm)	P (ppm)	Leaf area	Leaf wt.(g)	Dry shoot wt.	Pod no.
0 (Autoclaved soil)	0.14	5.1	4.3	0.13	87	8.60	478	12.5	8.2	10.6
30	0.35	4.8	3.9	0.26	144	18.2	249	2.8	3.3	6.2
0.50	0.36	4.9	4.0	0.27	148	12.3	281	8.8	4.0	8.8
0.25	0.39	4.9	4.0	0.26	147	12.9	232	7.4	3.5	8.4
0.10	0.55	4.9	4.0	0.27	144	18.8	107	3.5	1.9	3.6
LSD ($P = 0.05$)							210.3	4.93	1.88	3.21

Table 8. Comparison of growth of groundnut (cv. 55-437) in soils from good and bad patches in pot experiments. ICRISAT Sadore, 1988.

Soil source	Carbofuran 5G 8 kg a.i.ha^{-1}	Al+H^{+}	pH (H_2O)	P (ppm)	Organic matter (%)	N. total (ppm)	Nematode population (cm^{-3} soil)	Leaf area	Leaf wt.(g)	Dry shoot wt.(g)
good patch	-	0.34	4.9	17.6	0.30	160	0.8	403	10.2	5.1
	+	0.34	4.9	17.8	0.30	160	0.8	518	14.4	8.4
poor patch	-	0.51	4.9	17.1	0.23	138	0.1	164	5.0	2.5
	+	0.51	4.8	17.1	0.23	138	0.1	327	9.8	4.5
poor + good patch(1 1) (autoclaved)	-							438	12.4	5.6
poor + good patch(1 1) (autoclaved + carbofuran 5G 8 6 kg a.i. ha^{-1})	+							1034	28.8	11.7
LSD (P = 0.05)								179.4	4.36	1.90

Table 9. Analysis of soil samples collected from patches where variation in crop growth was visible within one week and after three weeks, ICRISAT, Sadore, 1989.

Soil source	pH (in H_2O)	H^+	Al	Organic matter (%)	N. total (ppn)	Nematode population 100 cm^{-3} soil at planting
Variability visible within a week after planting	4.9	0.20	0.35	0.27	144	40
Variability visible three weeks after planting	5.2	0.15	0.19	0.30	146	1010

Table 10. Effect of different presowing treatments on haulm and pod yield of groundnut (cv. 55-437).

Treatment	Haulm wt. (t ha^{-1})	Pod wt. (t ha^{-1})	Effect on nematode populations
1. Irrigation during summer fallow	1.01	0.79	NS
2. Bavistin	1.58	1.15	NS
3. Carbofuran 5G 10 kg a.i. ha^{-1}	2.43	2.24	S
4. Control	1.06	0.76	
F (Prob.)	0.098	0.025	

NS = Not significant; S = Significant

Vertical distribution of plant parasitic nematodes at the research farm of ICRISAT Sahelian Center:

This study was conducted in groundnut fields that had crop growth variability problem in 1987-88. Soil samples were collected at the time of sowing, during crop growth period and at crop maturity. On each of the three sampling dates soil samples were collected from six randomly selected locations and at each location samples were collected from 0 to 15 cm, 15 to 30 cm, 30 to 45 cm, 45 to 60 cm and 60 to 75 cm soil depths. Soil samples were handled carefully to avoid exposure to heat and direct sunlight. Groundnut was sown in rows and the row to row distance was 50 cm. Nematode population densities were assessed for every location and depth by processing 100 cm^3 of thoroughly mixed soil samples.

Results

S. clathricaudatum, X. parasetariae, and T. indicus were the major nematodes present in these fields. Helicotylenchus sp. and Pratylenchus sp. were present in low numbers. At the time of sowing, greatest population densities of all the nematodes were found in the 0-15 cm soil depth (Table 11). Pratylenchus sp. and Paralongidorus sp. populations were below detectable levels in the lower depths. S. clathricaudatum, X. parasetariae and T. indicus were present even in 15-30 cm soil depth. Very low densities of S. clathricaudatum in 30-45 cm depth and of T. indicus in 45-60 cm depth were observed.

S. clathricaudatum was not found below 45 cm soil depth at any time whereas populations of X. parasetariae, I. indicus, Helicotylenchus sp. and Paralongidorus sp. were found down to 75 cm depth during crop growth and/or at crop maturity. S. clathricaudatum population decreased in soil during the crop growth as more and more nematodes entered the root systems.

It is apparent from this study that these nematode species do not migrate vertically, but that the greater population densities are confined to the 0-30 cm depth. It appears likely that the populations of S. clathricaudatum do not migrate down words very much during the summer fallow period but enter into a phase of anhydrobiosis during these adverse conditions.

Table 11. Vertical distribution of plant-parasitic nematodes during crop growth at ICRISAT Sahelian Center Sadore', 1989.

Depth (cm)	Nematode populations 100 cm^{-3} of soil						
	SC	XP	TI	Hel.	Pr	Para	TOT
			At planting (July)				
0-15	33.4 (1.52)	11.0 (1.04)	8.3 (0.92)	1.5 (0.17)	2.2 (0.35)	1.6 (0.22)	73.5 (1.87)
15-30	19.3 (1.28)	2.5 (0.39)	3.3 (0.52)	1.6 (0.22)	0	0	30.2 (1.48)
30-45	1.6 (0.22)	0	0	0	0	0	1.7 (0.22)
45-60	0	0	(0.17)	0	0	0	(0.17)
60-75	0	0	0	0	0	0	0
LSD (P = 0.05)	(0.30)	(0.43)	(0.47)	(0.38)	(0.29)	(0.29)	(0.38)
			During crop growth (August)				
0-15	19.7 (1.29)	17.0 (1.23)	7.6 (0.88)	0	0	10.0 (1.00)	61.6 (1.79)
15-30	9.8 (0.99)	4.5 (0.65)	4.6 (0.66)	0	0	4.5 (0.65)	18.2 (1.26)
30-45	3.3 (0.52)	2.4 (0.38)	0	0	0	0	6.3 (0.80)
45-60	0	1.9 (0.27)	0	0	0	6.0 (0.78)	8.9 (0.95)
60-75	0	1.3 (0.12)	0	0	0	2.6 (0.41)	2.8 (0.45)
LSD (P=0.05)	(0.54)	(0.41)	(0.64)	-	-	(0.68)	(0.81)

Table 11 contd...

