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Full Length Research Paper

Chemical Properties of Soils from Mounds of *Macrotermes bellicosus* [Isoptera: Termitidae] in Sokoto, Semi-arid Zone

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Chemical properties of soils in and adjacent to the mounds of *Macrotermes bellicosus* were studied. Four Local Government Areas in Sokoto State namely; Shagari, Wamakko, Wurno and Yabo were selected for the study. Soil samples from eight medium-sized (1.50- 2.49 m in height) mounds in Fadama and Upland areas of each Local Government Area were collected and analysed for their chemical properties using standard procedures. Nine soil samples each weighing 200 g were collected from different parts of the mounds and their surroundings. Soil pH, electrical conductivity, organic carbon and organic matter contents were determined using the Walkley-Black Method, cation exchange capacity was determined by exchange with hexamine cobalt (III) cation at neutral soil pH 7, available phosphorus in the soils was determined using Bray No. 1 Method, amount of K and Na in the soils was determined using the flame photometer method, Ca and Mg were determined using atomic absorbance spectrometry (AAS) and percentage nitrogen in the soil was determined using the Kjeldahl method. The results showed that the soil pH was between 6.7 and 7.1 while the electrical conductivity has the highest mean of 266 µS/cmand the least was 23 µS/cm. The lowest organic matter and nitrogen content (105) was recorded at upland in Wurno while the highest (2.31) was at fadama land in Yabo. Higher phosphorous (1.54mg/kg) was observed in soils from fadama land in Wurno. The CEC value was highest at Wurno Fadama land with 12.62cmol/kg. Magnesium was the highest exchangeable bases recorded while calcium was the lowest. Soils from the mounds were observed to have little variation in their chemical properties with the surrounding environment. However, the chemical properties showed that the soils were fertile.

Keywords: *Macrotermes bellicosus*, mounds, soil, chemical properties

INTRODUCTION

Macrotermes bellicosus was reported as the most common mound- building termite in Sokoto State (Bandiya *et al.,* 2016). These termites build their mounds using different materials depending on the feeding habits and the availability of the material in the environment (Fall *et al.,* 2001). Jouquet *et al.* (2007) reported that plant remains, saliva and excreta are all incorporated in the construction of the mound and they added that particles extracted from the soil are the most frequently used, particularly, particles from the immediate vicinity. Soil particles used for construction are carried by the termites in their mandibles and re-distributed with little or no change in their composition (Lee and Wood, 1971).

Mound building activity of termites inevitably influence soil functions and processes and preserves soil and ecosystem diversity (Obi and Ogunkun, 2009; Abe and Wakatsuki, 2010). The termites also mix soil matter, thereby increasing their fertility (Umeh *et al*., 1999; Jouquet *et al*., 2007), they play a central role in nutrient fluxes (Lawton *et al*., 1996; Bignell *et al*., 1997; Eggleton *et al*., 1999), their activities such as mound-building, subterranean tunnelling as well as soil-feeding improves soil structure and quality (Holt and Lapage, 2000; Donovan *et al*., 2001; Fall *et al*., 2001; Jouquet *et al*., 2004). Termites are also important in habitat creation; nutrient cycling and they form a pivot upon which other components in the ecosystem depend (Meyer *et al*., 1999).

Termites have long been recognized as both domestic and agricultural pests (Logan *et al*., 1990).

The most significant effect of termites on man is the damage done to timber used in buildings and for other purposes (Lee and Wood, 1971). Among their destructive effects is damage to structural timber and other materials in structures. Damage extends to household furniture, paper products, many synthetic materials and food items (Edwards and Mill, 1986). They also damage underground cables and airfield, earthen dam and irrigation ditches (Ghilarov, 1962). They are reported consuming selected components of living and dead vegetation and modifying certain properties of the soil that influence the growth of plants (Lee and Wood, 1971). Malaka, (1973) and Agwu, (1981) reported damage to plant roots, trunks and leaves. They are important insect pests of forest (Harris, 1955; Greaves, 1962). Hussain, (1963) reported *Microtermesdiversus* (Silvestri) as a pest of date palm in Iraq. Agwu, (1981) listed termite workers and soldiers of *Armitermesevuncifer* as major pests of oil palms in Nigeria. Termites attack various species of crops in the tropics, however, the preference of some plant species over others by various termite species have been reported (Malaka, 1973; Wood *et al*., 1980; Umeh and Ivbijaro, 1997; Umeh *et al*., 1998). This research is aimed at assessing the chemical properties of soil from and within the mounds of *Macrotermes bellicosus*.

