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Etiology of crop growth variability in groundnut in Niger*

P. SUBRAHMANYAM[1], B.J. NDUNGURU[2], S.B. SHARMA[3], K.L. SAHRAWAT[3], D.C. GREENBERG[4] and H. VAN RIEL[5]
[1]*SADC/ICRISAT Groundnut Project, Chitedze Research Station, P.O. Box 1096, Lilongwe, Malawi,* [2]*Groundnut Improvement Program, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Sahelian Center, B.P. 12404, Niamey, Niger (via Paris),* [3]*ICRISAT Center, Patancheru P.O. Andhra Pradesh 502 324, India,* [4]*23 Pierce Lane, Fulbourn, Cambridge, CB1 5DJ, UK and* [5]*Département de Formation en Protection des Végétaux, Centre AGRHYMET, Niamey, Niger (via Paris)*

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Abstract

Six field trials were conducted during the rainy seasons in 1987 and 1988 and dry season of 1988 at ICRISAT Sahelian Center, Niger, to investigate the effects of soil applied nematicides, inorganic fertilizers and farm yard manure (FYM) on spacial variability of groundnut growth and yield. Soil samples from the rhizosphere and geocarposphere zones of the stunted plants showed high numbers of plant-parasitic nematodes (*Scutellonema clathricaudatum*, *Telotylenchus indicus* and *Xiphinema parasetariae*). Carbofuran alone at a rate of 10 kg a.i. ha^{-1} or in combination with FYM greatly reduced the population densities of plant-parasitic nematodes in the soil and roots as well as increased pod and haulm yields. Dibromochloropropane (DBCP) was most effective in reducing the variation in crop growth and significantly increased pod and haulm yields. No significant difference in crop growth, haulm and pod yields was observed between solarized and non-solarized plots.

Introduction

Variability in plant growth and yield is a constraint to groundnut (*Arachis hypogaea* L.) production in Niger. During our field surveys in 1986 and 1987 large variations in plant growth were observed, especially in sandy soils, in all the major groundnut producing areas of the country (ICRISAT, 1988). Within short distances vigorous, healthy plants were observed growing among weak, poor and sometimes dying plants. Affected plants were usually present in irregularly distributed patches. Factors contributing to variation in plant growth have not been fully elucidated. Chase et al. (1989) analyzed soil profiles of productive and unproductive millet (*Pennisetum glaucum*) patches and observed that high aluminium (Al) concentration correlated with poor millet plant growth. They suggested that plant variability within a field could be reduced by liming the top 30 cm of soil to reduce Al and manganese (Mn) toxicity and to increase phosphorus (P) availability. Fussel and Hebel (personal communication) have followed up the millet crop performance at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Sahelian Center, Sadoré, over several years and mapped the fields to ascertain whether variability within plots moved from one year to another. They observed that variability of millet yield moved from one year to the next and that P was not the cause of plant growth

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variability. However, all these workers have associated plant variability problems only with abiotic factors such as toxicities due to Al and Mn, and/or nutrient imbalances associated with the low pH characteristic of these soils. We have observed uniform good plant growth in plots at Sadoré that had previously been planted with cowpea. This led to the speculation that the added organic matter may be partly responsible for reducing plant variability. The present report deals with the effects of soil application of farm yard manure (FYM), mineral nutrients, and pesticides on variability in plant growth and yields of groundnut.

Materials and methods

Experiment site

Field trials were conducted during the rainy seasons (June to October) in 1987 and 1988, and the dry season of 1988 (January to May) at the research farm of ICRISAT Sahelian Center (13°, 29′N lat., 2°, 10′ long., 221 m alti.), Sadoré, 45 km south of Niamey, Niger. The long-term mean annual rainfall at the research farm is 560 mm and the rainfall exceeds potential evapotranspiration for a short period (Sivakumar 1991). Soils are Psammentic Paleustalf (sandy, siliceous, isohyperthermic) with low inherent fertility and low organic matter (sand 96%, clay 1.3%, total P 68 mg kg^{-1}, avaiable P 2.8 mg kg^{-1}, total N 123 mg kg^{-1}, pH 4.1, CEC 0.91 Cmol kg^{-1}).