Depth (cm)	Nematode populations 100 cm^{-3} of soil						
	SC	XP	TI	Hel.	Pr	Para	TOT
	At crop maturity (September)						
0-15	12.6 (1.10)	26.9 (1.43)	9.3 (0.97)	1.5 (0.17)	0	8.7 (0.94)	87.1 (1.94)
15-30	12.9 (1.11)	7.6 (0.88)	5.9 (0.77)	1.5 (0.17)	0	4.9 (0.69)	42.7 (1.63)
30-45	1.5 (0.17)	2.5 (0.40)	1.7 (0.22)	0	0	0	3.1 (0.49)
45-60	0	1.5 (0.17)	1.7 (0.22)	0	0	0	3.7 (0.57)
60-75	0	0	1.7 (0.22)	1.5 (0.17)	0	0	1.8 (0.25)
LSD (P=0.05)	(0.44)	(0.47)	NS	NS		(0.55)	(0.62)

SC = S. clathricaudatum; XP = X. parasetariae; TI = T. indicus; Hel. = Helicotylenchus sp.; Pr. = Pratylenchus sp., Par = Paralongidorus sp., TOT = Sum of all parasitic nematode populations

Figures in parentheses are log x+1 transformed values.

Host range of Scutellonema clathricaudatum and Xiphinema paraguayense:

Host ranges of S. clathricaudatum and X. paraguayense were studied in a field in which growth of the groundnut crop was very variable in 1988. The following plant species were examined for susceptibility to the plant-parasitic nematodes. Arachis hypogaea, Cajanus cajan, Helianthus annuus, Pennisetum glaucum, Sesamum indicum, Stylosanthes fruticosa, S. hamata, Sorghum bicolor, Vigna radiata, Vigna aconitifolia, Vigna sp., Voandzeia subterranea and Zea mays. Seed of these plant species were sown in plots of 2 m^2 size (2 rows of 4 m length). Row to row spacing was 50 cm. The plant species were sown in a randomized block design and there were three replications. Plots were treated with 40 kg ha^{-1} P_2O_5 at land preparation and groundnut seeds were treated with thiram before sowing. Sowing was completed on 5 July 1989. Population densities of S. clathricaudatum ranged between 10 and 30 nematodes 100 cm^{-3} soil and of X. paraguayense between 0 and 60 nematodes 100 cm^{-3} soil. Sixty days after sowing, root systems of the different plant species were examined for S. clathricaudatum infection and soil samples collected from the rhizosphere were analyzed for assessing the populations of different plant-parasitic nematodes.

Results

Population of S. clathricaudatum were found in the root samples of Cajanus cajan, Arachis hypogaea, Vigna aconitifolia, Vigna radiata, Vigna spp., P. glaucum, and Zea mays, (Table 12). This nematode population was not detected in the roots of H.

annuus, S. bicolor, Stylosanthes spp. and Sesamum indicum. Reaction of these species need to be confirmed as rhizosphere populations were higher than the at-sowing time populations of these nematodes. X. parasetariae population was higher in the rhizospheres of S. indicum, H. annuus, S. bicolor, Stylosanthes fruticosa, Cajanus cajan and A. hypogaea than in the rhizosphere of V. radiata, Vigna sp., P. glaucum and V. subterranea. Telotylenchus population was negligible at the time of sowing and it was found to be higher in rhizospheres of P. glaucum, S. bicolor and Vigna spp. than in the rhizospheres of S. fruticosa, C. cajan, A. hypogaea, H. annuus, and Vigna spp. Paralongidorus sp. population was detected in soil samples from the rhizospheres of S. indicum and A. hypogaea.

Table 12. Host ranges of S. clathricaudatum, X. parasetariae and T. indicus.

Plant species	Nematode species		
	S. clathri-caudatum	X. parase-tariae	T. indicus
Arachis hypogaea	+++	++	++
Cajanus cajan	+++	++	+
Helianthus annuus	-	+++	+
Pennisetum glaucum	++	++	+++
Sesamum indicum	-	+++	++
Vigna unguiculata (K.V.-61-6174)	++	+	++
V. unguiculata (t.10)	++	++	+++
Sorghum bicolor	-	++	+++
Vigna radiata	+++	++	++
Stylosanthes fruticosa	-	+	+
S. hamata	-	-	-
Zea mays	+	+	+
Voandzeia subterranea	++	++	+
Vigna aconitifolia	+		

+++ = good host; ++ = moderate host; + = poor host
- = non-host.

Standardization of a field screening technique for identification of groundnut genotypes tolerant/resistant to factors causing crop growth variability problem:

Groundnut genotypes that were found to be resistant to the crop growth variability problem in 1987, were very variable in relation to crop growth in 1988. This is mainly because variability in crop growth is always very heterogeneous and random and the possibility of escape is very high. An attempt was made to standardize a field screening technique for evaluation of groundnut genotypes for their reaction to the crop growth variability problem in a plant-parasitic nematodes infested field.

