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Soil Pests of Groundnut in West Africa—Species Diversity, Damage and Estimation of Yield Losses

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Abstract—Among the major arthropods in soil and plant samples taken from groundnut farms during the 1996 cropping season in Mali, Burkina-Faso, Niger, and Nigeria, termites in the genus *Microtermes* (Isoptera: Termitidae) were the most abundant and widely distributed species of economic importance. None of the termite species identified on trees in the surveyed farms attacked groundnuts. At plant maturity, termites were less frequently observed in soils taken from bare ground but were predominantly found on plants. Residues of previous cereal crops in the fields contributed to termite spread. Most of the whitegrub (Coleoptera: Scarabaeidae) and millipede (Myriapoda: Odontopygidae) species identified belonged to the genera of *Schyzonycha* and *Peridontopyge* respectively. There was a general decrease in both their population densities and the percentages of farms they infested at plant maturity compared to the early stages of the crop. Mean percentages of plants attacked by termites, whitegrubs and millipedes in the surveyed groundnut fields were 39.4, 10.9, and 9.3% respectively. Yield loss due to termites, which predominantly damaged harvested kernels, was estimated at 9.6–30.4%, and was significantly correlated with percentage of plants damaged by termites (r^2 = 0 73).

Key Words: *Arachis hypogaea*, groundnut soil pests, termites, West Africa

Résumé—Les échantillons de sols et de plantes pris dans les champs d'arachide pendant la campagne de 1996 au Mali, Burkina-Faso, Niger et Nigeria ont montré que parmi les groupes d'arthropodes nuisibles du sol d'importance économique, des espèces de termites *Microtermes* étaient les plus abondantes et largement distribuées. Aucune des espèces de termites identifiées sur les arbres échantillonnés n'avaient attaqué les arachides. Pendant la maturation des plantes, les termites ont été fréquemment moins observés dans les échantillons du sol prélevés, mais ils prédominaient dans les échantillons de plantes. Les résidus des cultures de céréales ont contibué à la propagation des termites. La plupart des espèces de vers blancs (Coléoptère: Scarabaeidae) et de mille-pattes (Myriapode: Odontopygidae) identifiées font partie des genres *Schyzonycha* et *Peridontopyge*, respectivement. Il y avait généralement une baisse des populations de ces espèces de vers blancs et mille-pattes, et le pourcentage de champs infestés pendant la maturité des plantes par rapport à 25–45 jours après les semis. Les pourcentages moyens de plantes attaquées par les termites, les vers blancs et les mille-pattes étaient de 39,4, 10,9, et 9,3% respectivement. Les pertes de rendements occasionnées aux gousses par les termites qui sont principalement responsables des dégâts sur les graines sont estimées à 9,6–30,4%, sont significativement corrélées au pourcentage de plantes endommagées par les termites (r^2 = 0,73).

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Introduction

Groundnut, *Arachis hypogaea* L., is a major cash crop and a source of protein for many households in the semi-arid tropics of West and Central Africa (WCA). Unfortunately, its premier position as one of the major export commodities in the sub-region has been reduced by unstable agricultural policies, drought, pests, diseases, and improper application of some cultural practices by farmers (Dicko and Lynch, 1995).

The economic importance of soil pests such as termites, whitegrubs (Coleoptera: Scarabaeidae) and millipedes (Myriapoda: Odontopygidae) in groundnut production is well documented (Johnson et al., 1981; Masses, 1981; Lynch et al., 1986). The additive effect of damage by soil pests to that due to diseases can result in significant yield loss of groundnuts. Under uncontrolled conditions, yield losses of up to 40% due to termite damage alone have been recorded (Johnson et al., 1981).

The most important group of termites associated with groundnuts are fungus growers of the sub-family Macrotermitinae, notably *Microtermes* and *Odontotermes* species. Whitegrubs damage groundnut roots and pods, thereby lowering the quality and quantity of harvested kernels (Wightman and Wightman, 1994). Millipedes usually damage germinating plants or soft developing pods, causing severe stand losses in some parts of WCA, especially at the early stage of groundnut growth. Masses (1981) reported a 20% reduction in plant density and 30–40% reduction in yields due to millipede damage in Senegal. Damage by soil pests was found to be associated with infection by various fungus species including *Aspergillus* spp. noted for the production of carcinogenic aflatoxins (Mercer, 1978; Johnson and Gumel, 1981; Waliyar et al., 1994 ; Wightman and Wightman, 1994).

Previous studies on soil pests of groundnut in West Africa centred on specific pest groups, and were concerned with individual countries. The present study cuts across the greater portion of the West African groundnut belt, and seeks to identify the major soil pests of groundnuts, their relative importance, factors affecting their abundance, level of damage and yield losses in the sub-region. The information thus obtained will be used in planning effective soil pest control measures for the sub-region. Surveys of 70 groundnut farms were undertaken in the 1996 cropping season along the groundnut belts of Mali, Burkina-Faso, Niger, and Nigeria (Fig. 1) which lie between latitudes 10° and 13° 30′, with annual rainfall of 600–1100 mm.