METHODOLOGY

The research was carried out in Sokoto State, located in the Northwest of Nigeria, between latitudes $11^0$30'N and 14°00'N and longitudes 4°00'E and 6°40'E. Sokoto State covers a total land area of 32,000 km^2 (Tureta *et al.,* 2006). Four Local Government Areas selected following preliminary studies namely; Wamakko, Wurno, Shagari, and Yabo Local Government Areas were selected for the study.

Soil samples from eight medium-sized (1.50- 2.49 m in height) mounds in Fadama and Upland areas of each Local Government Area were collected and analysed for their chemical properties using standard procedures outlined by Page *et al.*(1982). Nine soil samples each weighing 200 g were collected at each sampling point, out of which three samples belonging to the external surface of the mounds (0- 10 cm deep), three from the mound's gallery walls (20- 30 cm deep) and the remaining three from soil adjacent to the mounds, approximately 2 m away from the mounds without any visible termite activity. Each sample was placed in a labelled polythene bag. The soil samples were then air-dried in the laboratory for a week following the procedures described by Pleysier, (1990). Large soil clods were crushed to facilitate drying. After drying, the soils were then crushed using mortar and pestle. This was then sieved to fine powder using 2 mm sieve and labelled. The samples were then subjected to the following chemical analyses.

Soil pH and electrical conductivity were determined using methods described by Black (1965). During the experiment, soil and water were used in a 1: 1 ratio with twenty gram (20 g) of the air-dried soil placed into a 50 ml beaker and 20 ml of distilled water added. The mixture was allowed to stand for 30 minutes while stirring occasionally with a glass rod. Electrodes of the pH meter were inserted into the partly settled suspension and the pH was measured and recorded. The electrical conductivity of the soil was also obtained by stirring the mixture thoroughly with a glass rod, then electrodes of the conductivity meter were inserted into the suspension and the electrical conductivity was measured and recorded. All the soil samples were treated separately.

Soil organic carbon and organic matter contents were determined using the Walkley-Black Method (Black, 1965). Cation exchange capacity was determined by exchange with hexamine cobalt (III) cation at neutral soil pH 7, adopted from Black (1965). Available phosphorus in the soils was determined using Bray No. 1 Method (Jackson, 1962). Amount of K and Na in the soils was determined using the flame photometer method adopted from Black (1965). Ca and Mg were determined following procedures outline by Black (1965) and Johnson (1962) using atomic absorbance spectrometry (AAS). Percentage nitrogen in the soils was determined using the Kjeldahl method from Black, (1965).

Data generated was subjected to analysis of variance, where differences were observed, means were separated using least significant difference (LSD). SAS 9.3 Statistical package was used for the analysis (SAS, 2003®).

RESULTS AND DISCUSSION

Chemical properties of soils adjacent to the mounds of *M. bellicosus* are presented in (Table 1). It showed that Yabo fadama has the highest (7.1) soil pH (in H_2O) and the least (6.7) was in Shagari fadama. The electrical conductivity was highest at Wurno upland with 266µS/cm and lowest at fadama of Shagari with 23 µS/cm. Organic matter and Nitrogen contents were observed to be higher in the fadama lands than in uplands, with organic matter ranging from 1.05 in Wurno upland to 2.31 in Yabo fadama. The available phosphorous was highest in Wurno fadama (1.54 mg/kg) and lowest (1.27 mg/kg) in Yabo upland. The cation exchange capacity also showed Wurno fadama to have the highest value (12.62 cmol/kg) while Wurno upland had the least (8.08cmol/kg). Exchangeable bases also contained in the same (Table 1) showed magnesium to be the highest among the exchangeable bases while calcium was the least. Significant differences ($p<0.05$) occurred among the various soil parameters between fadama and uplands as observed in the (Table 2). It showed that Shagari fadama differed significantly ($p<0.05$) from the upland in available

Table 1. Some Chemical properties of soils adjacent to the Mounds of M. *bellicosus* in selected Local Government Areas of Sokoto State.