In order to circumvent the problem of nematode infestation variability and also the variation in crop growth, test rows were sown in small plots (1 m row) at eight (replication) different locations. The entire trial was surrounded on all four sides with a strip of the susceptible check (55-437) variety. Forty-nine test entries and susceptible checks were sown in alternate rows. Test plots and susceptible checks were arranged in such a way that each test entry was surrounded by four check rows. The layout looked checkered with alternating susceptible and test entry plots in both directions. Plot size was 1 row of 1 m length. Plant to plant distance was 10 cm, and row to row distance was 50 cm. The test entries and susceptible check in the checkered layout were arranged in a square lattice design. Soil samples were collected from all the eight replications. Eight soil cores were collected from each replication. S.

clathricaudatum population was very variable in different replicates and nematode populations ranged from 20 to 90 nematodes 100 cm^{-3} soil. Test and check plots were scored for variation in crop growth in September on a 1-9 scale (1 = uniform growth; 9 = highly variable growth). Reaction of each test row was compared with the four check rows that surrounded the test entry. There was a lot of variation in the reaction of even the check (susceptible) variety. Reaction of a test entry was considered reliable only when the surrounding check rows were very variable (7 to 9 score) in all the eight rows and the reaction of the test entry was (1 to 5). Mean score of the test entries was not considered. If the reaction of the test entry was between 1 to 5 and that of any of the check rows was also in this range, even in only one replicate, the reaction of the test row was not considered reliable. Reactions of different genotypes are given in Table 13. ICG (FDRS)41 was the only genotype growing uniformly well in all the eight replications, and the surrounding checks were variable in growth. Reaction of this genotype needs to be checked in larger plots.

This trial was repeated in a nematode-infested field and all the plots were treated with carbofuran 5G at the rate of 10 kg a.i. ha^{-1}. Check rows were not used in this experiment and reaction of each entry in carbofuran-treated plots and control plots (untreated) were compared.

Plant growth was vigorous and uniform in the carbofuran treated plots, however, some test entries (ICG 371, ICG 140, ICG

6322, ICG 8854, ICGS(E)13, ICGS(E)-76, 55-437 and 86397) showed variability in growth at least in one of the eight replications, even in the treated plots. Plant growth of all the test entries was better in the treated plots. Leaves were dark green, and plants were more vigorous than those in the untreated plots.

Table 13. Reaction of groundnut genotypes to the crop growth variability problem, ICRISAT, Sadore, 1989.

S.No.	Genotype	Reaction
1	ICG(FDRS)28	S (Susceptible)
2	ICGMS 68	S
3	ICG(FDRS)39	HS (Highly susceptible)
4	ICG(FDRS)6	HS
5	JL 24	HS
6	ICG(CGS)57	S
7	ICGS(E)13	S
8	ICG(FDRS)41	R (Resistant)
9	ICG(FDRS)27	HS
10	ICG(FDRS)19	HS
11	ICG(FDRS)62	HS
12	ICGS(E)55	S
13	J 11	S
14	55-437	HS
15	ICGS(E)30	HS
16	ICGMS 63	HS
17	ICGS 11	HS
18	ICGMS 5	HS
19	28-206	S
20	ICGMS 42	S
21	TS32-1	S
22	ICGS 76	HS
23	ICG(FDRS)42	HS
24	ICG(FDRS)34	S
25	ICG 6322	S
26	TX 813964	S
27	TX 86704	HS
28	ICG 3717	HS
29	ICG 2738	HS
30	ICG 10943	HS
31	86705	S
32	TX 813922	HS
33	ICG 10964	HS
34	PI 290696	HS
35	86703	S
36	87-519	-
37	ICG 10151	HS
38	86615	S
39	ICG 1518	S
40	ICG 7329	HS

Table 13 contd...

S.No.	Genotype	Reaction
41	ICG 1697	HS
42	86600	HS
43	ICG 8554	HS
44	ICG 10963	HS
45	ICG 10025	S
46	ICG 1402	HS
47	ICG 7629	HS
48	ICG 10913	HS
49	86397	HS

R = maximum score in 8 replications 5 or less;
S = maximum score 7;
HS = maximum score 9.

Important plant-parasitic nematodes associated with groundnut in parts of Benin, Burkina Faso and Nigeria:

Plant-parasitic nematodes are one of the important biotic factors in causing crop growth variability problem in the Sahel. Populations of Scutellonema clathricaudatum were found to be high in the roots of chlorotic and stunted plants in the regions having severe variations in crop growth of groundnut in Niger. Other commonly associated nematodes were Xiphinema, Paralongidorus and Telotylenchus sp. In August and September 1989, survey trips were undertaken to some of the groundnut producing regions in Benin, Burkina Faso, and Nigeria to get information on the fauna of plant-parasitic nematodes associated with groundnut crops. These surveys do not essentially represent the major problems in these countries and only highlight the presence of important crop-damaging nematode species. At each location, soil samples were collected in polythene bags from different fields and soil samples collected from different regions were processed using the techniques described earlier.

Plant-parasitic nematodes recorded in different regions of these countries are presented in Table 14. Presence of the pod-lesion nematode, Pratylenchus brachyurus, which is one of the most important nematode pests in the United States damaging groundnuts, in Benin and Nigeria, and the presence of Scutellonema spp. in Burkina Faso and Benin indicate that there is a need to map the distribution of these nematodes in these countries as well as to estimate the extent of crop losses being

caused by them on groundnut, pearl millet and sorghum. Ditylenchus sp. and Aphelenchoides sp. were found in many regions in these countries. These nematodes attack the seeds and pods. Aphelenchoides arachidis is so far reported in the seed of groundnut in Nigeria and Ditylenchus destructor in pods and seeds from the Transvaal Province of South Africa.