Groundut cultivar

The cultivar used in these studies was a West African cultivar 55–437.

Sowing and harvesting

Seeds were treated with a seed protectant (Thiram/Captan/Thioral)[1] at a rate of 3 g kg^{-1} seed before sowing. Seeds were sown singly at 10 or 20 cm spacing in 40 or 50 cm rows on flat or on raised ridges near the end of June. Plots were treated with 40 kg P_2O_5 ha^{-1} as single superphosphate at land preparation and 400 kg gypsum ha^{-1} as top dressing at peg initiation. In 1987, an additional 15 kg N ha^{-1} was also given. Two sprays of an insecticidal mixture (dimethoate and cypermethrin), were given to all experimental plots to control foliar pests.

Trials were conducted under rainfed conditions during the cropping season or irrigated conditions during the dry seasons. All plots were harvested at maturity with yields of pods and haulms recorded.

Assessment of plant growth

Plant growth was examined at weekly intervals. At maturity, five to ten plants were arbitrarily selected from each replicated plot and length of the main stem and tap root, number of leaves on the main stem, and number of pods per plant was recorded.

Sampling procedure of plant-parasitic nematodes

For every replicated plot in 1988, 4 to 6 soil samples to a 20-cm deep were collected from the rhizosphere using a shovel. Samples from each plot were mixed and a 100 cm^3 sub-sample was processed using a decanting and siveing technique (Cobb, 1918; Schindlet, 1961). Groundnut roots were collected from each replicated plot and about 5 g roots were cut into small pieces to extract nematodes using the same method employed for extracting nematodes from soil.

Detection of peanut clump (PCV)

Soil samples were collected up to 10-cm deep using a shovel from six groundnut fields showing severe variation in crop growth and used for testing the soil transmission of crop growth variability in plastic pots. Groundnut (cv. 55-437) seeds treated with captan (3 g kg^{-1} seed) were sown (5 seeds pot^{-1}) in plastic pots and watered twice a day with sterilized tap water. Plants grown in soils collected from areas where the plant growth was uniform served as controls.

[1]The use of trade names do not constitute endorsement of or any discrimination against any product by the Institute.

Twenty pots were used for each soil sample. Plants showing stunted growth were recorded, 40 days after sowing. The young quadrifoliates from 10 stunted plants were collected and homogenised in 0.05 *M* phosphate buffer (pH 7.0). Mechanical inoculations were carried out by rubbing the extract on young primary leaves of groundnut (cv. 55-437), common bean (*Phaseolus vulgaris* L., cv. Top crop) and cowpea (*Vigna unguiculata* (l) Walp., cv. C-152). Four plants of each species were inoculated and resulting symptoms were recorded. Mechanical inoculations were repeated thrice on different dates. Young quadrifoliates collected from stunted groundnut plants were fixed in 3% glutaraldehyde prepared in 0.1 *M* phosphate buffer (pH 7.3) for 1 h and processed for electron microscopy as described by Reddy et al. (1983).

Soil mites and other pests

Soil samples and groundnut roots collected from study fields showing severe variation in crop growth were scanned using a stereomicroscope (×70) for the presence of mites and other soil pests. Soil residues collected from various sieves during the extraction of nematodes also were examined for the presence of soil pests.

Effect of nutrients, carbofurant and FYM

A trial was laid out at Sadoré with the following treatments:

Complete: this treatment supplemented 40 N, 80 P_2O_5, 40 S, 120, Ca, 30 mg, 0.6 B, 2.2 Zn, 20 Fe, 0.2 Mo ha^{-1} and carbofuran at the rate of 6 kg ha^{-1} a.i.; complete – N; complete – P; complete – S; complete – Ca; complete – Mg; complete – B; complete – Zn; complete – Cu; complete – Fe; complete – Mo; complete – carbofuran; complete + farm yard manure (FYM); complete + carbofuran; FYM alone and Control.