Soil Parameters	Local Government area/ Land Type								SE (±)
	Shagari		Wamakko		Wurno		Yabo		
	Fadama	Upland	Fadama	Upland	Fadama	Upland	Fadama	Upland	
pH (H_2O)	6.7^{a}	6.7^{a}	6.9^{a}	6.9^{a}	6.8^{a}	6.9^{a}	7.1^{a}	6.8^{b}	0.05
E. C. (µS/cm)	23^{a}	35^{a}	40^{a}	58^{a}	54^{a}	266^{b}	146^{a}	67^{a}	28.93
Org. Matter(g/kg)	1.85^{a}	1.71^{a}	2.28^{a}	1.37^{b}	1.23^{a}	1.05^{a}	2.31^{a}	1.43^{b}	0.17
Total N (g/kg)	0.42^{a}	0.28^{a}	0.74^{a}	0.57^{a}	0.35^{a}	0.32^{a}	0.63^{a}	0.32^{b}	0.06
Available P (mg/kg)	1.48^{a}	1.31^{b}	1.41^{a}	1.46^{a}	1.33^{a}	1.49^{b}	1.54^{a}	1.27^{b}	0.04
C. E. C. (cmol/kg)	10.72^{a}	10.62^{a}	10.66^{a}	8.96^{b}	12.62^{a}	8.08^{b}	10.73^{a}	10.68^{a}	0.48
Ca (cmol/kg)	0.25^{a}	0.20^{a}	0.35^{a}	0.20^{b}	0.30^{a}	0.25^{a}	0.45^{a}	0.10^{b}	0.04
Mg (cmol/kg)	1.9^{a}	1.6^{a}	2.3^{a}	1.4^{b}	2.6^{a}	1.5^{b}	3.1^{a}	2.5^{a}	0.22
K (cmol/kg)	0.90^{a}	1.46^{a}	1.33^{a}	0.64^{b}	2.08^{a}	0.33^{b}	1.38^{a}	1.02^{a}	0.19
Na (cmol/kg)	0.61^{a}	0.61^{a}	0.61^{a}	0.40^{a}	0.695^{a}	0.48^{b}	0.96^{a}	0.74^{b}	0.06

Means based on three replicates.
Means followed by the same letter as superscript in a Local Government area within a particular soil parameter are not significantly different ($p>0.05$) LSD (SAS, 2003®).

Table 2. Some chemical properties of soils from surface of M. *bellicosus* Mounds in selected Local Government Areas of Sokoto State.

Soil Parameters	Local Government area/ Land Type								SE (±)
	Shagari		Wamakko		Wurno		Yabo		
	Fadama	Upland	Fadama	Upland	Fadama	Upland	Fadama	Upland	
pH (H_2O)	6.8^{a}	6.8^{a}	7.0^{a}	7.0^{a}	7.0^{a}	6.9^{a}	6.9^{a}	6.7^{b}	0.04
E. C. (µS/cm)	44^{a}	91^{a}	62^{a}	107^{a}	111^{a}	433^{b}	261^{a}	174^{a}	45.89
Org. Matter(g/kg)	1.88^{a}	2.34^{b}	2.48^{a}	1.98^{b}	2.26^{a}	1.74^{b}	2.09^{a}	1.75^{a}	0.10
Total N (g/kg)	0.35^{a}	0.28^{a}	0.70^{a}	0.49^{b}	0.32^{a}	0.28^{a}	0.46^{a}	0.42^{a}	0.05
Available P (mg/kg)	1.29^{a}	0.24^{b}	0.26^{a}	0.27^{a}	0.26^{a}	0.28^{a}	0.24^{a}	0.24^{a}	0.13
C. E. C. (cmol/kg)	10.26^{a}	11.12^{a}	11.72^{a}	10.64^{a}	12.33^{a}	13.50^{a}	10.51^{a}	13.66^{b}	0.47
Ca (cmol/kg)	0.35^{a}	0.35^{a}	0.50^{a}	0.45^{a}	0.50^{a}	0.25^{b}	0.35^{a}	0.11^{b}	0.05
Mg (cmol/kg)	2.9^{a}	3.2^{a}	3.5^{a}	1.8^{b}	2.4^{a}	1.3^{b}	4.5^{a}	3.8^{a}	0.37
K (cmol/kg)	1.33^{a}	2.31^{b}	1.44^{a}	0.87^{a}	2.08^{a}	2.51^{a}	1.36^{a}	1.03^{a}	0.21
Na (cmol/kg)	0.65^{a}	0.74^{a}	1.04^{a}	0.48^{b}	0.78^{a}	0.74^{a}	0.65^{a}	0.83^{a}	0.06