Table 14. List of some important nematode species found associated with groundnut in different regions of Benin, Burkina Faso and Niger.

Country/ Region	Nematode spp.
Benin	
Biou	Ditylenchus sp., Helicotylenchus dihystera
Bambereke	Helicotylenchus sp., Scutellonema clathricaudatum, Scutellonema sp., Xiphinema parasetariae
Dadeh	S. clathricaudatum, Scutellonema sp.
Ina	Aphelenchoides, Ditylenchus sp., Helicotylenchus sp., Hoplolaimus pararobustus, Scutellonema sp., Pratylenchus sp.
Kandi	Aphelenchoides, Helicotylenchus sp., H. pararobustus, S. clathricaudatum, Scutellonema sp., Pratylenchus brachyurus, Pratylenchus sp., X. parasetariae.
Malanville	H. dihystera, X. parasetariae, Pratylenchus sp.
Nikki	Criconemoides sp., Ditylenchus sp., P. brachyurus, Scutellonema sp., Xiphinema sp.
Burkina Faso	
Banfora	H. dihystera, H. pararobustus, S. clathricaudatum, Scutellonema sp., Pratylenchus sp.
Dengoumdongou	Ditylenchus sp., Helicotylenchus sp., Hemicaloosia paradoxa, Hemicycliophora sp., Rotylenchulus parvus, S. clathricaudatum, Scutellonema sp., Triversus annulatus.
Fada	Aphelenchoides sp., S. clathricaudatum, Scutellonema sp., Pratylenchus sp., Triversus annulatus.
Hounde	Aphelenchoides sp., Helicotylenchus sp., Pratylenchus sp.
Kinoghin	Ditylenchus sp., Helicotylenchus sp., Hoplolaimus sp., Pratylenchus sp.

Nigeria

Kaduna	Aphelenchoides sp., Helicotylenchus sp., Criconemoides, sp., Scutellonema sp., Tylenchorynchus sp. and Pratylenchus sp., Xiphinema sp.
Katsina	Aphelenchoides sp., Helicotylenchus sp., Criconemoides sp., P. delattrei, P. brachyurus, Scutellonema sp.
Zaria	Aphelenchoides arachidis, Helicotylenchus sp., Criconemoides sp., Hoplolaimus sp., P. delattrei, P. brachyurus, Tylenchorynchus sp., Rotylenchulus sp., Scutellonema sp.

Effects of application of DBCP and carbofuran 5G on population densities of plant-parasitic nematodes:

Effects of application of dibromo chloropropane (DBCP) at the rate of 20 liter in 85 liter of water ha^{-1} and carbofuran 5G at the rate of 10 kg a.i. ha^{-1} before sowing on growth and yield of groundnut and millet and on population densities of plant-parasitic nematodes were investigated in a field having the crop growth variability problem. Plots (5 rows of 5.6 m length of millet (CIVT) and 6 rows of 5.6 m length of groundnut (55-437) were arranged in randomized block design with six replications. Row to row distance was 50 cm for groundnut and 80 cm for millet and plant to plant distance was 10 cm for groundnut and 80 cm for millet. Groundnut seeds were treated with (Thioral) before sowing. Population densities of plant-parasitic nematodes were estimated before sowing and at crop maturity.

Results

Population densities of plant-parasitic nematodes were significantly ($P=0.05$) reduced by the application of carbofuran 5% and DBCP in groundnut and pearl millet plots (Table 15). Application of DBCP 20 lit ha^{-1} caused 70.3 percent reduction in the densities of plant-parasitic nematodes, carbofuran 5G (10 kg a.i. ha^{-1}) reduced the nematode population densities by 67.5 percent. Carbofuran 5G appeared to be more effective on groundnut than DBCP, while the latter was found to be more effective on pearl millet (Table 16). Nematode populations in the roots of pearl millet and groundnut were very low in the nematicide-treated plots (Table 17). Population densities of Pratylenchus sp. were

very high in the roots of pearl millet in particular, and groundnut in the control plots (Table 17).

Table 15. Effect of application of DBCP and carbofuran 5G on the population densities of plant-parasitic nematodes, ICRISAT Sadore, 1989.

Treatment	SC	TI	Pr	Tot
DBCP 20 lit ha^{-1}	5.0	1.2	3.8	29.5
Carbofuran 5G 10 kg a.i. ha^{-1}	3.2	0.0	8.5	32.3
Control	12.3	2.4	18.6	99.3
F. Pr.	0.096	0.03	0.02	0.02

SC = S. clathricaudatum; TI = T. indicus; Pr = Pratylenchus sp., Tot = Sum of total parasitic nematodes
Nematode population densities are in 100 cm^3 soil samples.

Table 16. Effect of application of DBCP and carbofuran 5G on the population densities of X. paraseteriae and total parasitic nematodes on groundnut and pearl millet, ICRISAT Sadore, 1989.

Crop	Nematode	DBCP	Carbofuran 5G	Control
Groundnut	Tot	50.6	15.0	96.6
Pearl millet		17.1	68.5	120.1
F. Pr		0.03		
Groundnut	X. paraseteriae	25.6	3.7	28.5
Pearl millet		5.1	10.9	8.1
F. Pr		0.003		

Table 17. Effects of application of DBCP and carbofuran on the plant-parasitic nematode populations in the roots of groundnut and pearl millet, ICRISAT Sadore, 1989.