Materials and Methods

Soil and plant sampling

In each selected area, the 70 smallholder groundnut farms were sampled (at least 2 km apart) 25–45 days after planting (DAP) from late June to early August 1996, and again at maturity from late September to early November to assess yield losses.

In each of the small (less than 2500 m^2 area) farms, 40 core soil samples of 7 cm diameter and 30 cm depth were taken with an Edelman auger, while in farms 2500 m^2 or bigger, 60 were taken. To isolate soil pests, the soil samples were passed through a 40 x 40 cm locally made sieve of 1.5 mm mesh into a plastic container, then the sieved soil sorted manually for any remaining soil arthropods which may have passed through the mesh. All retrieved soil pests were then counted and representative samples were stored in 70% alcohol for further identification in the laboratory. Core soil samples taken from each field were mixed and a representative sample taken from the mixture to analyse for sand, silt, clay, and organic matter content, and pH level. The soils were classified using the textural triangle of Brady (1984).

Termite mounds, where present, were opened using a cutlass or hoe and termites species within them were identified. Observation on damage by soil pests was made on a plant close to where each soil sample was taken. Therefore, the same number of soil and plant samples were taken in each farm. Damaged plants were uprooted in order to observe the extent of damage and its possible causes. Yield losses were estimated by using the methods of Johnson et al. (1981).

Effects of arboreal termites, levels of plant residues, weeds, and annual rainfall on damage to groundnuts

Termite species found on the trees present in sampled farms were identified and compared with those damaging groundnuts in order to establish if there was any relationship between them. The levels of plant residues and weeds were rated in terms of percentage of sampled plants surrounded by residues or weeds as follows: 0%=

