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Effect of liming and carbofuran on groundnut yield in sandy soils in Niger*

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Abstract

One of the constraints to groundnut production in sandy soils of Niger is crop growth variability. In early 1989, a trial on the effect of lime and carbofuran on soil pH, Al toxicity, nematode population and groundnut yield was initiated to study crop growth variability. Groundnut was sown in the 1989 rainy season, followed by pearl millet (*Pennisatum glaucum*) in the 1989–90 dry season and again groundnut in the 1990–91 rainy, and dry seasons. In 1989 the carbofuran treatment increased the pod yield. Lime application did not change the pH and exchangeable Al^{+++} contents in the soil and did not increase groundnut yield. In the 1990–91 rainy and dry season, however, the application of 10 t ha^{-1} of lime increased pH, decreased exchangeable Al^{+++}, improved crop growth and increased the yield of groundnut to the same level as was achieved by the carbofuran treatment. Application of lime did not affect the nematode population, which were reduced by the carbofuran.

Introduction

One of the constraints to groundnut production in the sandy soils of Niger is crop growth variability. Within the same field plants show variation in their height, growth and productivity. This makes selection of varieties under these conditions virtually impossible.

Subrahmanyam *et al.* [13] described three categories of crop growth variability. The first category consists of severely stunted plants with chlorotic leaves, poor shoot and root development. Roots are necrotic with severe shredding of cortex tissues. Plants have few pods with necrotic lesions appearing on the pod surfaces. The second category consists of plants that are severely stunted, bushy, and have dark green leaves with mild mosaic symptoms on young leaves. Plants also become chlorotic towards maturity. The third category involves plants that are severely stunted, but older leaves show black necrotic lesions on the margins. Subrahmanyam *et al.* [12] and Sharma *et al.* [11] showed, that nematodes and peanut clump virus play important roles in crop growth variability at the ICRISAT Sahelian Center farm, and that carbofuran application significantly increased pod yield.

Groundnut is not the only crop that suffers from crop growth variability. Chase *et al.* [5] analyzed soils from productive and unproductive millet patches at the ICRISAT Sahelian Center at Sadore and found that low soil pH and high exchangeable Al^{+++} concentrations correlated with poor millet plant growth. These authors suggested that field variability could be reduced

*International Crops Research Institute for the Semi-Arid Tropics (ICRISAT); Submitted as ICRISAT Journal Article No 1228 by liming the top 30 cm of the soil to reduce Al and Mn concentrations and also to increase P availability.

An understanding of this variability problem can aid in the design of practical management strategies. The objective of this study was to determine the relationships between nematode populations, exchangeable aluminium level and crop growth variability in groundnut with different lime and carbofuran treatments.

Materials and methods

Experimental site

Field trials were conducted during the 1989 rainy season, 1989–1990 dry season, 1990 rainy season, and 1990–91 dry season at the ICRISAT Sahelian Center farm at Sadore near the town of Say, 45 km south of Niamey, Niger. The long term mean annual rainfall at the research farm is 560 mm. The soils from the experimental sites are derived from eolian deposits. The soil is classified as a sandy silicious isohyperthermic Psammentic Paleustalf. The top soil layer (0–15 cm) contains 960 g kg^{-1} sand and 30 g kg^{-1} clay with an effective cation exchange capacity of 0.9 Cmol kg^{-1}, and an organic matter content of 0.2%. The soil is acidic, with a pH (KCl) of 4.1. Phosphorus is the most limiting factor for crop growth. The available P is about 2.8 mg P kg^{-1} [3], with a total P content of 68 mg kg^{-1}. Water infiltration rate is in excess of 100 mm h^{-1}, and a rapid hydraulic conductivity assures a quick return to field capacity after a rainfall event. Available moisture ranges from 0.07 to 0.10 cm^3/cm^{-3} [9].