Treatment	Nematode populations 1 g^{-1} root			
	S. clathri-caudatum	Pratylenchus sp.		Total parasitic nematodes
DBCP 20 t ha^{-1}	1.3*	1.8*,	4.8**	3.1*
Carbofuran 5G 10 kg a.i. ha^{-1}	0	1.7,	10.2	2.5
Control	8.2	28.7,	43.7	56.2
F. Pr.	0.03	0.001,	0.01	0.01

* In groundnut roots

** In pearl millet roots

Effects of different crop rotations on population densities of plant-parasitic nematodes:

This study utilized a long-term agronomy trial designed to evaluate the performance of groundnut in rotation with millet and Rhodes grass and to study the effects of different rotations on the crop growth variability problem. There are four replications for each of the following 12 treatments:

	Years (1989-1992)			
Treatment No.	1989	1990	1991	1992
1	R	G	G	G
2	R	M	M	M
3	R	G/M	G/M	G/M
4	R	G	M	G/M
5	R	M	G/M	G
6	R	G/M	G	M
7	G	G	G	G
8	M	M	M	M
9	G/M	G/M	G/M	G/M
10	G/M	G	M	G/M
11	G	M	G/M	G
12	M	G/M	G	M

R = Rhodes grass; G = Groundnut; M = Millet

Plot size is 6 m x 6 m. For estimation of population densities of plant-parasitic nematodes, soil cores were collected near the plant rows from six randomly selected locations from each plot.

Soil samples were collected before sowing and at crop maturity at the research farm of ICRISAT, Sadore, and at the research farm of INRAN, Maradi.

Results

The nematode communities at these two locations were similar. Populations of Pratylenchus sp. were present at Maradi whereas T. indicus was present at Sadore. Populations of S. clathricaudatum, X. parasetariae and Hoplolaimus pararobustus were found at both locations. Population densities of plant-parasitic nematodes and total parasitic nematodes in different treatments did not differ significantly (Table 18). Population densities of X. parasetariae at Sadore, and X. parasetariae and Pratylenchus sp. at Maradi were significantly higher ($P = 0.05$) at crop maturity (Table 19). Nematode population per g of roots generally did not differ between different treatments, however, the Pratylenchus sp. opulation was highest in the groundnut-millet intercropped plots.

Table 18. Effects of different crop rotations on population densities of plant-parasitic nematodes, Niger, 1989.

Treatment	Nematode population 100 cm^{-3} soil					
	SC	TI	XP	Hop	Pr	Tot
Sadore						
R	57.5	1.7	2.2	6.8	-	81.3
R	114.8	1.5	1.8	2.8	-	123.0
R	79.4	6.9	2.3	1.7	-	114.8
R	70.8	2.5	0	5.3	-	95.5
R	43.6	2.2	1.5	2.1	-	79.4
R	53.7	4.8	1.7	4.2	-	79.4
G	89.1	7.2	3.7	2.8	-	138.0
M	67.6	4.2	1.7	5.8	-	120.2
G/M	74.1	3.7	4.8	7.8	-	120.2
G/M	83.2	10.1	5.9	2.5	-	144.5
G	44.7	3.7	1.7	3.3	-	87.1
M	87.1	4.2	1.5	18.2	-	147.9
F. Prob	NS	NS	NS	NS	-	NS
Maradi						
R	34.7	-	18.6	3.3	4.1	81.2
R	17.0	-	12.6	4.1	19.1	89.1
R	20.4	-	4.0	4.1	9.3	49.0
R	29.5	-	6.9	2.2	5.1	57.5
R	36.3	-	3.1	2.8	11.5	56.1
R	15.8	-	9.1	2.8	5.9	70.8
G	19.1	-	6.9	3.3	1.7	52.4
M	27.5	-	4.6	3.3	28.2	70.8
G/M	22.9	-	13.5	3.7	9.5	83.2
G/M	31.6	-	15.1	2.5	20.0	97.7
G	12.9	-	1.9	1.5	7.2	39.8
M	20.9	-	25.1	2.5	7.1	81.3
F. Prob	NS	-	0.08	NS	NS	NS

SC = S. clathricaudatum; TI = T. indicus; XP = X. parasetariae
HOP= H. pararobustus; Pr = Pratylenchus sp.
Tot= Sum of total parasitic nematodes

Table 19. Nematode population densities at the time of sowing and at crop maturity, Niger, 1989.

Sampling time	Nematode population 100 cm^{-3} soil					
	SC	TI	XP	Hop.	Pr.	Tot
Sadore						
At sowing	112.2	3.3	1.1	3.5	-	138.0
At maturity	42.7	4.3	3.9	4.8	-	85.1
F. Prob	0.07	NS	0.003	NS	-	0.07
Maradi						
At sowing	22.9	-	4.5	4.3	4.4	60.5
At maturity	22.9	-	12.6	2.0	15.9	76.1
F. Prob	NS	-	0.04	NS	0.03	0.06

SC = S. clathricaudatum; TI = T. indicus; XP = X. paraguariae
HOP= H. pararobustus; Pr = Pratylenchus sp.
Tot= Sum of total parasitic nematodes

Effects of intercropping pearl millet with groundnut on population build up of plant-parasitic nematodes:

Sole groundnut (cv 55-437), sole millet (CIVT), and three combinations of groundnut and pearl millet intercrop were studied in a randomized block design. There were four replications. Row to row distance in groundnut was 50 cm and plant to plant distance was 10 cm, and in millet row to row distance was 100 cm. In the three intercrop treatments, millet was sown at 1 m x 1m, 1 m x 2 m, and 1 m x 3 m whereas groundnut was sown at 50 x 10 cm in these plots. Plot size was 6 m x 6 m. Plots were treated with a basal dose of 36 kg P_2O_5 ha^{-1} and top dressed with 10 kg ha^{-1} of CAN for millet and with 400 kg gypsum ha^{-1} at pegging for groundnut. Soil samples for assessment of plant-parasitic nematodes were collected close to the plant rows. Root samples were collected from groundnut and millet plants from each plot.