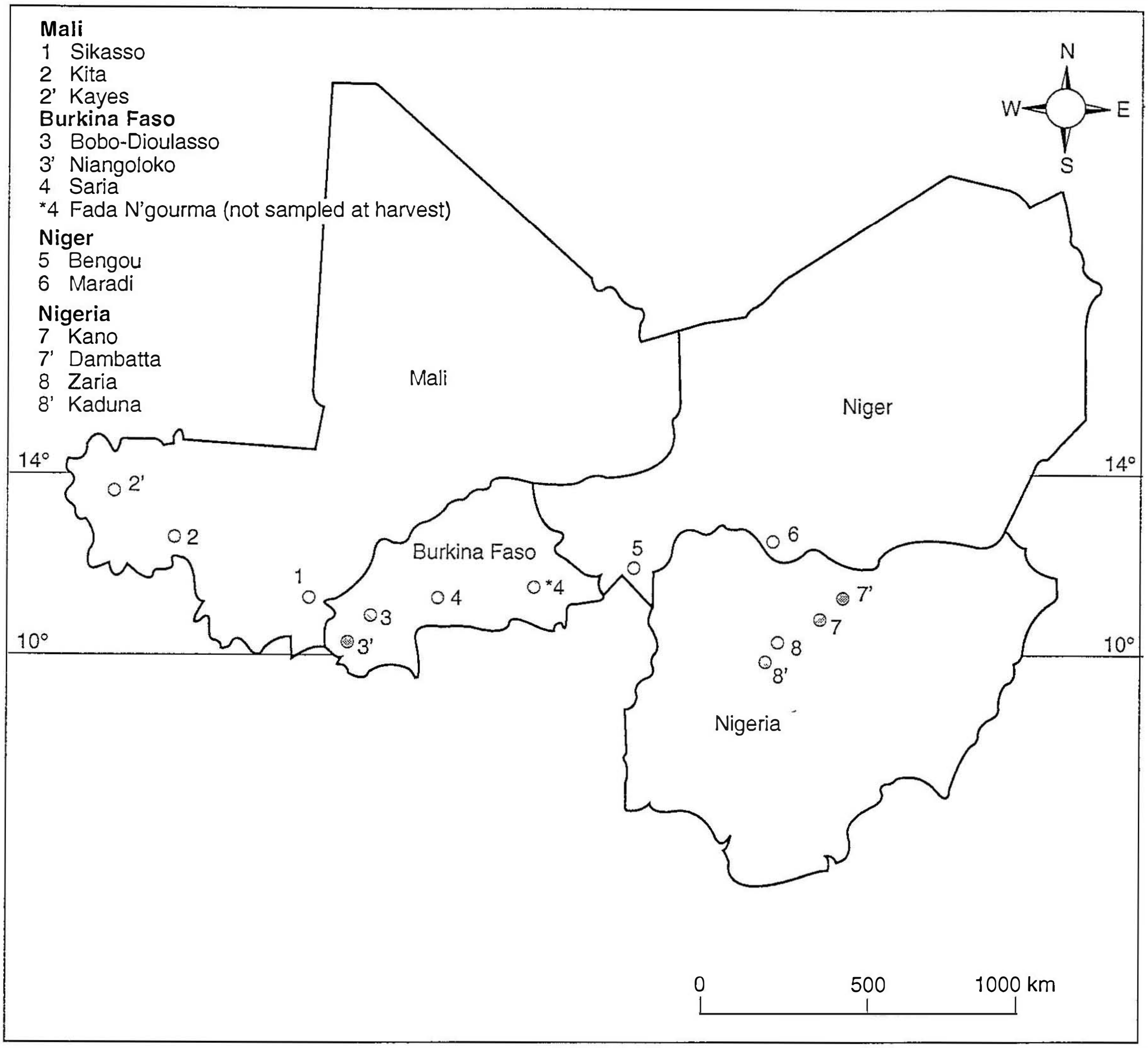

Fig. 1. Localities in four countries in West Africa surveyed for termites on groundnut

0 (none); 1–5%= 1 (very low); 6–15% = 2 (low); 16–25% = 3 (Fairly high); 26–35% = 4 (high); 36–45% = 5 (very high). Farms overgrown with weeds were not sampled.

The influence of rainfall on soil pest abundance was evaluated using mean annual rainfall values derived from an established rainfall map for the sub-region (l'Hôte and Mahé, 1996) compiled with data collected between 1951–1989.

Statistical analysis

The levels of weed and of plant residues were grouped and rated. These were subjected to simple regression analyses in relation to termite frequency of occurrence in the soils. Simple and multiple regression analyses were computed for other factors associated with termite abundance. Data on percentage of plants attacked by termite were transformed for the regression analysis. T-test analyses were also computed for soil pest population densities at 25–45 DAP and at harvest using transformed data. All data were analysed using the SAS statistical analysis program (SAS Inc., 1985).

Results

Diversity of soil-borne arthropods and in relation to soil textures

Several soil arthropods belonging to 3 families were identified across the groundnut belts (Table 1) out of which the termites (Isoptera: Termitidae), whitegrubs (Coleoptera: Scarabaeidae) and millipedes (Diplopoda: Odontopygidae) were

Table 1. Incidence and diversity of soil pests in soil of groundnut farms in Mali, Burkina-Faso, Niger and Nigeria

Soil pests observed on groundnut	Localities	Soil texture of infested farms
Isoptera		
Microtermes lepidus Sjostedt	1, 2, 3, 4, 5, 6, 7	S, LS, SL, SCL
M. parvulus Sjostedt	1, 4, 7, 8	S, LS, SL, SCL
Microtermes sp.	6	S, LS, SL, SCL
Odontotermes smeathmani Sjostedt	8	LS, SL, SCL
Odontotermes sp.	1, 6	LS, SL, SCL
Pseucanthotermes militaris Hagen	1	LS
Pericapritermes sp.	1	LS
Macrotermes subhyalinus Rambur	1, 2, 7	LS, SL, SCL
Trinervitermes sp.	1	LS
Coleoptera+		
Scarabaeidae		
Schyzonicha africana Lap.	1, 2, 5, 6, 7, 8	S, LS, SL
Heteronychus sp. (larva and adult)	6	S, LS, SL
Anomala sp.	2	LS
Trochalus sp.	3	S
Elateridae		
Cardiophorus sp.		
Unidentified larva	1, 6	LS, LS
Zophosis sp. (adult)		
Unidentified larva	1, 5, 6, 7, 8	S, LS, SL. SLC
Carabidae		
Clivina sp. (adult)	7	S
Curculionidae		
Anaemerus sp.	6	S
Myriapoda		
Odontopygidae		
Peridontopyge spinossima Silvestri	1, 2, 3, 7, 8	S, LS, SL, SCL
Peridontopyge sp. 1	1, 3, 4, 6, 8	S, LS, SL, SCL
Peridontopyge sp. 2	3, 4, 6	S, LS, SL, SCL

+Larva stages unless otherwise stated.
S, Sandy; LS, Loamy sand; SL, Sandy loam; SCL, Sandy clay loam.
1, Sikasso; 2, Kita/Kayes; 3, Bobo-Dioulasso/Niangoloko; 4, Saria; 5, Bengou; 6, Maradi; 7, Kano/Dambatta; 8, Zaria/Kaduna.

classified as being economically important. Some species were limited to only a few of the localities while others were widely distributed across the region. The latter category included termite species such as *Microtermes lepidus* Sjöstedt, *Microtermes parvulus* Sjöstedt, and to a lesser extent *Odontotermes* spp. and *Macrotermes subhyalinus* Rambur. Widely distributed coleopteran and myriapod species were *Schyzonycha africana* Lap. and *Peridontopyge* spp. All millipede species belonged to the same family, although some could not be named. The incidence of wireworms (Coleoptera: Elateridae) and false wireworms (Coleoptera: Tenebrionidae) was almost negligible.

