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Role of *Scutellonema clathricaudatum* in etiology of groundnut growth variability in Niger*

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Abstract

Variation in crop growth is an important limiting factor for groundnut production in Niger. Populations of *Aphelenchoides* sp., *Ditylenchus* sp., *Helicotylenchus* sp., *Hoplolaimus pararobustus*, *Macroposthonia curvata*, *Paralongidorus bullatus*, *Scutellonema clathricaudatum*, *Telotylenchus indicus* and *Xiphinema parasetariae* have been associated with groundnut crop growth variability. *S. clathricaudatum*, *X. parasetariae and T. indicus* were widespread and *S. clathricaudatum* was most abundant nematode. Population densities of *S. clathricaudatum* was always higher in the roots of poorly growing, chlorotic and stunted plants than in the roots of apparently healthy plants. A preplant population density of 1.3 *S. clathricaudatum* cm^{-3} soil caused ($p = 0.05$) reduction in plant growth of groundnut cv. 55-437. *S. clathricaudatum* was mainly confined to 0–15 cm soil depth at the time of planting in June and was not found below 45 cm depth at any time during the crop growth period. Soil application of carbofuran (10 kg a.i ha^{-1}) reduced the nematode population densities and resulted in vigorous and uniform crop growth. Higher Al and H-ion concentrations (0.50 meq 100 g^{-1} soil) also was associated with poorly growing chlorotic seedlings. Symptoms of nematode-caused variable growth were evident 3 to 4 weeks after seedling emergence.

Introduction

Variability in crop growth is an important limiting factor for groundnut (*Arachis hypogaea* L.) production in Niger. Surveys of the major groundnut-producing areas of Niger revealed that plant growth variability was a major problem in sandy soils and plant-parasitic nematodes were wide spread in these soils (Sharma et al., 1990). Apparently healthy plants and severely stunted plants are frequently randomly distributed in the same field and foliar symptoms are similar to 'peanut stunting and chlorosis' problem in central and northern regions of Senegal (Drevon and Diabaye, 1981). Soil applications of 1, 3 dibromochloropropane (DBCP), aldicarb and carbofuran at the research farm of ICRISAT Sahelian Center, located at 13 °N, 2 °E, 45 km south of Niamey, dramatically reduced the variability in growth of the groundnut crop (Subrahmanyam et al., 1988) suggesting that plant-parasitic nematodes may play a causal role in the observed crop growth variability (Sharma, 1989).

The objective of this study was to further investigate the communities of plant-parasitic nematodes associated with groundnut, their ver-

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tical distribution in soil and their relationships with crop growth. Soil samples were also analysed for exchangeable aluminium, total nitrogen and phosphorus.

Materials and methods

Experimental site

Trials were conducted during rainy season (June to October) in 1988–90 at the research farm of ICRISAT Sahelian Center. The long-term mean annual rainfall is 560 mm, and the soils are reddish, friable and sandy (87.3% sand) and have low inherent fertility and organic matter. Rainfall was 35 mm in May 1989, 36 mm in June, 92 mm in July, 234 mm in August, 198 mm in September and 28 mm in October. Average maximum soil temperature 5 cm deep ranged between 30.5 °C in January and 45.1 °C in May.

Collection and processing of soil and root samples

Soil and root samples were collected with a 25 cm long steel shovel from different fields at the research farm. For each 9 m × 4 m plot, six soil cores were collected to a 20 cm depth and placed in polyethylene bags. Soil samples were protected from direct sunlight and heat. To characterize the nematode population densities in roots of both stunted and vigorous plants, whole plants were carefully uprooted by digging in the rhizosphere.

A thoroughly mixed 100 cm^3 subsample of each soil sample was processed by decanting and sieving (Cobb, 1918) followed by modified Baermann funnel technique (Schindler, 1961). Roots (1–5g) were carefully washed, cut into pieces of 0.5–1.0 cm long and placed on a tissue paper supported on a wire mesh immersed in water in 9-cm diameter petri dishes for 36 to 72 h at 25 °C. This water was then examined under a stereomicroscope.