Treatments were applied by hand on small furrows 5 cm deep on the flat or ridges.

Field plots (10.8 m^2) were treated with the different treatments at land preparation. The trial planted on 4 July 1987 was laid out as balanced lattice design with five replications.

Effect of carbofuran

Effects of soil treatment with carbofuran, were investigated under irrigated conditions during the 1987 and 1988 rainy seasons. Supplementary water was provided by irrigation when necessary. Plots (6 m^2 in 1987, and 10 m^2 in the 1988) were treated with different rates of carbofuran (2, 4, 6, 8, and 10 kg a.i. ha^{-1} in 1987 and 3, 6, 9, 12, and 15 kg a.i. ha^{-1} in 1988) at land preparation. Untreated plots served as control. Plots were replicated four times and were arranged in Randomized Block Design. Plant growth and yields were recorded.

Effects of FYM and carbofuran

The effects of FYM (10 t ha^{-1}) and carbofuran (10 kg a.i. ha^{-1}) on growth and yield of groundnut were investigated under rainy and irrigated conditions during the 1987 and 1988 rainy seasons. Field plots (16 m^2 each) were treated with either FYM or carbofuran, or both, at land preparation. Untreated plots served as control. No additional fertilizer was added to the plots. Plots were arranged in Randomized Block Design with six replications in the 1987 irrigated trial or in a latin square design with four replications in other trials. Plant growth and yields were recorded. Field plots that were treated with FYM and/or carbofuran during the 1987 rainy season were sown with groundnut to investigate the residual effects of these treatments on crop growth variability and on yield during the 1988 dry season. No additional fertilizer was added to the plots.

Effects of soil application of pesticides

Effects of soil application of aldicarb (4 kg a.i. ha^{-1}) and carbofuran (6 kg a.i. ha^{-1}) and dibromochlorpropane (DBCP) (20 L in 85 L of water ha^{-1}), on growth and yield of groundnut were investigated under rainfed and irrigated conditions during the 1987 and 1988 rainy seasons. Dazomet (300 kg ha^{-1}) and isazophos (6 kg a.i. ha^{-1}) were tested only in the 1987 and 1988 rainy season, respectively. Carbofuran, aldicarb and isazophos were applied by hand to field plots (8 m^2 in 1987 and 10 m^2 in 1988) on the day of sowing. DBCP was injected in the soil using a Sismar injector. Dazomet was applied by hand 15 days before sowing. Untreated plots served as control. Plots were arranged in a Randomised Block Design with four (irrigated trial) or five (rainfed trial) replications in 1987 and with four replications under both irrigated and rainfed conditions in 1988. Plant growth and yields were recorded as described above. Plots treated in 1987 were sown with groundnut seeds 55-437 to investigate the residual effects of these treatments on crop growth variability and on yields during the 1988 off-season.

Effect of Oxamyl

Effects of foliar Oxamyl sprays (5 and 10 L in 500 L water ha^{-1}) at 20, 35, and 50 days after sowing on crop growth and yield were studied in the 1988 rainy season. Control plots were sprayed with water (500 L ha^{-1}) and plant height and yield were recorded.

Effect of soil solarization

Effects of soil solarization plots (4.8 m^2) irrigated and covered with a clear polyethylene sheet (Chauhan et al. 1988) from April to June 1987 and April to May 1988 on crop growth variability was investigated. Soil solarization is a method of heating soil by covering it with transparent polythene sheeting during hot periods to control soilborne diseases. The effects, advantages, and limitations of this technique have been recently reviewed by Katan (1981). The technique has been commercially exploited for growing high-value crops in diseased soils in environments with a hot summer (maximum daily air temperatures regularly exceeding 35°C). Examples include control of verticilium and fusarium diseases in vegetable crops in Israel and control of *Verticillium dahliae* in pistachio orchards in California, USA (Katan 1981).