Soils in groundnut farms were predominantly of sandy (52%) or loamy sand (32%) in texture. Sandy loam and sandy clay loam soils were only observed in 16% of the farms. The predominant *Microtermes* spp. were identified in all soil types in the localities studied (Table 1).

In 85% of the farms infested by whitegrubs, the soils were of sandy and loamy sand texture. Very few grubs were observed in soils with sandy clay loam texture. There was a negative correlation ($r^2 = 0.43$; $P < 0.03$; n = 10) between the percentage of clay in a farm (x_1) and the occurrence of whitegrubs in it (y_1). The latter was predicted by the model $y_1 = 5.401 – 0.218x_1$. However, correlation analysis between whitegrub population density and the percentage of clay was low and non-significant. Neither millipede population density nor its frequency of occurrence bore any relationship with the soil texture of the surveyed farms. Organic carbon content of sampled fields, which ranged between 0.10 and 0.88%, did not

Table 2. Population densities of termites#, white grubs and millipedes from soil samples in groundnut farms in localities of Mali, Burkina-Faso, Niger and Nigeria

Localities	Mean population density of soil pests (no./m²)						Annual rainfall (mm)
	Termites		Whitegrubs		Millipedes		
	25–45 DAP	Harvest	25–45 DAP	Harvest	25–45 DAP	Harvest	
Sikasso+	183 ± 45[a]	170 ± 35[b]	0.6 ± 0.3	0.6 ± 0.2	0.4 ± 0.1	2.2 ± 0.5	1100
Kita/Kayes+	75 ± 13[c]	2.1 ± 0.4	7.3 ± 2.8	0	7.2 ± 2.1	0	900
Bobo-Dioulasso/ Niangoloko+	15 ± 6	15 ± 6	2.1 ± 0.5	1.6 ± 0.8	3.9 ± 1	2.9 ± 1.2	1100
Saria++	0	49 ± 4.7	0	0	2.6 ± 0.4	0.2 ± 0.1	700
Bengou++	0	146 ± 34	1.6 ± 0.2	0.8 ± 0.1	7.6 ± 1.4	0.6 ± 0.1	800
Maradi+	123 ± 39	18 ± 5	2.5 ± 0.6	1.8 ± 0.4	0.9 ± 0.3	0.7 ± 0.3	600
Kano/Dambatta+	4 ± 1.2	5 ± 2	0.6 ± 0.2	0.2 ± 0.1	2.4 ± 0.7	0.6 ± 0.2	800
Zaria/Kaduna+	189 ± 90[d]	4 ± 1.2	5.2 ± 1.7	0	10.3 ± 2.8	0.8 ± 0.3	1100

+10 farms sampled; ++ 5 farms sampled.
#Unless otherwise stated termite population density refers to *Microtermes* spp.
[a]*Odontotermes* constituted 2% of population; [b]*Macrotermes* constituted 9.6% of population;
[c]*Odontotermes* constituted 15% of population; [d]*Macrotermes* constituted 16% of population.

play any significant role in soil arthropod distribution. The pH of the classified soils varied between 4.9 and 7.4, with 87% of the soil samples being acidic (mean pH of 5.9). No relationship of pH with the frequency of occurrence or population density of the observed soil arthropods was found.

Table 3. Incidence of soil pests, associated damage and yield losses of groundnuts in localities of Mali, Burkina-Faso, Niger and Nigeria

	Number of farms infested by soil pests (observed from soil and plant samples)			Number of farms with infested soils and mean % attacked plants at 25–45 DAP			Number of farms with infested soils and mean % attacked plants at plant maturity			Mean (%) yield loss
	T	W	M	T	W	M	T	W	M	
Sikasso +	8	2	6	4 (10)#	1 (0.5)	0 (0)	8 (12.5)	2 (2)	6 (13)	13.80
Kita/Kayes+	7	5	7	5 (3.1)	5 (6.8)	7 (4.2)	2 (39.4)	0 (0)	0 (0)	30.40
Bobo-Dioulasso/ Niangoloko+	6	2	4	3 (1.3)	1 (1.2)	3 (2.5)	3 (12)	2 (0)	1 (06)	9.6
Saria++	3	0	1	2 (0)	0 (0)	1 (1.5)	2 (13)	0 (0)	0 (0)	18.50
Bengou++	3	2	3	0 (0)	2 (0)	3 (9.3)	3 (11)	1 (11)	1 (1.5)	22.80
Maradi+	8	7	3	6 (2.7)	3 (1)	3 (1.5)	3 (14)	5 (0.5)	2 (0.4)	21.10
Kano/ Dambatta+	4	2	2	2 (6)	2 (0)	1 (2.6)	2 (20.3)	1 (0.6)	1 (0.4)	16.90
Zaria/ Kaduna+	5	4	7	3 (1.9)	4 (1.4)	5 (3.7)	5 (6.4)	2 (1.3)	2 (9)	10.0

+10 farms sampled; ++5 farms sampled.
T = termites, W = whitegrubs, M = millipedes.
#Mean % attacked plants.