Means based on three replicates.
Means followed by the same letter as superscript in a Local Government area within a particular soil separate are not significantly different ($p>0.05$) LSD (SAS, 2003®).

phosphorous while in Wamakko the soils differed significantly ($p<0.05$) in organic matter content, cation exchange capacity and some exchangeable bases (Ca, Mg and K). Similarly, Wurno fadama differed significantly ($p<0.05$) with the upland in terms of electrical conductivity, available phosphorous, cation exchange capacity and exchangeable bases. Yabo fadama differed significantly ($p<0.05$) with the upland in terms of pH (H_2O), organic matter, total nitrogen, available phosphorous and some exchangeable bases (Ca and Na).

Similarly, the results of analyses of soils from the surfaces of the mounds and the soils from gallery walls in the mounds were presented in (Tables 2 and 3) respectively. The results as evident from the tables were similar to the results in (Table 1) in most respects; the pH was generally almost neutral, the electrical conductivity values ranged from 30 to 433 µS/cm. The organic matter content of the soil, total nitrogen, available phosphorous, the cation exchange capacities as well as the exchangeable bases were all high.

Table 4 showed the result of analyses for the soil pH (in H_2O), electrical conductivity, and organic matter content, total nitrogen, available phosphorous, cation exchange capacity and exchangeable bases from soils adjacent to the mounds according to land types and Local Government areas. It showed the pH almost neutral, ranging from a mean value of 6.7 to 7.1 while the electrical conductivity ranged from 23.00 to 266 µS/cm. The soil organic matter had mean values ranging from 1.05 to 2.31 g/kg, total nitrogen ranged from 0.28 to 0.42 g/kg and available phosphorous from 1.27 to 1.54 mg/kg. The cation exchange capacity ranged 8.08 to 12.62 cmol/kg while in the exchangeable bases calcium ranged from 0.10 to 0.45 cmol/kg, magnesium (1.40- 2.60 cmol/kg), potassium (0.33- 2.08 cmol/kg) and sodium (0.40- 0.96 cmol/kg).

Similarly, Tables 5 and 6 that showed the same parameters with respect to soil from the surfaces and gallery walls of the mounds respectively and they also had a similar pattern occurrence with respect to the results according land types and Local Government areas

Table 3. Some chemical properties of soils from gallery walls in the Mounds of M. *bellicosus* in selected Local Government Areas of Sokoto State.

Soil Parameters	Local Government area/ Land Type								SE (±)
	Shagari		Wamakko		Wurno		Yabo		
	Fadama	Upland	Fadama	Upland	Fadama	Upland	Fadama	Upland	
pH (H_2O)	6.7^{a}	6.9^{b}	7.0^{a}	7.0^{a}	7.0^{a}	6.9^{a}	6.9^{a}	6.7^{b}	0.04
E. C. (µS/cm)	30^{a}	59^{b}	44^{a}	51^{a}	58^{a}	84^{b}	76^{a}	73^{a}	6.32
Org. Matter(g/kg)	1.84^{a}	1.47^{b}	2.03^{a}	1.76^{a}	2.13^{a}	1.57^{b}	1.88^{a}	1.43^{b}	0.09
Total N (g/kg)	0.42^{a}	0.25^{b}	0.70^{a}	0.60^{a}	0.43^{a}	0.35^{a}	0.40^{a}	0.35^{a}	0.05
Available P (mg/kg)	1.28^{a}	0.24^{b}	0.26^{a}	0.27^{a}	0.26^{a}	0.28^{a}	0.23^{a}	0.29^{a}	0.13
C. E. C. (cmol/kg)	10.84^{a}	14.27^{b}	10.45^{a}	11.35^{a}	11.64^{a}	14.62^{b}	10.26^{a}	12.77^{b}	0.60
Ca (cmol/kg)	0.35^{a}	0.30^{a}	0.55^{a}	0.55^{a}	0.40^{a}	0.35^{a}	0.45^{a}	0.11^{a}	0.50
Mg (cmol/kg)	2.2^{a}	3.5^{b}	3.2^{a}	2.9^{a}	2.8^{a}	2.7^{a}	2.2^{a}	3.5^{a}	0.18
K (cmol/kg)	1.77^{a}	2.51^{b}	1.31^{a}	1.08^{a}	2.49^{a}	2.51^{a}	1.82^{a}	1.44^{a}	0.20
Na (cmol/kg)	0.65^{a}	0.91^{b}	0.78^{a}	0.61^{b}	0.78^{a}	0.87^{a}	0.74^{a}	0.78^{a}	0.04

Means based on three replicates.
Means followed by the same letter as superscript in a Local Government area within a particular soil separate are not significantly different ($p>0.05$) LSD (SAS, 2003®).