Results

Population densities of T. indicus, X. parasetariae, and the total population of parasitic nematodes increased significantly ($P = 0.05$) on these crops (Table 20). S. clathricaudatum population was significantly ($P = 0.05$) more in the rhizosphere of sole millet than in that of sole groundnut however, population in roots was highest in the sole groundnut plots (Table 21). Population densities of X. parasetariae were significantly ($P = 0.05$) more in the soil samples collected from intercropped plots than in samples from sole crop plots. T. indicus population did not differ in different treatments. Hoplolaimus sp. population was lowest in the roots of sole groundnut than in groundnut with

millet (1 m x 3 m). Population densities of total plant-parasitic nematodes (sum of all parasitic nematode populations) did not differ between different treatments, however, some trends indicating preference of S. clathricaudatum for groundnut were noted.

Table 20. Effects of intercropping pearl millet with groundnut on plant-parasitic nematodes, ICRISAT Sadore, 1989.

Treatment	Nematode populations 100 cm^{-3} soil				Root (g^{-1})	
	SC	XP	TI	TOT	SC	Hop
Groundnut (55-437)	9.4 (0.97)	5.1 (0.71)	26.3 (1.42)	57.5 (1.76)	47.5	2.5
Millet (CIVT)	22.7 (1.36)	5.3 (0.72)	29.5 (1.47)	67.6 (1.83)	15.0	12.5
Groundnut + Millet (1m x 1m)	8.8 (0.94)	23.6 (1.38)	29.5 (1.47)	75.9 (1.88)	17.5	7.5
Groundnut + Millet (1m x 2m)	12.6 (1.10)	13.5 (1.13)	44.7 (1.65)	87.1 (1.94)	27.5	16.3
Groundnut + Millet (1m x 3m)	6.6 (0.82)	18.5 (1.27)	33.9 (1.53)	72.4 (1.86)	11.3	2.5
LSD (P = 0.05)		(0.28)			23.1	8.9

SC = S. clathricaudatum; XP = X. parasetariae
TI = T. indicus; Hop = Hoplolaimus pararobustus
Tot = Sum of total parasitic nematodes

Figures in parentheses are log x+1 values.

Table 21. Population densities of different parasitic nematode species in pearl millet and groundnut, ICRISAT Sadore, 1989.

Nematode sp.	Time of Sampling	Nematode populations 100 cm^{-3} soil					
		Groundnut	Millet	Groundnut + millet (1m x 1m)	Groundnut + millet (1m x 2m)	Groundnut + millet (1m x 3m)	Mean population
Tylenchorhynchus indicus	At sowing (30-6-89)	18.2 (1.28)	21.4 (1.34)	25.1 (1.4)	52.5 (1.72)	25.1 (1.4)	28.4 (1.42)
	At maturity (8-9-89)	38.0 (1.58)	40.7 (1.61)	33.9 (1.53)	38.0 (1.58)	45.7 (1.66)	38.9 (1.59)
						LSD (P=0.05)	(0.11)
Xiphinema parasetariae	At sowing	2.4 (0.37)	3.3 (0.52)	17.9 (1.25)	12.9 (1.11)	1.1 (0.04)	7.2 (0.86)
	At maturity	10.9 (1.04)	8.3 (0.92)	31.2 (1.48)	14.1 (1.15)	31.2 (1.48)	16.9 (1.22)
						LSD (P=0.05)	(0.16)
Total population of parasitic nematodes	At sowing	48.7 (1.68)	58.2 (1.75)	86.1 (1.82)	102.3 (2.01)	49.0 (1.69)	81.7 (1.79)
	At maturity	72.4 (1.86)	81.3 (1.91)	87.1 (1.94)	74.1 (1.87)	104.7 (2.02)	83.2 (1.92)
						LSD (P=0.05)	(0.08)

Effects of application of different crop residues, EDTA (chellate) and P_2O_5:

Effects of eight treatments: 1. Control, 2. P_2O_5 (SSP) 36 kg ha^{-1}, 3. Crop residue 2 t ha^{-1}, 4. Crop residue 4 t ha^{-1}, 5. EDTA 80 kg ha^{-1}, 6. P_2O_5 36 kg ha^{-1} + Crop residue 2 t ha^{-1}, 7. P_2O_5 36 kg ha^{-1} + crop residue 4 t ha^{-1}, 8. P_2O_5 36 kg ha^{-1} + EDTA 80 kg ha^{-1} were studied on the population densities of S. clathricaudatum, X. parasetariae, I. indicus, Paralongidorus sp., H. pararobustus Helicotylenchus sp. and total plant-parasitic nematodes. Soil samples were collected for estimation of nematode populations at the time of sowing (June) and at crop maturity (September) using the methodology described earlier.

Results

Populations of all the plant-parasitic nematodes except H. pararobustus were not affected significantly by the application of different crop residues, EDTA and P_2O_5 (Table 22). Paralongidorus sp. was below detectable level at the time of sowing and the nematode population increased during the crop growth period. The nematode density was lowest in control plots. Density of X. parasetariae was very low at the time of sowing and it increased significantly ($P = 0.05$) during crop development (Table 23). The increase in population density was low in plots treated with P_2O_5 + chellate, or with crop residues.

Table 22. Effects of different crop residues, chellate and phosphorus application on population densities of plant-parasitic nématodes ICRISAT, Sadore, 1989.