Results

Occurrence of PCV

Incidence of plants showing symptoms of stunting and chlorosis varied greatly from field to field. Out of 6 fields showing symptoms, 5 fields had 92 to 100% plants with symptoms. The incidence of plants showing symptoms of stunting, dark green and bushy was 0–3%. However, in one field the incidence of this type of plants was 90%. Plants grown in soils collected from fields showing uniform crop growth were apparently healthy (i.e. without symptoms). 100% of plants inoculated with sap from symptomatic plants developed similar symptoms. Inoculated groundnut plants were severely stunted with dark green leaves. Young leaves showed mild mosaic mottling with chloritic rings. A characteristic systemic veinal necrosis on common beans and chlorotic local lesions on cowpea were observed and thin sections of leaves showed the presence of rod-shaped particles characteristic of PCV (Reddy et al. 1983). Plants inoculated mechanically with sap from asymptomatic groundnut plants did not show any development of symptoms on ground nut, common bean or cowpea.

Occurrence of plant-parasitic nematodes

Analysis of soil samples collected from the rhizosphere and geocarposhere zones of the affected plants in the experiments showed the presence of various plant-parasitic nematodes, especially of *Scutellonema clathricaudatum* Whitehead, *Telotylenchus indicus* Siddiqi and *Xiphinema parasetariae* Luc.

Soil mites

There was no evidence of the presence of mites or any other soil pests in soils and groundnut roots collected from the fields showing severe variability in crop growth. Pineapple mealy bugs (*Dysmicoccus brevipes*) were observed on groundnut roots in some cases but the incidence was negligible.

Effect of nutrients, carbofuran and FYM

The mean pod yield of 1.3 ± 0.15 t ha^{-1} in treatments with no mineral or nematicide additions was different ($p \leq 0.05$) from the mean pod yield of 1.8 ± 0.06 t ha^{-1} of all the other supplemented treatments. The means of treatments which did not have mineral supplementation gave a mean pod yield of 1.4 ± 0.12 t ha^{-1}, and the rest of the supplemented treatments gave a mean yield of 1.8 ± 0.06 t ha^{-1} ($p \leq 0.05$). Similarly a difference ($p \leq 0.05$) was found when treatments which did not have carbofuran and gave a mean pod yield of 1.4 ± 0.12 t ha^{-1}, were compared with the rest of the treatments, which gave a mean pod yield of 1.8 ± 0.06 t ha^{-1} (Table 1).

Soil treatment with carbofuran greatly reduced the variation in plant growth and increased pod and haulm yields in both years ($p \leq 0.05$). Plant height, pod and haulm yields were highest when carbofuran was applied at 10 kg a.i. ha^{-1} in 1987 and at 9 kg a.i. ha^{-1} in 1988 (Fig. 1. There was a reduction in the plant height and yields at 12 and 15 kg a.i. ha^{-1} ($p \leq 0.05$). Plants were apparently normal and vigorous in carbofuran treated plots especially at 6 to 10 kg a.i. ha^{-1}. In control plots, variability in plant growth was high. Treatments of FYM and carbofuran, or carbofuran alone were effective in reducing the variability in plant growth and increasing the yields ($p = 0.01$). Soil treatment with FYM alone was not effective in reducing the variability in plant growth. Carbofuran alone or in combination with FYM, greatly reduced the population density of plant-parasitic nematodes in soil samples and roots (Table 2) ($p \leq 0.05$). Population density of *S. clathricaudatum* in 5 g root sample was 120 in control, 100 in FYM alone, 20 in carbofuran and 30 in FYM and carbofuran treatments. Population densities were negatively correlated ($r = -0.73$) with pod yield and regression of pod yield on nematode densities was significant ($R^2 = 0.54$). Pod yields in the the dry season were low compared to those in the rainy season. Plants in plots treated with carbofuran and FYM