Experimental set up

Treatments with six replications were in a RCBD in split-plot arrangement. Carbofuran was main plots and lime as subplots. The groundnut trial in the 1989 rainy seasons was sown on July 4, and harvested on October 2. Millet was sown on January 29, 1990 (dry season 1989–90) as a cover crop and was harvested on May 23, 1990. The 1990 rainy season trial was planted with ground nut on June 18 and harvested on September 29. The dry season trial was sown with groundnut on November 22, 1990 and was harvested on March 25, 1991. Two rates (0 and 10 kg ha^{-1} a.i.) of carbofuran and four rates (0, 5, 10 and 20 t ha^{-1}) of lime were applied 34% Ca and 20% Mg before sowing during the first and second cropping season.

Plot size was 4 × 4 m. Seeds were sown singly at 10 cm intervals within rows and 50 cm between rows. An adapted groundnut cultivar, 55–437, was used in the trials. During the 1989–90 dry season, millet cv. CIVT was used as an irrigated cover crop in order to facilitate the interaction of lime and soil during the dry season. Soil samples were collected from each plot in order to determine the initial pH before treatments were applied. Soil pH and exchangeable aluminum were measured at each sowing one month after sowing and at harvest.

Soil samples were collected from five points in each plot and thoroughly mixed to constitute a plot sample. A soil soil volume of 100 cm^{-3} was used for plant parasitic nematode population counts on a per plot basis. Samples were processed with a decanting and sieving technique (Sharma, unpublished data).

Results

Plant parasitic nematode population

Scutellonema clathricaudatum, *Telotylenchus indicus*, *Xiphinema parasetariae* and *Paralongidorus* sp. were the most important plant parasitic nematodes in soil and roots. During the 1989 rainy season, application of carbofuran significantly ($p = 0.01$) reduced the plant parasitic nematodes (Table 1). Observation showed that variation in crop growth was high in the plots that were not treated with carbofuran. Application of different levels of lime did not affect the nematode population and did not improve crop growth (Table 2). A similar trend was found in subsequent crops (Table 3). In the 1990 rainy seasons trial the average plant parasitic nematode population with carbofuran was 55 on 100 cm^3 of soil and 151 without carbofuran.

Soil pH and exchangeable aluminium

In 1989 the initial exchangeable aluminium was at 0.35 cmol [+] kg^{-1} and did not significantly

Table 1. Effect of application of carbofuran 5G on plant-parasitic nematodes in groundnut in Sadore, Niger, rainy season 1989

Treatment	Sampling time	Nematode populations per 100 cm^{-3} soil				Nematode populations in 1 g root
		SC	XP	TI	Tot	
No carbofuran	At sowing	20.6	33.8	5.0	68.1	
	One month after sowing	4.4	76.3	8.1	105.6	
	At harvest	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	
	One month after sowing	0.6	28.8	0.0	33.8	
	At harvest	6.9	28.1	9.4	49.4	34.7
	F. prob.	0.01	0.01	0.01	0.01	0.05

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

Table 2. Effect of different levels of lime on plant parasitic nematode, Sadore, rainy season 1989

Lime (t ha^{-1})	Nematode populations per 100 cm^{-3} soil			
	SC	XP	TI	Tot
No lime	13.8	40.0	6.7	69.6
5	11.7	36.3	11.3	67.9
10	13.3	37.5	7.1	69.6
20	14.6	46.7	7.1	77.9
F. prob.	NS	NS	NS	NS

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

differ between treatments by harvest, but changes already started to appear by the end of 1989 (Table 4).

When the millet cover crop was harvested (April 1990), pH and Al^{+++} were unchanged in the plots that did not receive lime and some changes started to appear where 10 and 20 t ha^{-1} of dolomite had been applied.