Soil arthropod distribution and annual rainfall

In all localities, at least 40% of the sampled farms were infested with termites, while at least 30 and 40% respectively were infested with whitegrubs and millipedes. At crop maturity, termites, whitegrubs and millipedes were present in soil samples in less than 28% of the farms. The population density of termites observed in soil samples decreased towards the end of the season (Table 2) except in Saria and Bengou areas where the early-maturing varieties planted there matured before the end of the rainy season. Similarly, whitegrub and millipede population densities decreased at plant maturity except in Sikasso and Saria areas where early-maturing varieties were cultivated. Frequencies of occurrence of soil arthropods in soil samples generally decreased at groundnut maturity except in Sikasso and Bobo Dioulasso (Table 2; Figs. 2a, 2b and 2c).

During the later part of the cropping season, localities with ≤ 900 mm annual rainfall had more termites on plants than in the soils (Tables 2 and 3). In Maradi, with 600 mm mean annual rainfall for example, the mean population densities of termites in soils at early and mature stages of

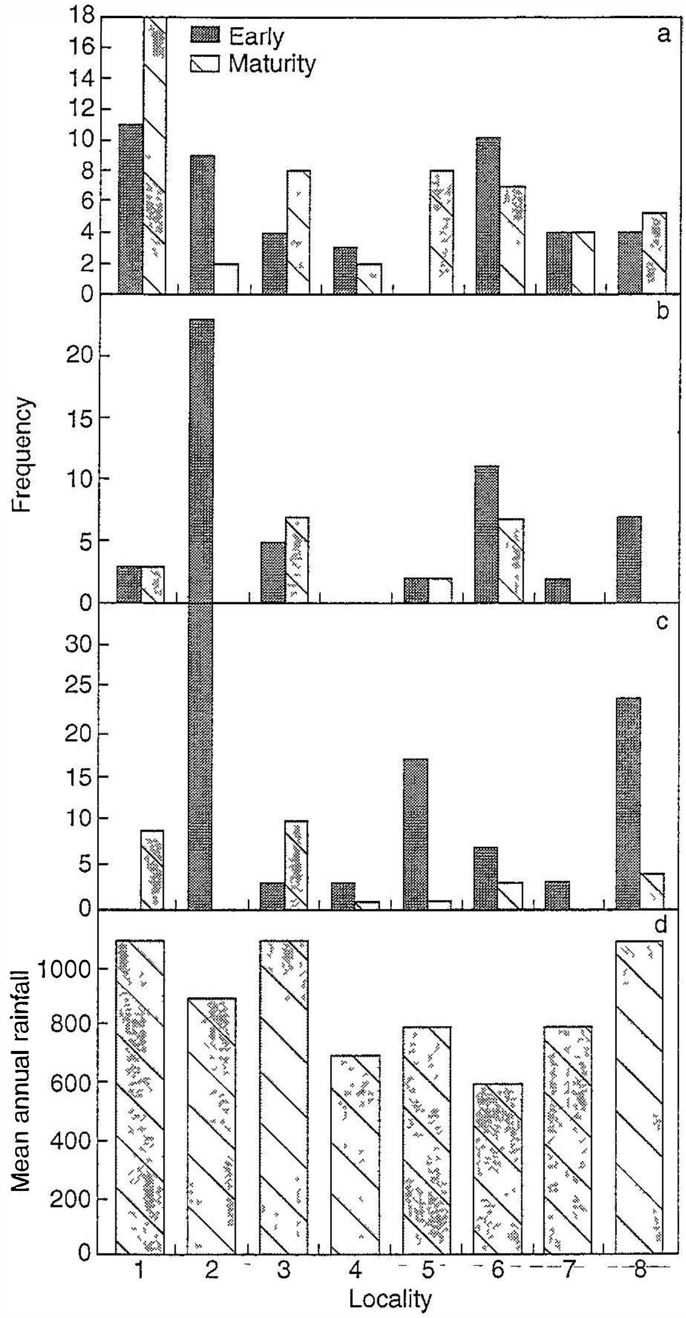

Fig. 2. Relationships between mean annual rainfall and frequencies of occurrence of (a) termites, (b) whitegrubs, and (c) millipedes in groundnut farms in some West African localities: 1, Sikasso (Mali); 2, Kita/Kayes (Mali); 3, Bobo-Dioulasso/Niangoloko (Burkina-Faso); 4, Saria (Burkina-Faso); 5, Bengou (Niger); 6, Maradi (Niger); 7, Kano/Dambatta (Nigeria); 8, Kaduna/Zaria (Nigeria)