Table 1. Effect of nutrient amendments, carbofuran and Farm Yard Manure on pod yield of groundnut during the rainy season 1987

Treatment	Pod yield (t ha^{-1})
Complete	1.72
Complete − N	1.81
Complete − P	1.66
Complete − S	1.56
Complete − Ca	2.10
Complete − Mg	1.47
Complete − B	1.78
Complete − Zn	1.91
Complete − Cu	1.96
Complete − Fe	1.66
Complete − Mo	1.95
Complete − Carbofuran	1.53
Complete + FYM	2.24
Complete + Carbofuran	1.46
FYM alone	1.43
Control	1.34
SE	±0.24
CV (%)	32

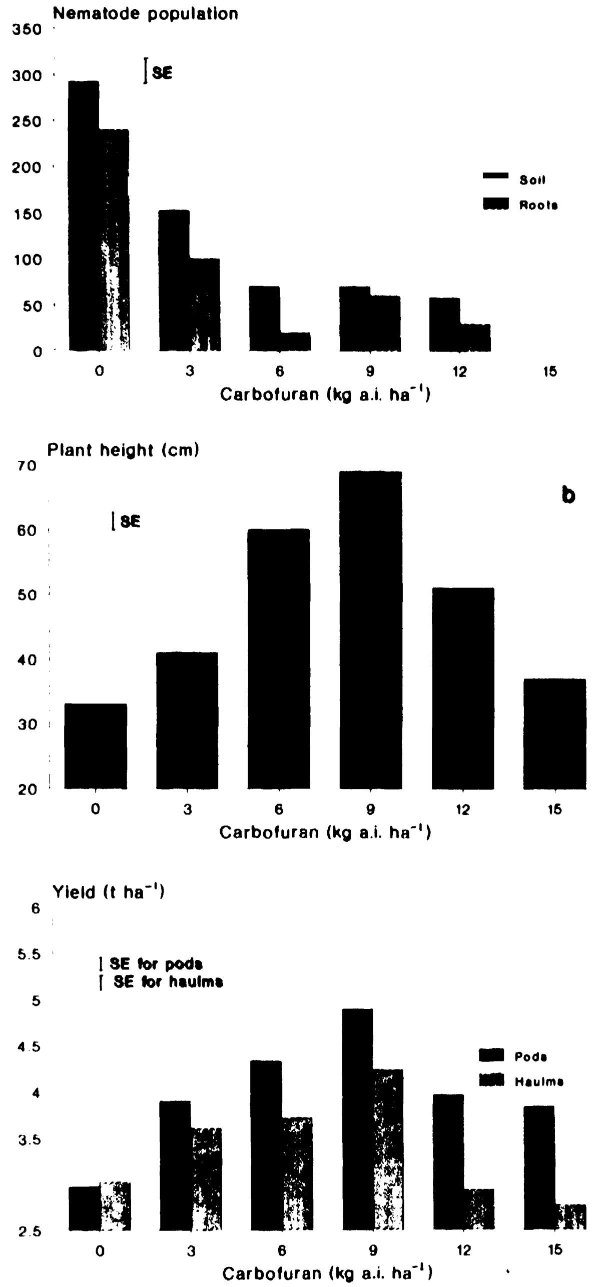

Fig. 1. Effect of different levels of carbofuran on (**a**) nematode populations (nos. in 100 cm^3 soil and 5 g roots); (**b**) plant height; and (**c**) pod and haulm yields of groundnut (cv. 55-437) at Sadore, Niger, rainy season 1988.