Table 4. Some chemical properties of soils adjacent to the Mounds of M. *bellicosus* in different land type in selected Local Government Areas of Sokoto State.

Land Type	L. G. A.	Soil Parameters						Exchangeable Bases (cmol/kg)			
		pH (H_2O)	E. C. (µS/cm)	Org. Matter (g/kg)	Total N (g/kg)	Available P (mg/kg)	C. E. C. (cmol/kg)	Ca	Na	Mg	K
Fadama	Shagari	6.7^{b}	23^{b}	1.85^{bd}	0.42^{bc}	1.48^{a}	10.72^{b}	0.25^{a}	1.9^{b}	0.90^{b}	0.61^{b}
	Wamakko	6.9^{bc}	40^{b}	2.28^{ac}	0.74^{a}	1.41^{a}	10.66^{b}	0.35^{ab}	2.3^{b}	1.33^{b}	0.61^{b}
	Wurno	6.8^{b}	54^{b}	1.23^{bd}	0.35^{b}	1.33^{bc}	12.62^{a}	0.30^{ab}	2.6^{bc}	2.08^{a}	0.70^{b}
	Yabo	7.1^{ac}	146^{a}	2.31^{ac}	0.63^{ac}	1.54^{ad}	10.73^{b}	0.10^{ac}	3.1^{ac}	1.38^{b}	0.96^{a}
	SE (±)	0.09	27.49	0.29	0.09	0.05	0.49	0.05	0.25	0.25	0.08
Upland	Shagari	6.7^{a}	35^{b}	1.71^{a}	0.28^{b}	1.31^{b}	10.62^{a}	0.20^{b}	1.6^{b}	1.46^{a}	0.61^{a}
	Wamakko	6.9^{a}	58^{b}	1.37^{bc}	0.57^{a}	1.46^{a}	8.96^{ac}	0.20^{b}	1.4^{b}	0.64^{bc}	0.40^{ac}
	Wurno	6.9^{a}	266^{a}	1.05^{bc}	0.32^{b}	1.49^{a}	8.08^{bc}	0.25^{b}	1.5^{b}	0.33^{bc}	0.48^{bc}
	Yabo	6.8^{a}	67^{b}	1.43^{ac}	0.32^{b}	1.27^{b}	10.68^{a}	0.45^{a}	2.5^{a}	1.02^{ac}	0.74^{ad}
	SE (±)	0.05	53.59	0.10	0.07	0.05	0.64	0.06	0.25	0.24	0.07

Means based on three replicates.
Means followed by the same letter as superscript in a land type within a Local Government area are not significantly different ($p>0.05$) LSD (SAS, 2003®).

Table 5. Some chemical properties of soils from the surfaces of M. *bellicosus* Mounds in different land types in selected Local Government Areas of Sokoto State.