Soil samples were analyzed for physical and chemical properties at the Soil Science Laboratory of ICRISAT Sahelian Center. Data were recorded on pH, exchangeable aluminium, organic matter (%), total nitrogen (mg kg^{-1}) and phosphorus (mg kg^{-1}) (Page et al., 1982).

Survey of groundnut crop for plant-parasitic nematodes

Soil samples were collected during the 1988 and 1989 crop seasons from rhizosphere and geocarposphere of groundnut plants from different locations at the ICRISAT Sahelian Center research farm. Seventy seven soil samples were examined for plant-parasitic nematodes. Roots and pods were examined for symptoms of nematode infection. Above-ground symptoms were also recorded. Species of plant-parasitic nematodes present in soil and root samples were identified.

Vertical distribution of plant-parasitic nematodes was studied by collecting soil samples using a 100 cm long 2.5 cm diameter tube auger from a groundnut (cv. 55-437) field at the time of sowing, during the crop growth period and at crop maturity. 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 deep at six randomly selected locations. Nematode densities were assessed as previously described.

Nematode densities vs. crop growth

A field naturally infested with *Scutellonema clathricaudatum* and exhibited extensive growth variability was selected for investigating the relationship between population densities of plant-parasitic nematodes and crop growth and yield of groundnut. This field (35 m × 20 m) was divided into 28 plots of 16 m^2 size and to have different levels of population densities of plant-parasitic nematodes in different plots, 16 plots were surface irrigated during the hot summer months in April and in May 1989 with an objective to activate and expose plant-parasitic nematodes to unfavorable summer fallow conditions. Each plot had 4 m long 8 rows; row to row distance was 50 cm and seed were sown at 10 cm spacing. The different irrigation treatments and chemical treatments were: three irrigations in April (one irrigation per week); three irrigations in April and four in May; one irrigation in April and four in May; one irrigation in April and one in May; application of a carbendazim (200 kg ha^{-1}) at the time of sowing (June); application of carbofuran (10 kg a.i. ha^{-1}) at the time of sowing (June); and control (no irrigation and no chemical treat-

ment). The chemicals were manually incorporated 5–6 cm deep in rows before sowing of seeds. Each treatment was replicated four times and arranged in a randomized block design. Seeds of a groundnut cv. 55-437, a spanish type, were sown on 10 June 1989.

Soil samples were collected at the time of sowing, at four times during growth of the crop, and at crop harvest. Root samples were collected at 30, 60 days and at harvest. To compare the nematode infection levels in stunted and vigorous plants, samples were collected from both types of plants from the same plot. Five stunted plants and adjacent apparently healthy plants were randomly selected 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, September and *S. clathricaudatum* population densities were estimated. Crop growth in every plot was visually assessed just before harvest. The crop was harvested at maturity, and haulm and pod yields were measured.

Bulk soil samples were collected from plots with 130, 50, 20 and 10 individuals of *S. clathricaudatum* 100 cm^{-3} of soil and were analyzed for exchangeable aluminium, total nitrogen, phosphorus, organic matter and pH. These soil and autoclaved soil (without *S. clathricaudatum*) were filled in 15-cm diameter plastic pots. Two seeds of the groundnut cv. 55-437 were sown in each pot. These pots, with their necks about 3 cm above the ground were buried in a fallow land. Plants were harvested 45 days after seedling emergence and dry shoot mass, leaf mass, and leaf area were recorded.

Bulk soil samples also were collected from a field with stunted groundnut plants, and from another field with healthy crop growth. Nematode population densities were estimated in both of these soils. The soil samples were analyzed for exchangeable aluminium, total nitrogen, phosphorus, organic matter (%), and pH. A portion of each soil (approx. 30 kg) was autoclaved. Soils collected from fields exhibiting poor and good crop growth and autoclaved soil were placed in 15-cm diameter plastic pots. In four pots for each of these soils, carbofuran 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. Data on leaf area, leaf mass, and dry shoot mass were recorded.