At the time of sowing for the 1990 rainy season pH-KCl was 4.11 in control plots (no lime, with or without carbofuran). With the

Table 3. Effect of lime and carbofuran on nematode populations at ISC, Sadore, rainy season 1990 and dry season 1991[1]

	Lime (t ha^{-1})	1990	1991	
		Nematode populations[2]	Nematode populations	
		harvest	sowing	harvest
With carbofuran	0	21 (1.31)[3]	12 (1.33)	27 (0.93)
	5	55 (1.70)	3(1.20)	17 (0.96)
	10	71 (1.79)	10 (1.27)	24 (1.06)
	20	74 (1.85)	10 (1.31)	24 (1.08)
Without carbofuran	0	172 (2.21)	34 (1.64)	65 (1.49)
	5	139 (2.12)	8 (1.42)	28 (1.34)
	10	154 (2.17)	28 (1.70)	53 (1.30)
	20	139 (2.08)	35 (1.68)	52 (1.46)
SE		±20 (±0.09)	±8 (±0.14)	±12 (±0.08)
CV (%)		47 (11)	91 (23)	80 (16)

[1]Split-plot design with six replications, plot size 16 m^2;
[2]Nematode populations in 100 cm^{-3} of soil;
[3]Figures in parentheses are Log transformed values.

Table 4. Effect of lime and carbofuran on soil pH at ISC, Sadore, rainy season 1989, 1990 and dry season 1991[1]

	lime ($t\ ha^{-1}$)	1989 pH harvest	1989 Al^{+++} harvest	1990 pH sowing	1990 pH harvest	1990 Al^{+++} sowing	1990 Al^{+++} harvest	1991 pH sowing	1991 pH harvest	1991 Al^{+++} sowing	1991 Al^{+++} harvest
With carbofuran	0	4.04	0.34	4.11	4.00	0.31	0.26	4.12	4.34	0.23	0.17
	5	4.03	0.34	4.23	4.25	0.24	0.14	4.60	5.31	0.20	0.03
	10	4.06	0.30	4.32	4.67	0.19	0.08	5.33	5.93	0.00	0.00
	20	4.13	0.28	4.74	5.16	0.08	0.02	5.58	6.05	0.00	0.00
Without carbofuran	0	4.05	0.31	4.11	3.99	0.29	0.25	4.23	4.59	0.16	0.10
	5	4.06	0.29	4.22	4.38	0.26	0.11	4.82	5.67	0.04	0.01
	10	4.12	0.26	4.40	4.82	0.14	0.02	5.53	6.18	0.00	0.00
	20	4.19	0.21	4.82	5.22	0.06	0.01	5.72	6.14	0.00	0.00
SE ±		0.03	0.03	0.10	0.21	0.03	0.02	0.18	0.11	0.05	0.02
CV (%)		2	26	5	6	41	48	9	5	139	131

[1]Split-plot design with six replications, plot size $16\ m^2$.

application of different levels of lime soil, pH in KCl varied between 4.22 and 4.82 (Table 4). The aluminium concentration at the start of the 1990 rainy season was high in the no lime treatment (0.31 cmol [+] kg^{-1} but with increasing lime applications, it became as low as 0.06 (Table 4). There was no effect of carbofuran on either pH or exchangeable aluminium level in the soil.

At harvest (1990) pH-KCl was increased by another 0.40, reaching 5.22 with 20 t ha^{-1} and 4.82 with 10 t ha^{-1}. The exchangeable aluminium was dramatically reduced in both 10 and 20 t ha^{-1} of lime treatments (Table 4). By sowing time of the following dry season (November 1990) pH had continued to increase and reached 5.72 with the application of 20 t ha^{-1} of lime. By the following harvest in March 1991, the pH-KCl was about 6 with lime rates greater than 10 t ha^{-1}. The low rate of 5 t ha^{-1} had also significantly increased the pH level. Exchangeable Al^{+++} was by then almost zero in all the lime applications.

Pod and haulm yields

In 1989 pod and haulm yields were significantly ($p = 0.001$) higher in plots treated with carbofuran (mean pod yield of 2.18 t ha^{-1}) than without carbofuran (1.03 t ha^{-1}) (Table 5). Lime

Table 5. Effect of lime and carbofuran on groundnut yields (t ha^{-1}) at ISC, Sadore, rainy season 1989, 1990 and dry season 1990–1991[1]