Land Type	L. G. A.	Soil Parameters									
		pH (H_2O)	E. C. (µS/cm)	Org. Matter (g/kg)	Total N (g/kg)	Available P (mg/kg)	C. E. C. (cmol/kg)	Exchangeable Bases (cmol/kg)			
								Ca	Mg	K	Na
Fadama	Shagari	6.8^{b}	44^{b}	1.88^{b}	0.35^{b}	1.29^{a}	10.26^{b}	0.35^{b}	2.9^{b}	1.33^{b}	0.65^{a}
	Wamakko	7.0^{ac}	62^{b}	2.48^{a}	0.70^{a}	0.26^{b}	11.72^{bc}	0.50^{a}	3.5^{bc}	1.44^{b}	1.04^{bc}
	Wurno	7.0^{ac}	111^{b}	2.26^{a}	0.32^{b}	0.26^{b}	12.33^{ac}	0.50^{a}	2.4^{b}	2.08^{a}	0.78^{ac}
	Yabo	6.9^{bc}	261^{a}	2.09^{b}	0.46^{a}	0.24^{b}	10.51^{b}	0.35^{b}	4.5^{ac}	1.36^{b}	0.65^{a}
	SE (±)	0.048	49.24	0.127	0.09	0.26	0.49	0.04	0.45	0.18	0.09
Upland	Shagari	6.8^{b}	91^{b}	2.34^{a}	0.28^{b}	0.24^{b}	11.12^{b}	0.35^{a}	3.2^{a}	2.31^{a}	0.74^{a}
	Wamakko	7.0^{ac}	107^{b}	1.98^{ac}	0.49^{a}	0.27^{a}	10.64^{b}	0.45^{a}	1.8^{a}	0.87^{b}	0.48^{b}
	Wurno	6.9^{b}	433^{a}	1.74^{bc}	0.28^{bc}	0.28^{a}	13.50^{a}	0.25^{a}	1.3^{b}	2.51^{a}	0.74^{a}
	Yabo	6.7^{ad}	174^{b}	1.75^{bc}	0.42^{ac}	0.24^{b}	13.66^{a}	0.11^{b}	3.8^{a}	1.03^{b}	0.83^{a}
	SE (±)	0.07	79.31	0.14	0.05	0.01	0.79	0.07	0.59	0.43	0.08

Means based on three replicates.
Means followed by the same letter as superscript in a land type within a Local Government area are not significantly different ($p>0.05$) LSD (SAS, 2003®).

as (Table 4).

Figure 1 depicted the mean values with mean separation for soil organic matter, total nitrogen, available phosphorous, cation exchange capacity and exchangeable bases. The figure showed the means of the soil's organic matter to be higher in surface soils while available phosphorous was higher in the soils adjacent to the mounds in both fadama and uplands. However, the cation exchange capacity was shown in the same (Figure 1) to be higher in uplands and lower in

Table 6. Some chemical properties of soils from the gallery walls in the Mounds of M. bellicosus in different land type in selected Local Government Areas of Sokoto State.

Land Type	L. G. A.	Soil Parameters									
		pH (H_2O)	E. C. (µS/cm)	Org. Matter (g/kg)	Total N (g/kg)	Available P (mg/kg)	C. E. C. (cmol/kg)	Exchangeable Bases (cmol/kg)			
								Ca	Mg	K	Na
Fadama	Shagari	6.7^{b}	30^{b}	1.84^{a}	0.42^{b}	1.28^{a}	10.84^{a}	0.35^{b}	2.2^{b}	1.77^{a}	0.65^{b}
	Wamakko	7.0^{a}	44^{bc}	2.03^{ac}	0.70^{a}	0.26^{b}	10.45^{ac}	0.55^{ac}	3.2^{ac}	1.31^{ab}	0.78^{a}
	Wurno	7.0^{a}	58^{bcd}	2.13^{bc}	0.43^{b}	0.26^{b}	11.64^{ad}	0.40^{bc}	2.8^{bc}	2.49^{ac}	0.78^{a}
	Yabo	6.9^{b}	76^{ad}	1.88^{ad}	0.40^{b}	0.23^{b}	10.26^{bc}	0.45^{bc}	2.2^{b}	1.82^{a}	0.74^{b}
	SE (±)	0.071	9.83	0.067	0.071	0.258	0.306	0.052	0.245	0.243	0.031
Upland	Shagari	6.9^{a}	50^{b}	1.47^{b}	0.25^{b}	0.24^{a}	14.27^{a}	0.30^{ac}	3.5^{a}	2.51^{a}	0.91^{a}
	Wamakko	7.0^{ac}	51^{b}	1.76^{ac}	0.60^{a}	0.27^{b}	11.35^{bc}	0.55^{a}	2.9^{ac}	1.08^{bc}	0.61^{bc}
	Wurno	6.9^{a}	84^{ac}	1.57^{bc}	0.35^{b}	0.28^{b}	14.62^{a}	0.35^{ac}	2.7^{bc}	2.51^{a}	0.87^{a}
	Yabo	6.7^{bd}	73^{bc}	1.43^{bd}	0.35^{b}	0.29^{b}	12.77^{ac}	0.11^{bc}	3.5^{a}	1.44^{ac}	0.78^{ac}
	SE (±)	0.062	8.39	0.074	0.075	0.011	0.75	0.091	0.21	0.368	0.067

Means based on three replicates.
Means followed by the same letter as superscript in a land type within a Local Government area are not significantly different ($p>0.05$) LSD (SAS, 2003®).