Results

Plant-parasitic nematodes and their distribution

Populations of *Aphelenchoides* sp., *Ditylenchus* sp., *Helicotylenchus* sp., *Holpolaimus pararobustus Schuurmans, Stekhoven* and *Tuenissen, Macroposthonia curvata Raski, Paralongidorus bullatus* Sharma and Siddiqi, *Scutellonema clathricaudatum* Whitehead, *Telotylenchus indicus* Siddiqi and *Xiphinema parasetariae* Luc were present in soil samples collected from various groundnut fields at the research farm of ICRISAT Sahelian Center. *S. clathricaudatum* was present in 96% samples and in 30% samples the nematode density was more than one individual cm^{-3} soil. Frequencies of occurrence of *T. indicus* and *X. parasitariae* were 64% and 36%, respectively. Population densities of these nematodes were less than one nematode cm^{-3} soil in more than 90% samples. Other nematode species were present in less than 25% samples. Root population densities of *S. clathricaudatum* was higher (more than 40 *S. clathricaudatum* g^{-1} of root) in roots collected from patches showing poor and stunted growth than in roots collected from apparently healthy plants. Groundnut pods were generally free of lesions. At the time of sowing, population densities of *S. clathricaudatum*, *X. parasetariae* and *T. indicus* were greater ($p = 0.05$) at 0–30 cm soil depth than at lower depths. More than 95% of the total population density of *S. clathricaudatum* was in 0–30 cm deep soil at sowing and very low densities of the nematode were found at 30–45 cm depth. The nematode was not found below 45 cm soil depth at any time, whereas populations of *X. parasetariae*, *T. indicus*, *Helicotylenchus* sp. and *P. bullatus* were found at 75 cm depth during the crop growth period and at crop maturity. *S. clathricaudatum* population densities decreased in soil during the crop growth period as the nematode entered in the roots and at the time of crop maturity, the nematode densities 0–15 cm

and 15–30 cm deep did not differ ($p = 0.05$). Soil pH ranged between 4.7 (0–15 cm deep) and 4.8 (45–60 cm deep), Al and H-ion concentration ranged between 30 meq 100 g^{-1} soil (0–15 cm deep) and 54 meq 100 g^{-1} soil (15–30 cm deep).

Nematode densities vs. crop growth and yield

Populations of *S. clathricaudatum*, *X. parasetariae*, and *T. indicus* were present in soil at the time of sowing and their average densities 100 cm^{-3} soil were 173, 9 and 17, respectively. Irrigations during the summer fallow period in April and May did not affect ($p = 0.05$) the nematode population densities. The nematode densities (average of nematode densities recorded at 5 sampling dates) were lowest in plots treated with carbofuran ($p = 0.05$, Table 1). Carbofuran-treated plants had nearly uniform growth and there were only a few randomly distributed stunted plants. In other treatments plants were generally stunted and chlorotic. Stunted plants had higher than average numbers of *S. clathricaudatum* per plot irrespective of the treatment. Average density of *S. clathricaudatum*, in roots was greater ($p = 0.05$) in presowing treatment of one irrigation in April and four irrigations in May than the other irrigation treatments. The nematode population densities ranged between 4 and 34 nematodes g^{-1} roots and were 2 to 5 times higher in the stunted plants than in the vigorous plants. Application of carbendazim did not ($p = 0.05$) affect the nematode densities. Variability in crop growth in some plots was noticed from the early seedling stage. Approximately one-week-old seedlings were chlorotic and stunted. These seedlings grew slowly and roots were brittle and poorly developed with very few nodules. In some other plots crop growth was uniform for the first three weeks after germination. Plants were vigorous and apparently healthy. After three weeks, however, variability in crop growth was evident in these plots and it gradually increased. Leaves were chlorotic and plants were stunted. Root systems of these plants were less well developed than the apparently healthy plants. In some cases root tips were slightly swollen and necrotic and lateral roots were branched and stubby. Analysis of soil samples from some of these plots indicated that Al and H-ions was high (more than 0.35 meq 100 g^{-1} soil) in the plots where crop growth variability was observed from the very beginning of crop emergence, and it was comparatively lower in plots where crop growth variability was evident only after three weeks. In the later plots, nematode densities were greater than in other plots (Table 2). Pod yield was signifi-

Table 1. Effects of different pre-sowing treatments on the population densities of plant-parasitic nematodes