Plant part	Lime $t\ ha^{-1}$	1989 +CBF[2]	1989 −CBF	1990 +CBF	1990 −CBF	1990–91 +CBF	1990–91 −CBF	Mean +CBF	Mean −CBF
pod	0	2.12	1.02	1.82	0.88	1.43	0.54	1.79	0.81
	5	2.03	0.95	1.77	1.34	1.40	0.85	1.73	1.05
	10	2.23	1.01	1.75	1.79	1.56	1.03	1.85	1.28
	20	2.35	1.13	1.82	1.88	1.59	1.12	1.92	1.38
	Mean	2.18	1.03	1.79	1.47	1.50	0.89	1.82	1.13
	SE±		0.17		0.16		0.09		
	CV (%)		25		23		19		
Haulm	0	1.80	1.14	1.30	0.93	1.30	1.15	1.47	1.07
	5	1.73	0.95	1.23	1.31	1.84	1.67	1.60	1.31
	10	1.90	1.04	1.44	1.48	2.30	2.80	1.88	1.77
	20	2.01	1.34	1.53	1.56	2.00	2.12	1.85	1.67
	Mean	1.86	1.12	1.38	1.32	1.86	1.94	1.70	1.46
	SE±		0.13		0.12		0.12		
	CV (%)		22		22		26		

[1]Split-plot design with six replications, plot size $16\ m^2$;
[2]CBF = Carbofuran.

application did not increase pod yield. The interaction between lime and carbofuran was not statistically significant.

In 1990 there was no significant differences in pod and haulm yields between lime treatments when carbofuran was applied. Without carbofuran, however, lime had a significant effect on yield (Table 5). The application of 5 t ha^{-1} and above increased haulm yields of groundnut to the same level as was achieved by the carbofuran treatment. The same effect for pods were found only at 10 t ha^{-1} lime and above. In general the same trend was observed for pod yield in 1990–1991. A combination of lime and carbofuran tended to give high haulm yield (Table 5).

Discussion

Application of a high dose of carbofuran reduced plant parasitic nematode populations in the soil and improved yield of groundnut. In a pot experiment, Germani [7, 10] reported an increase in shoot and root weight of groundnut in sterilized soil by the application of carbofuran (Sharma *et al.*, 1990). Similarly, growth stimulation of groundnut by the application of DBCP in different soils in Senegal [4].

The primary effects of lime on groundnut are the increase of available soil Ca in the pegging zone [14] and the reduction of Al toxicity, which is a major factor of infertility in acid soils. In our trials, liming increased soil pH and significantly reduced exchangeable Al concentration. The non-response to liming in the first cropping season was probably due to the low reactivity of the liming material and the low rainfall. Depending on the fineness and pulverization of the liming material and the method of application, reactivity takes between two and three years [2]. Dolomite is known to dissolve more slowly than other liming agents. Major shifts in soil pH result in significant changes in the availability of inorganic plant nutrients (such as phosphorus). Low soil pH results in the formation of insoluble Al and Fe phosphates [1]. The increased availability of inorganic plant nutrients could have contributed to the increase in pod and haulm yields. In the present investigations, a change in pH due to liming may have resulted in increased availability of molybdenum [15], which plays a vital role in symbiotic dinitrogen fixation by groundnut. Hafner *et al.* [8] reported a high response of groundnut to molybdenum application in the sandy soils of the Sahel. The low buffering capacity of these soils suggests that the lime needed to change the soil pH should be more carefully determined in order to avoid overliming which induces copper and zinc deficiencies [3, 6], as indicated by the depressed yields at 20 t ha^{-1} of lime during the last crop (dry season 1991).

The absence of a significant interaction between lime and carbofuran is of particular interest. In the present experiments nutrient uptake was not measured, but there is evidence that lime affects the availability of Ca and other plant inorganic nutrients whereas carbofuran mainly affects the nematodes and other soil pests [4]. It is possible that the control of nematodes could have resulted in normal root development and thus improved water and nutrient uptake. Additionally, carbofuran may have other growth regulating effects not related to nutrient uptake.

The dynamics of nematode behavior in their response to various stimuli under field conditions have been investigated in the Sahel. The lack of lime response on nematode distribution and population suggests that pH may not be a factor that influences their distribution.

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