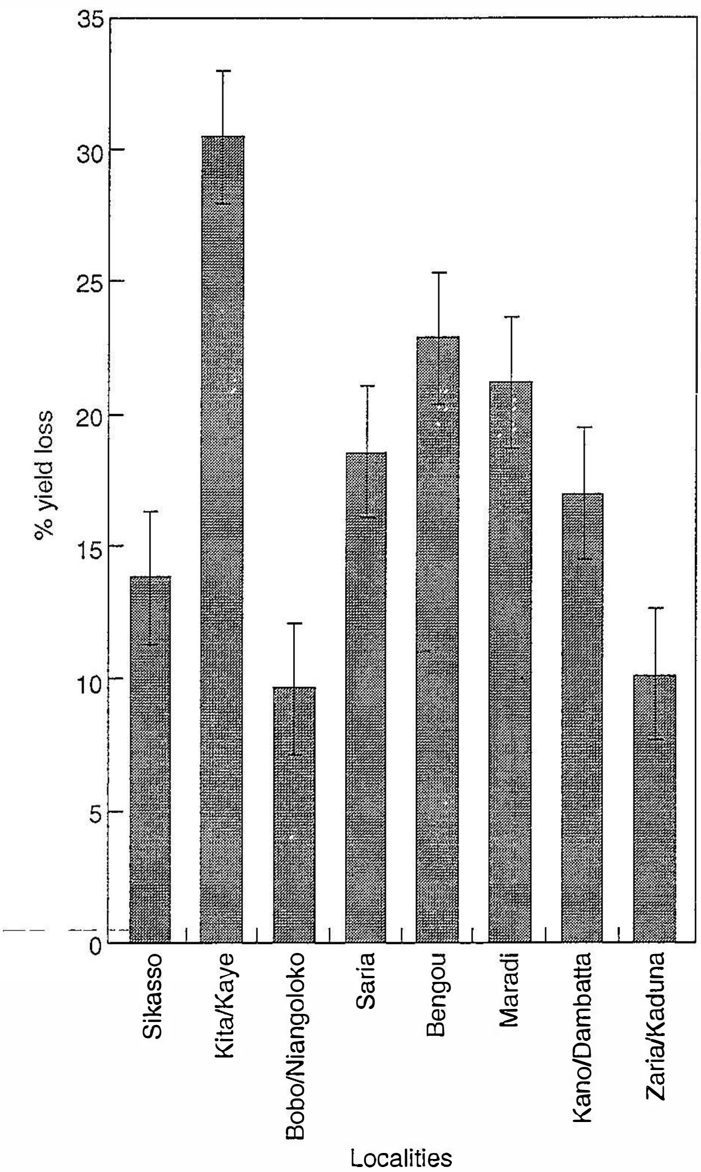

Fig. 3. Groundnut yield losses due to soil pest damage in West Africa

groundnut were 123/m^2 and 18/m^2 respectively, while the percentage of attacked plants increased from 2.7% at the early stage of the crop to 14% at harvest. However, regression coefficients of the population density and frequency of occurrence of termites, whitegrubs, and millipedes against the annual rainfall levels were not significantly different ($P < 0.05$). T-test analysis of the mean population densities of the soil pests in the soil samples at 25–45 DAP and at harvest showed no significant difference in the termite population densities. There were significant differences between 25–45 DAP and harvest population densities of whitegrubs ($t = 2.12$; $n = 8$; $P < 0.05$) and millipedes ($t = 2.72$; $n = 8$; $P < 0.01$).

Influence of crop residue and weed levels on termite spread

The distribution of *Microtermes* species in groundnut farms was influenced by residues of previous cereal crops such as sorghum, maize and millet. At 25–45 DAP, 68% of the farms in which the level of cereal residues were rated as 'high' and 100% of those in which residues were rated as 'very high' were infested with *Microtermes* species. There was a positive correlation ($r^2 = 0.227$; $P < 0.01$; $n = 28$) between the frequency of termite occurrence (y_2) and the level of residues (x_2) as predicted by the model $y_2 = 0.9448 + 0.847x_2$. However, the correlation between population densities and levels of residue was very low ($r = 0.38$). No relationship was observed between the frequency of termite occurrence or its population density and the levels of weeds.