Table 2. Effects of carbofuran and farmyard manure (FYM) on population densities of plant-parasitic nematodes in soil and on plant height and pod yield of groundnut (cv 55–437) under irrigated and rainfed conditions at Sadoré, Niger[a]

Treatment[b]	1987 (residual)						1988						1988 residual effects[f]		
	Plant height (cm^{-1})		Yield (t ha^{-1})				Nematode density (no. per 100 cm^3)[c] Soil		Plant height (cm)[d]		Pod yield t ha^{-1}		Plant height (cm)	Pod yield (t ha^{-1})	Haulm yield (t ha^{-1})
	Irrigated	Rainfed	Irrigated		Rainfed		Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed			
			Pod	Haulms	Pods	Haulms									
Carbofuran + farmyard manure	25	16	3.04	2.55	1.75	1.23	25(4.8[e])	40(6.3)	59	62	3.51	4.88	20	1.24	2.21
Carbofuran	21	15	2.14	1.30	1.67	1.05	38(5.8)	58(7.6)	41	44	2.13	3.67	10	0.62	1.30
Farmyard manure	14	10	1.10	1.03	0.78	0.70	135(11.1)	93(9.6)	20	48	0.94	3.46	12	0.43	1.67
Control	11	8	0.84	0.80	0.66	0.61	160(12.5)	130(11.3)	14	22	0.73	2.61	8	0.25	0.95
SE	±2	±1	±0.20	±0.10	±0.10	±0.06	(1.1)	(0.5)	±4	±2	±0.21	±0.17	±1	±0.08	±0.01
CV (%)	24	22	27	25	16	14	(26)	(12)	23	11	23	9	23	30	21

[a]RBD in 1987 and Latin-square design in 1988 with 4 replications; plot size 16 m^2. Residual after 1987 application.
[b]Carbofuran (10 kg a.i. ha^{-1}), and FYM (10 t ha^{-1}) were applied to the field plots just before sowing.
[c]*Scutellonema clathricaudatum*, *Telotylenchus indicus*, and *Xiphinema parasetariae*.
[d]Mean of 5 plant per replication in 1987 and 10 in 1988.
[e]Square-root transformed data shown in parenthesis.
[f]Treatments were applied to field plots just before sowing the 1987 rainy season crop.

Table 3. Effects of four pesticides on plant height and yield of groundnut (cv 55-437) at Sadore, Niger[a]

Treatment[b]	1987						1988				1988 residual effects[d]		
	Plant height (cm)[c]		Yield (t ha^{-1})				Plant height (cm)[c]		Pod yield (t ha^{-1})		Plant height (cm)	Pod yield (t ha^{-1})	Haulm yield (t ha^{-1})
	Irrigated	Rainfed	Irrigated		Rainfed		Irrigated	Rainfed	Irrigated	Rainfed			
			Pod	Haulms	Pods	Haulms							
Dibromochloropropane	32	15	3.85	3.41	1.86	1.78	70	34	5.16	3.50	18	0.71	2.31
Dazomet	25	12	2.89	2.59	1.10	1.00	53	37	4.12	3.42	16	0.83	2.14
Carbofuran	17	14	2.50	1.98	1.93	1.66	48	36	4.31	3.38	14	0.65	1.76
Aldicard	18	18	1.97	1.71	2.25	1.96	36	32	3.60	2.98	14	0.61	1.57
Control	12	11	1.19	1.09	1.09	0.92	22	20	2.01	2.27	10	0.37	1.06
SE	±2	– ± 1	± 0.33	±0.33	±0.12	±0.20	±4	±3	±0.30	±0.18	±2	±0.05	±0.14
CV (%)	23	12	27	30	17	30	18	17	16	12	22	15	16

[a]Randomized-block design with 4 replications under irrigation and 4 replications under rainfed conditions; plot size 8 m^2.
[b]Dibromochloropropane (20 L in 85 L of water ha^{-1}), carbofuran (6 kg a.i. h^{-1}), and aldicarb (4 kg a.i. ha^{-1}) were applied to the field plots on the day of sowing. Dazomet (300 kg ha^{-1}) was applied 15 days before sowing.
[c]Mean of five plants per replication in 1987 and 10 in 1988.
[d]Pesticides were applied 15 days before sowing of the 1987 rainy season crop and no pesticide treatment was given in 1988.

in 1987 showed vigorous and healthy growth and gave pod yields of 1.24 t ha^{-1}. Although we found no differences in vegetative growth between the carbofuran and FYM treatments, the carbofuran treated plots gave higher pod yields ($p \leq 0.05$) than FYM treated ones (Table 2).