Treatment	Nematode population densities[a] 100 cm^{-3} soil		
	S. clathricaudatum	*X. parasetariae*	Sum of total parasitic nematodes
Presowing irrigation[b]	35.5	15.8	89.1
	(1.55)	(1.20)	(1.95)
Carbendazim	66.1	16.2	131.8
(200 kg ha^{-1})	(1.82)	(1.21)	(2.12)
Carbofuran	18.6	6.2	43.6
(10 kg a.i. ha^{-1})	(1.27)	(0.79)	(1.64)
Control	39.8	18.2	87.1
	(1.60)	(1.26)	(1.94)
LSD ($p = 0.05$)	(0.268)	(0.251)	(0.187)

[a] Average of nematode densities recorded at 5 sampling dates.
[b] Average of nematode densities recorded in different presowing irrigation treatments. (Nematode densities in irrigation treatments did not differ ($p = 0.05$).
Figures in parentheses are log x + 1 transformed values.

Table 2. Analysis of soil samples collected from patches where variation in groundnut crop growth was visible about a week after sowing, and three weeks later at ICRISAT, Sadore, 1989

Soil source	pH	H-ions	Al-ions	Organic matter (%)	Total nitrogen (mg kg^{-1})	Nematode population 100 cm^{-3} soil at sowing
Variability visible about a week after seedling emergence	4.9	0.20	0.35	0.27	144	40
Variability visible three weeks after seedling emergence	5.2	0.15	0.19	0.30	146	1010

cantly improved in these plots treated with carbofuran at the time of sowing (Table 3).

Growth of *S. clathricaudatum*-susceptible cv. 55-437 was poor in soil with an infestation level of 130 *S. clathricaudatum* 100 cm^{-3} soil at sowing time (pH = 4.8 and Al and H ions =0.35 meq 100 g^{-1} soil). Plant biomass and leaf area were significantly ($p = 0.05$) reduced. Plant growth in the soils containing 50 *S. clathricaudatum* 100 cm^{-3} of soil was not different from that in the autoclaved soil (no *S. clathricaudatum* and Al and H ions = 0.14 meq 100 g^{-1} soil). Plant growth was significantly ($p = 0.05$) reduced in soil with a low population of 10 *S. clathricaudatum* 100 cm^{-3} soil and higher Al and H-ions (0.55 meq 100 g^{-1} soil) (Table 4). Soil samples collected from areas with both good and poor crop growth differed in Al and H-ions (0.34 meq 100 g^{-1} soil or less in good patches and 0.51 meq 100 g^{-1} soil in bad patches). Application of carbofuran in soil with 80 *S. clathricaudatum* 100 cm^{-3} soil (Al and H-ions = 0.34) did not improve plant growth, but it significantly ($p = 0.05$) improved the plant growth in soil with higher Al and H-ions (0.51 meq 100 g^{-1} soil) and lower nematode density cm^{-3} soil (Table 5). Application of carbofuran even in autoclaved soil resulted in vigorous crop growth.

Table 3. Effect of different pre-sowing treatments on haulm and pod yields of groundnut (cv. 55-437) at Sadore, Niger, rainy season, 1989

Treatment	Yield (Mg ha^{-1})		Effect on nematode populations
	Haulm	Pod	
Irrigation during summer fallow	1.01	0.79	NS
Carbendazim (200 Kg ha^{-1})	1.58	1.15	NS
Carbofuran (10 kg a.i. ha^{-1})	2.43	2.24	S
Control	1.06	0.67	
LSD ($p = 0.05$)	NS	1.31	

NS = Not significant; S = Significnat ($p = 0.05$).

Table 4. Relationship between population densities of *Scutellonema clathricaudatum*, pH, aluminium levels in soil and growth of groundnut cv. 55-437 in pot experiments, Sadore, Niger, 1989

Nematode population density 100 cm^{-3} soil	Al + H-ions	pH	Organic matter (%)	N total (mg kg^{-1})	P (mg kg^{-1})	Leaf area (cm^2)	Leaf mass (g)	Dry shoot mass(g)
0	0.14	5.1	0.13	87	6.6	478	12.5	5.2
130	0.35	4.8	3.9	144	18.2	249	5.6	3.3
50	0.36	4.9	4.0	146	12.3	281	8.8	4.0
25	0.39	4.9	4.0	147	12.9	232	7.4	3.5
10	0.55	4.9	4.0	144	18.6	107	3.5	1.9
LSD ($p = 0.05$)						210.3	4.93	1.86

[a] Autoclaved soil.