Groundnut damage by soil pests

Termite damage was most severe at plant maturity (Table 3). The varieties attacked—mostly local varieties—varied considerably within a locality and across the sub-region. The damaging termites in order of decreasing importance were *Microtermes*, *Odontotermes*, and *Macrotermes* species. The percentage of plants attacked had a low positive correlation ($r = 0.35$; $P < 0.05$; $n = 25$) with the *Microtermes* population density in soil samples at 25–45 DAP. At plant maturity, no such correlation was observed. The mean percentage of attacked plants was up to 39.4% in the Kita localities where 90% plant attack was observed in a farm.

Termite were found in various species of *Acacia* and the Shea tree, *Butyrospermum parkii* (G. Don) Kotschy. The termites *Nasutitermes* and *Coptotermes* spp. which occurred on these trees were not associated with groundnut damage.

Active termite mounds were rarely observed in the sampled cultivated farms. Only 1 or 2 mounds per farm were seen on 2 farms at Kita and 3 at Sikasso. *Macrotermes subhyalinus* Rambur colonies damaged groundnuts located at radii not exceeding 6 m from their mounds.

Eleven percent of the sampled plants were attacked by whitegrubs. The percentages of plants attacked at 25–45 DAP (y_3) and at plant maturity (y_1) were positively correlated with the population densities of whitegrub (x_3 and x_4) in soils at the two respective periods [($r^2 = 0.43$; n=18 P<0.01)and ($r^2 = 0.72$; n =13; $P < 0.01$;)], and were predicted by the models $y_3 = 0.141 + 0.745x_3$ and $y_4 = 0.037 + 0.71x_4$. The percentages of attacked plants were also positively correlated with the frequencies of whitegrub occurrence at 25–45 DAP ($r^2 = 0.35$; $P < 0.05$; n =18) and at maturity ($r^2 = 0.59$; $P < 0.01$; n = 13). Multiple regression analysis of the percentage of plants attacked by whitegrub at 25–45 DAP versus whitegrub population density and mean annual rainfall showed that the increase of $r^2 = 0.43$ (for the population density alone) to $R^2 = 0.46$ (population density and rainfall) was not significant ($P > 0.05$).

There was a decrease in millipede attack at plant maturity in all localities, with the exception of Sikasso area where groundnuts matured well before the end of the rains (Table 3). The maximum mean plants attacked by millipedes per farm was 9.3% at plant maturity.

Millipede population densities and their frequencies of occurrence were positively correlated with the percentages of attacked plants both at 25–45 DAP ($r^2 = 46$ and $r^2 = 42$ respectively; $P < 0.05$; n = 20) and at plant maturity ($r^2 = 0.81$ and $r^2 = 0.78$ respectively; $P < 0.001$; n = 13). Millipede population densities x_5 and x_6 predicted attacks y_5 and y_6 as follows: $y_5 = 1.82 + 0.37Xx$ and $y_6 = 1.051 + 0.36x_5$ at 25–45 DAP and at maturity respectively. In Fada N'gourma area the mean percentage of attacked plants at 25 DAP by the soil pests was 15%. This area was not visited at harvest, hence, no data on damage at maturity was obtained.

Estimation of yield losses

Damage of pods at plant maturity was predominantly caused by termites. Pod damage by whitegrubs and millipedes was low and accounted for less than 5% of the damage where observed. Summing up the mean percentages of plants attacked in each locality by the three major groups of soil pests (Table 3), a maximum of 39% of attacked plants was observed. However, it became obvious during yield loss assessment that some soft pods damaged by millipedes were decaying, indicating that pods attacked earlier could have decayed long before harvest. Losses such as these did not allow for the computation of all yield losses.

Yield losses of groundnut kernels from plants attacked by termites, the major damage-causing group, ranged between 21.1% and 38%. Mean percentage yield losses exceeding 20% (Table 3) were recorded in farms in the localities of Kita/ Kayes (Mali), Bengou and Maradi in Niger (Fig. 3). A significant positive correlation ($r^2 = 0.731$; $P < 0.001$; n = 25) existed between the percentage of sampled plants attacked by termites (x_7) and the yield loss (y_7), and the latter was predicted by the model $y_7 = 9.907 + 0.698x_7$.

Discussion

Termites were the major soil-borne arthropods in the surveyed areas, followed by whitegrubs and millipedes. Sandy and loamy sand soils favourable for groundnut production were preferred over the other types by three major groups of soil arthropods. Whereas termites and millipedes were present in all soil types, whitegrubs on the other hand were rarely observed in soils with a high proportion of clay as shown by regression analysis. This was probably due to the compact nature of clayey soils which may deter easy penetration by the relatively soft bodies of whitegrubs.