Soil application of pesticides and their residual effects

Plots treated with pesticides showed vigorous and uniform plant growth, and good nodulation. Plants in control plots were stunted and chlorotic/dark green with severely necrotic root systems. DBCP was most effective in reducing ($p \leq 0.01$) the variation in crop growth and increasing the pod and haulm yields under both irrigated and rainfed conditions in 1988, and under irrigated conditions in 1987 (Table 3). Plants were vigorous and healthy in plots treated with pesticides, especially DBCP ($p \leq 0.05$). Pod yields were highest in the DBCP treated plots followed by dazomet, carbofuran and aldicarb. Haulm yields were also higher ($p \leq 0.05$) in pesticide treated plots than in the control plots (Table 3).

Effect of Oxamyl

Plant height, haulm and pod yields were greater ($p \leq 0.05$) in oxamyl treated plots especially at the higher rate than in the control plots (Table 4).

Table 4. Effects of foliar application of Oxamyl on plant height and yield of groundnut (cv 55-437) at Sadoré, Niger during the rainy season 1988[a]

Spray treatment[b]	Plant height (cm)[c]	Yield (t ha^{-1})	
		Pods	Haulms
Oxamyl 10 L	33	1.31	1.68
Oxamyl 5 L	21	0.73	0.74
Water (control)	15	0.40	0.49
SE	±1	± 0.07	±0.10
CV (%)	9	19	23

[a]Randomized-block design with five replications: plot size 8.2 m^2.
[b]Oxamyl (5 and 10 L in 500 L of water ha^{-1}) was sprayed to the field plots at 20, 35 and 50 days after sowing. Control plots were sprayed with water (500 L ha^{-1}).
[c]Mean of ten plants per replication.

Effect of solarization

There was no difference in crop growth and pod yields between solarized (0.062 ± 0.14 t ha^{-1}) and non-solarized (0.71 ± 0.14 t ha^{-1}) treatments in 1987. Similar results were obtained in 1988, but the yields were lower. Nematode densities were not recorded in this trial.

Discussion

Variability in plant growth is one of the constraints of groundnut production in Niger. Analysis of soil and root samples collected from fields showing severe plant variability had higher population densities of plant-parasitic nematodes than samples collected from fields showing uniform plant growth. PCV infected plants become severely stunted, and show symptoms of dark green with chlorotic ring spots on younger leaves. Such plants were totally or partially unproductive. Symptoms on indicator hosts (common bean and cowpea) and electron microscopy studies confirm the occurrence of PCV. These results indicate that plant-parasitic nematodes and PCV play important roles in plant growth variability in groundnut. Studies have shown that *S. clathricaudatum* is pathogenic to groundnut and it reduces growth of groundnut (Sharma et al., 1990, 1992). However, plant-parasitic nematodes are not the only factors responsible for crop growth variability. Growth variability problem in the Sahel is a syndrome and many factors (low pH, aluminium toxicity, nematodes, viruses, etc. . .) individually and in combination are responsible (Sharma et al., 1992). Another species of *Scutellonema* (*S. cavenessi*) has been associated with similar symptoms on groundnut in Senegal (German, 1981; Luc and Germani, 1983). Baujard (1990) reported that DBCP has been used in Senegal to decrease nematode population densities with the resulting increase of both pod and haulm yields in groundnut. Incidence of PCV was also reduced in pesticide treated plots. Investigations are needed on the role of plant-parasitic nematodes and PCV before practical solutions to this problem can be attained. Although soil pesticides were effective in reducing variability in plant growth their extended utilization is not a practical proposition. These chemicals are expensive, difficult to handle and apply and they were effective only at high doses. Furthermore, the factors influencing the persistence of carbofuran incorporated into the soil and environmental impact of such treatments have not been assessed in the Sahel.

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