Table 5. Comparison of growth of groundnut cv. 55-437 in soils from fields with histories of good and bad groundnut growth at ICRISAT Sadore, 1989

Soil source	Carbofuran	Nematode population density 100 cm^{-3} soil	Leaf area (cm^2)	Leaf mass (g)	Dry shoot mass (g)
Good patch	−	80	403	10.2	5.1
	+	80	516	14.4	6.4
Poor patch	−	10	164	5.0	2.5
	+	10	327	9.6	4.5
Poor + good patch (1 : 1) (autoclaved)	−	0	436	12.4	5.6
Poor + good patch (1 : 1) (autoclaved + carbofuran)	+	0	1034	26.9	11.7
LSD ($p = 0.05$)			179.4	4.36	1.90

Al and H-ions concentration (meq 100 g^{-1} soil) 0.34 and 0.51, pH in (water) 4.9 and 4.9, phosphorus (mg kg^{-1}) 17.6 and 17.1, nitrogen (mg kg^{-1}) 160 and 138, and organic matter (%) 0.30 and 0.23 in good and bad patches, respectively.
− = Control; + = treated with carbofuran 8 kg a.i. ha^{-1}.

Discussion

Aluminium toxicity, low pH and plant-parasitic nematodes are probably the major factors in growth variability of groundnut in the Sahel. Drevon and Diabaye (1981) concluded that peanut chlorosis in Senegal was due to the impairment of symbiotic fixation of atmospheric nitrogen resulting from delay and reduction in nodulation. These are linked to soil characterized by low pH, presence of exchangeable aluminium and low calcium and magnesium. Luc and Germani (1983) reported that *Scutellonema cavenessi* thrives at low soil pH and that peanut chlorosis is related to presence of *S. cavenessi*. The nematode reduces plant biomass and nodulaton (Germani, 1981). We observed good crop growth in patches with a soil pH as low as 4.9 (Tables 4, 5). Also variability in crop growth occurred in patches with low densities of plant-parasitic nematodes (Tables 4, 5). These observation further confounded this enigmatic problem of crop growth variability. Our results indicated however, that plant-parasitic nematodes contributed to crop growth variability. Affected plants exhibited symptoms of nutrient deficiency as well as nematode infection. These symptoms were evident when crop growth was monitored from sowing to harvest. Where variability in crop growth appeared from the very beginning of plant growth, plant-parasitic nematodes were not the primary cause of crop growth variability. In these patches Al and H-ion concentrations were elevated. Crop growth was extremely poor in patches where concentration of Al and H-ions was more than 0.50 meq 100 g^{-1} soil. In another case, crop growth was uniform and healthy for 2 to 3 weeks after sowing and then variation in crop growth appeared in patches due to *S. clathricaudatum* infestation. Symptoms may vary in patches with moderate levels of Al and H-ions and *S. clathricaudatum*. We observed that in patches where Al and H-ions was high and plant growth was very poor from the beginning, the nematode populations were low because of lack of host plant roots. If soils are not moved during the inter cultivation operations, patches appearing due to high Al and H-ions should reappear at the same place next year, whereas patches due to nematode infection may spread in subsequent growing seasons.

Major shifts in soil pH result in significant changes in the availability of inorganic plant nutrients such as phosphorus, whereas low soil pH results in the formation of insoluble Al and Fe phosphate (Luc and Germani, 1983). Application of carbofuran and DBCP dramatically increased the crop growth in Senegal (Baujard et

al., 1989; Germani, 1979a) and our results confirmed these reports. Carbofuran not only reduced the densities of plant-parasitic nematodes but also increased the plant growth even in autoclaved soil. Germani (1979 b) found that carbonfuran significantly increased the root and shoot weights of groundnut in sterilized soil.

Further studies on interactions between *S. clathricaudatum* and exchangeable aluminium levels in soil, and effect of pH and application of lime on the biology and pathogenicity of *S. clathricaudatum* are desirable.

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