During the later part of the cropping season, localities with 900 mm annual rainfall or less had more termites on groundnut plants than in the surrounding soils, possibly because termites left the bare soils, to obtain food and moisture directly from the plants. This may explain the high termite damage on plants usually associated with dry periods and regions. Johnson et al. (1981) similarly reported that termite invasion of taproots was particularly severe with the onset of the dry season. In high rainfall areas, a period of drought may also result in serious termite damage (such erratic rainfall patterns are characteristic of tropical West Africa). In the present study, this may have contributed to the non-significant correlation between termite attack and the mean annual rainfall. However, in areas where annual rainfall was ≤ 900 mm, there was an earlier onset of dry season and associated reflected by the high yield losses due to the termites.

The low occurrence of whitegrubs observed at plant maturity may mean that the dry soil topsoils (up to 30 cm) at the end of the cropping season could not support their presence in soils and the grubs may have migrated to deeper; more moist sub-soils. Wightman and Wightman (1994) reported the occurrence of high whitegrub densities in areas of high annual rainfall (> 1000 mm per year). Demange (1975) reported the incidence of vertical migration associated with declining levels of moisture in various soil strata and reported 30–60 cm depths as being most commonly occupied by millipedes at the beginning of the dry season. Rossion (1976) also noted among other factors that millipedes aestivate in microhabitats in which sufficient moisture is available, such as cavities of abandoned termite mounds, and in roots of trees and shrubs.

Abundance of previous-season cereal residues contributed to the high frequency of occurrence of *Microtermes* spp. in the farms, since the identified species were mostly plant litter feeders which thrive on these residues. Maize, for example, has been identified as one of the crops preferred by *Microtermes* (Wood et al., 1980; Umeh and Ivbijaro, 1997). A higher positive relationship was obtained when correlating termite frequencies of occurrence instead of population densities with residue levels. This may be due to termite aggregation or their foraging behaviour of taking food away from the sources (sampled areas). Therefore the number of points with termite presence was frequently observed in relation with residues distribution in fields than their population. The removal or partial burning of the residues is likely to reduce population carry-over. The contribution of crop residues to termite damage has been documented by Sands, (1977), Srivastava and Butani (1987), Umeh (1995), and Umeh and Ivbijaro (1997).

A very low positive correlation existed between termite population density in the soil and the percentage of attacked plants 25–45 DAP. This correlation disappeared at plant maturity. This was attributed to the concentration of termites in mature groundnut pods and roots rather than in the dry soils.

Despite lower attack of groundnut by whitegrubs compared to termites, strong positive relationships were calculated between the population densities and frequencies of occurrence of whitegrubs and the percentage of attacked plants. The feeding of whitegrubs on roots close to their temporary nests increases the chances of encountering the grubs in soil samples and the corresponding damaged plants. Termites, on the other hand, may forage for food far from their nests. The observed trend of millipede attack was similar to that of Demange (1975), where it was reported that food materials with less than 40% moisture are not preferred by millipedes; hardened pods with less moisture were less attacked than germinating seeds or developing pods. The significantly high positive relationships between millipede populations and the percentage of attacked plants indicated that the millipedes were likely to be present in the vicinity of the plants they damaged and thus were positively scored (in soil samples) simultaneously with the plants they attacked. This might be connected with the more favourable micro-climate existing in the vicinity of the plants than in bare soils elsewhere in the farm.

Termites of the genera *Nasutitermes* and *Coptotermes* identified on trees were not associated with groundnut damage and therefore may not have been a cause for concern for groundnut farmers. However, they are known to pose considerable problems to the production of economic trees (Harris, 1971; Lee and Wood, 1971), and therefore should be controlled. Damage by the epigeous *Macrotermes subhyalinus* was localised within a few metres of their mounds, and can thus be controlled physically by mound destruction and removal of the queen termites (Darlington, 1985).

Groundnut damage by soil pests and the pest species involved varied from one locality to another. Areas of Kita/Kayes (Mali), and Bengou and Maradi (Niger) recorded higher attack by termites, whitegrubs and millipedes than any other area. However, the results showed that pod yield losses were mostly caused by termites.

The results establishes the relative importance of termites, whitegrubs, and millipedes as major biotic constraints in the groundnut belts of Mali, Burkina-Faso, Niger and Nigeria. Although the importance of each group varied from one location to another, pod yield losses during harvest were predominantly caused by termites in all locations. Cereal residues usually left on the soil by the farmers contributed significantly to termite spread within such farms. Increased termite damage may also have been influenced by early onset of the dry season associated with low annual rainfall areas. Comparatively lower percentages of attacked plants were observed in the high rainfall areas of Sikasso, Bobo-Dioulasso/Niangoloko and Zaria/Kaduna, although these were not significantly different. Soils with low clay contents were observed to be most preferred by whitegrubs compared to termites and millipedes, which colonised all soils types. The present study also showed that all the three major groups of pests should be taken into consideration in designing control measures for groundnut soil pests.

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