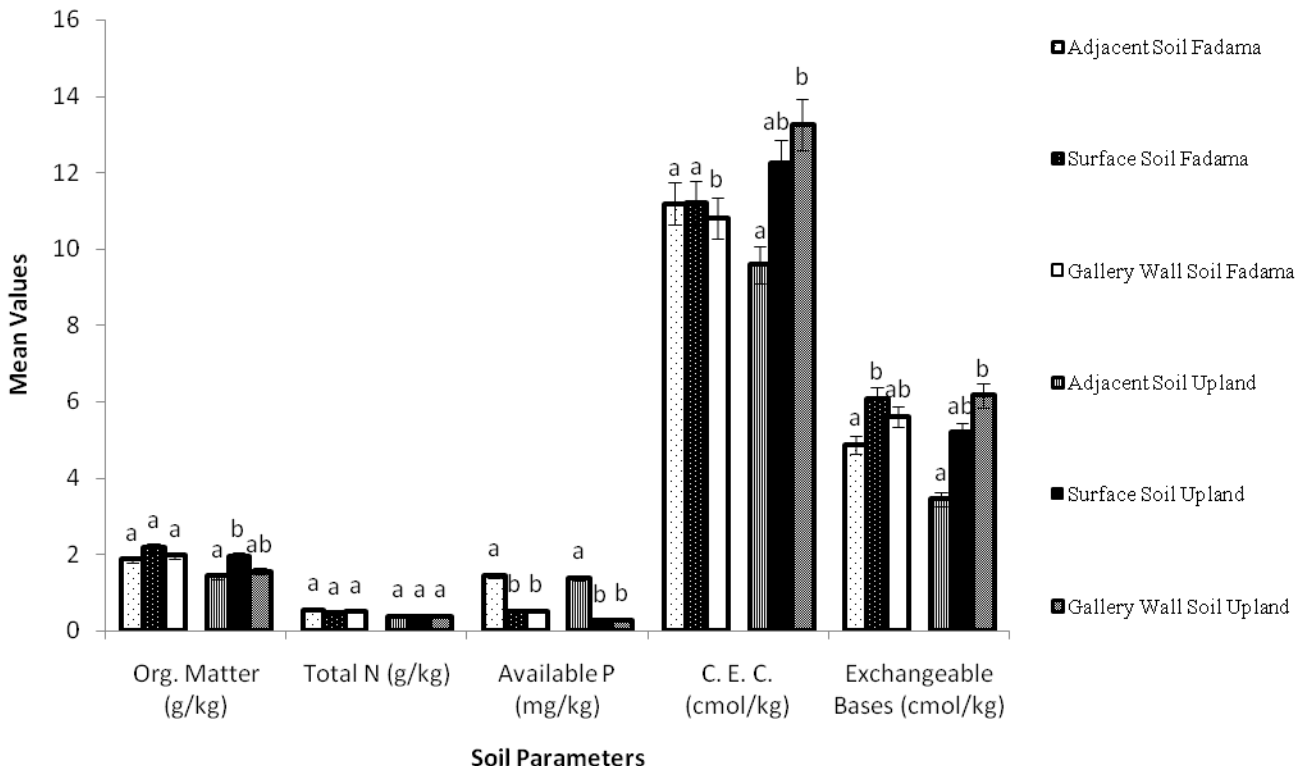

Figure 1. Values of some soil parameters from soils in and adjacent to the Mounds of *M. bellicosus* in different land types in selected Local Government Areas of Sokoto State.

fadama lands in soils from gallery walls. The exchangeable bases on the other hand were lower in the soils adjacent to the mounds but higher in the surface soil in fadama and higher in the soils from gallery walls in uplands. Available phosphorous differed significantly ($p<0.05$) in soils adjacent to the mounds with the other soils in the two land types. Also, significant differences ($p<0.05$) occurred between soils from gallery walls in the mounds and soil adjacent to the mounds and from the surfaces of the mounds in fadama land type (Figure 1).