Treatment	Nematode population 100 cm^{-3} soil			
	SC	Hop	Helico	Tot
Control	32.7	37.1	3.5	99.8
P_2O_5 (SSP) 36 kg a.i. ha^{-1}	32.2	23.7	5.1	105.9
Crop residue 2 t ha^{-1}	30.3	5.6	4.0	77.4
Crop residue 4 t ha^{-1}	37.4	49.0	5.6	139.6
EDTA 80 kg ha^{-1}	19.3	33.1	10.5	106.2
P_2O_5 36 kg ha^{-1} + crop residue 2 t ha^{-1}	32.7	30.9	2.1	93.5
P_2O_5 36 kg ha^{-1} + crop residue 4 t ha^{-1}	17.2	20.4	2.2	88.5
P_2O_5 36 kg ha^{-1} + EDTA 80 kg ha^{-1}	16.9	17.0	2.1	65.8
F. prob.	NS	0.01	NS	NS

Table 23. Population densities of *X. parasetariae* and *Paralongidorus* sp. at the time of sowing and during crop growth ICRISAT Sadore, 1989.

Treatment	Nematode population 100 cm^{-3} soil			
	X. parasetariae		*Paralongidorus* sp.	
	At sowing	During crop growth	At sowing	During crop growth
Control	0	7.8	0	2.5
P_2O_5 (SSP) 36 kg a.i. ha^{-1}	1.8	7.8	0	17.8
Crop residue 2 t ha^{-1}	1.8	11.0	0	9.3
Crop residue 4 t ha^{-1}	0	9.0	0	8.3
EDTA 80 kg ha^{-1}	0	4.3	0	8.3
P_2O_5 36 kg ha^{-1} + crop residue 2 t ha^{-1}	0	3.9	0	15.2
P_2O_5 36 kg ha^{-1} + crop residue 4 t ha^{-1}	1.8	4.6	0	9.8
P_2O_5 36 kg ha^{-1} + EDTA 80 kg ha^{-1}	0	3.9	0	10.5
Mean	1.2	6.1	0	9.1
F. Pr.		0.01		0.03

Effects of application of carbofuran and different sources phosphorus on population densities of plant-parasitic nematodes:

Effects on the populations of different plant-parasitic nematodes.of different sources of phosphorus: 1. Control rock, 2. Tahoua rock phosphate 40 kg ha^{-1} P_2O_5, 3. Triple super phosphate 40 kg ha^{-1} P_2O_5, 4. Single super phosphate 40 kg ha^{-1} P_2O_5 5. Partially acidulated parc-W rock phosphate 40 kg ha^{-1} P_2O_5, with and without carbofuran 5G were studied. This trial was conducted at ICRISAT research farm at Sadore, and the research farm of INRAN at Maradi. Nematode populations were assessed at both the locations at the time of planting and at crop maturity.

Results

Population densities of plant-parasitic nematodes were significantly reduced (P=0.01) by the application of carbofuran 5G at both the locations (Table 24). Application of different sources of phosphorus did not affect the population densities of different plant-parasitic nematodes (S. clathricaudatum, I. indicus, Paralongidorus sp., X. parasetariae, Pratylenchus sp.) (Table 25) at either location.

Table 24. Effects of application of carbofuran 5G and different sources of phosphorus on plant-parasitic nematodes at Sadore, and Maradi, Niger.

Location	Treatment	Parasitic nematodes 100 cm^{-3} soil
Sadore	Control	37.5
	Carbofuran 5G	8.1
F. prob.		0.001
Maradi	Control	41.4
	Carbofuran 5G	23.3
F. prob.		0.001

Table 25. Effects of application of different sources of phosphorus on plant parasitic nematodes at Sadore and Maradi, Niger.

Treatment	Nematode population 100 cm^{-3} soil	
	Sadore	Maradi
Control	25.8	30.0
Tohou rock phosphate (40 kg ha^{-1} P_2O_5)	15.0	43.3
Triple super phosphate (40 kg ha^{-1} P_2O_5)	23.3	35.0
Single super phosphate (40 kg ha^{-1} P_2O_5)	20.8	50.0
Partially audulated parc-W rock phosphate (40 kg ha^{-1} P_2O_5)	30.8	38.7
Parc-W rock phosphate (40 kg ha^{-1} P_2O_5)	20.8	20.8
F. prob.	NS	NS

Effects of application of different levels of calcium carbonates and carbofuran 5 G.

This is a long-term experiment to study the effects of change in pH following addition of lime on the crop growth variability problem. Treatments were arranged in a split plot design and were replicated six times. Application of carbofuran 5G at the rate of 10 kg a.i. ha^{-1} and no carbofuran application were the main plots, and calcium carbonate levels (250 kg ha^{-1}, 500 kg ha^{-1} and 1000 kg ha^{-1}) were the sub plots. Sub plot size was 16 m^2 (8 rows of 4 m). Nematode population densities were assessed at the time of sowing (July), 21 days after sowing and at crop maturity in late September.

Results

Application of carbofuran significantly (P=0.01) reduced the population levels of S. clathricaudatum, T. indicus, X. parasetariae, and Paralongidorus sp. (Table 26) in soil and roots (Table 27). Application of different dosages of calcium carbonate did not affect the nematode populations. Variation in crop growth was high in the plots that were not treated with carbofuran 5G. Application of calcium carbonate apparently did not improve the crop growth.

Table 26. Effects of application of carbofuran 5G and different levels of calcium carbonate on plant-parasitic nematodes in groundnut in Badore, Niger.

Treatment	Sampling time	Nematode populations 100 cm^{-3} soil				Nematode population in 1g root	
		SC	XP	TI	TOT		
Control	At sowing	20.6	33.8	5.0	68.1		
	21 day after planting	4.4	76.3	8.1	105.6		
	At crop maturity	23.1	37.5	14.4	91.9	57.5	
Carbofuran 5G (10 kg a.i. ha^{-1})	At sowing	24.4	36.3	11.3	78.8		
	21 days after planting	0.6	28.8	0	33.8		
	At crop maturity	6.9	28.1	9.4	49.4	34.7	
	F. prob.	0.01	0.01	0.01	0.01	0.05	

Table 27. Effects of different levels of calcium carbonate on plant parasitic nematodes.

Treatment	Nematode population 100 cm^{-3} soil			
	SC	XP	TI	Tot
Control	13.8	40.0	6.7	69.6
$CaCO_3$ 250 kg ha^{-1}	11.7	36.3	11.3	67.9
$CaCO_3$ 500 kg ha^{-1}	13.3	37.5	7.1	69.6
$CaCO_3$ 1000 kg ha^{-1}	14.6	46.7	7.1	77.9
F. prob.	NS	NS	NS	NS

SC = S. *glathricaudatum*, XP = X. *parasetariae*, TI = T. *indicus* Tot = Sum of parasitic nematode populations.

Discussion and Remarks

Variation in crop growth is a very serious constraint to groundnut production in the Sahel. Marked differences in crop growth and yield over relatively small areas of land confound farmers and scientists all across the Sahel. Attempts have been made in the past to understand the etiology of this problem. While variation in topography, soil type, storm damage, organic matter, nutritional status, and viral diseases all contribute to variability in crop growth, there are some other more problematic factors as well. Low pH, aluminium toxicity and plant-parasitic nematodes are strongly suspected to be the major factors in the variability problem. However, good crop growth is observed in patches having soil pH as low as 4.0, whereas very stunted and chlorotic patches are seen in areas having low aluminium content. Also variability in crop growth occurs in patches having very low densities of plant-parasitic nematodes. These observation further confound this enigmatic problem. Results obtained in the 1989 crop season help to some extent in explaining these observations and clearly indicate that plant-parasitic nematodes can cause crop growth variability, however, crop growth variability is a syndrome. Affected plants exhibit symptoms of toxicity as well as of nematode infection. These symptoms are diagnosable if the crop growth is monitored from sowing time onward. Where variability in crop growth appears from the beginning (within 7 days of germination), plant-parasitic nematodes may not be the primary cause of variability. These patches have very stunted plant growth, leaves are small and chlorotic and root systems are very poorly developed with very few

nodules. Very few lateral roots are produced. These roots ar brittle and possibly dead. These can be easily broken from the main root systems. Tips of the roots are discolored. Higher $Al^{3+} + H^{+}$ may be the primary cause of this kind of crop growth variability. Crop growth is extremely poor in patches where $Al^{3+} + H^{+}$ is more than 0.50 meq 100^{-9} soil. In another case, crop growth is apparently uniform and healthy for initial 2 to 4 weeks and then variation in crop growth appears in patches. These patches hav stunted plant growth and generally the new leaves produced after this initial growth period are less green to chlorotic. Root systems have small bunches of lateral roots. Lateral roots are stubby and root tips may be swollen. In this kind of variability the plant-parasitic nematodes (mainly Scutellonema spp) are the primary cause and $Al^{3+} + H^{+}$ in these patches may be low. Some times, leaves in these patches become very chlorotic during the pod initiation stage. This symptom expression relates well with maximum population peaks of Xiphinema sp. and Paralongidorus sp. Symptoms may vary in patches having moderate levels (less than 0.30) of $Al^{+3} + H^{+}$ and Scutellonema sp. Interaction between these two factor were not studied. It was observed that in patches where $Al^{3+} + H^{+}$ was high and plant growth was very poor from the beginning, th nematode populations were low because of lack of host roots to feed. If soils are not moved during the inter cultivation operations, the patches appearing due to high $Al^{3+} + H^{+}$ should reappear at the same place next year where as patches due to nematode infection may show some movement and spread. Effect of low pH may be indirect on the crop growth : increased availability of aluminium etc. and Scutellonema sp. also prefers low pH.

Application of carbofuran 5G is reported to dramatically increase the crop growth in Senegal and our results in 1988 confirmed this. This broad spectrum pesticide not only controls the plant-parasitic nematodes but it boosts the plant growth even in autoclaved soil.

Scutellonema spp. do not migrate to lower soil depths during the dry fallow period. The nematode appear to enter into anhydrobiosis. I still feel that this dormancy can be broken by irrigation during the summer fallow period and exposing the sub-soil to solar heat. Of different irrigation treatments tested in 1989, one irrigation in April followed by one in May was comparatively more effective. Scutellonema spp. are polyphagous, however, it is apparent that the nematode has host preference. Some of the plant species that were found to be less susceptible this year need to be tested again. Use of a field screening technique wherein reaction of the groundnut genotypes are compared in small plots with more replications, with the surrounding local susceptible checks. indicates that genotypes that have tolerance/resistance to factor(s) causing variability in crop growth can be selected by adopting this methodology.

Surveys of some groundnut regions in Burkina Faso, Benin and Nigeria indicated that the damaging species (Scutellonema sp., Pratylenchus sp.) of plant-parasitic nematodes are present in these countries. Heterodera gambiensis was found on pearl millet in Niger. Scutellonema, Pratylenchus, and Xiphinema are already reported from Mali, Niger and Senegal. These species infect groundnut and pearl millet. Losses caused by nematode species to

these crops in different regions of the Africa have not bee investigated.

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