Generally, the chemical analyses of soils from mound material and the surrounding soils were observed to be similar in many respects with few exceptions because of similarities in physical environment and climatic condition. Also, Jouquet *et al.* (2002) and Abe *et al.* (2009) reported that termite select soils for the construction of their mounds from both top and subsoil, this could have influenced the similarity in the composition of the soil from both the mound and its surroundings.

The soil pH that was observed to be near neutral in the present study may be as a result of incorporation of salivary material in the construction of the mound or because the termite selectively control the pH to match the requirement of the fungus being cultivated in the mound as fungus were reported to prefer a slightly acidic pH for their growth (Vashista and Sinha, 2005). However, Stoops, (1964) reported a little increase in the pH of mounds than the adjacent soil and Lee and Wood, (1971) concluded that increase or decrease in the soil pH does not correlate with any other chemical property and is very small. Abe and Wakatsuki, (2010) also suggested that *M. bellicosus* can manipulate soil to match their ecological requirements, such as structural stability of mound constructions.

Electrical conductivity was observed to be higher in the surface soil and lower in the soils from the gallery walls. This is probably because the termites use this to control growth of grasses on the surface of the mound as this will lead to the mound surface to be more porous, as higher values of electrical conductivity hinders plant growth (Landon, 1991).

Organic matter content observed to be higher in the soils could be attributed to the activities of the termites in the mound and involvement of fecal matter and salivary material in the construction of the mounds. This was in agreement with Lee and Wood, (1971) which reported that most termite mounds and other structures have higher organic matter content than the surrounding soils. Similarly, total nitrogen seen to parallel organic matter content may be because nitrogen content results from mineralization of nitrogen contained in the organic matter of the mound. The observed nitrogen content could also be attributed to the soil pH as reported by Landon, (1991) that major nutrients like nitrogen and phosphorus are most available at around neutral pH (6- 8). Jouquet et al. (2002) observed that nitrogen content in the soils from the mounds and their surroundings do not differ. Kozlova, (1951) stated that the favorable conditions of temperature and moisture in the mounds favored mineralization of nitrogen contained in organic matter in the mounds.

The higher cation exchange capacity observed may also be due to the incorporation of faecal and salivary materials with the soil during mound construction. The observed higher values of cation exchange capacity compared to exchangeable bases may be due to the concentration of hydrogen ions as most of the soil samples are acidic. The higher cation exchange capacity observed in the soil from gallery walls in the uplands could be because more saliva was used in the construction, compared to the fadama where moisture content was high in the environment and used in the construction. Jouquet et al. (2004) asserted that cation exchange capacity was significantly higher in termite mounds than the adjacent soil. Lee and Wood, (1971) also reported similar increase with respect to both cation exchange capacity and exchangeable bases. Calcium, magnesium, potassium and sodium content were all observed to be higher in the materials from the mounds than the surrounding soils. This increase may have resulted from incorporation of organic materials to the mounds during construction. Perhaps due to exchangeable bases, which are constituent of plant tissues and this might be their source in the termite structures. The observed higher amounts of magnesium among the exchangeable bases in the mounds may be because it is among the inorganic nutrients, the termite selectively choose with a view to meeting the nutrient requirements of the fungus it grows, as it is listed by Vashista and Sinha, (2005) to be among the inorganic nutrient required by the fungi in fairly large amount. Similar observations were made by Goodland, (1965) and Lee and Wood, (1971) who reported an increased in the calcium, potassium, magnesium and sodium content in nearly all chemical analyses of termite mounds.

Conclusion

The properties of the soils from the mounds and their surroundings suggest that the termites select the materials for the construction of the mounds to match their ecological, physiological and behavioral needs as well as that of the fungus they cultivate. The higher organic matter content, total nitrogen, cation exchange capacity, calcium and magnesium suggest that the soil from the mounds is fertile and could be used as fertilizer supplement in agricultural development.

REFERENCES

Abe SS, Wakatsuki T (2010). Possible Influence of Termites (*Macrotermes bellicosus*) on Forms and Composition of Free Sesquioxides in Tropical Soils. *Pedobiologia*, 53: 301- 306.

Abe SS, Yamamoto S, Wakatsuki T (2009). Soil- particle Selection by the Mound- building Termite *Macrotermes bellicosus* on a Sandy Loam Soil Catena in Nigerian Tropical Savanna. *Journal of Tropical Ecology*, 25: 449- 452.

Agwu SI (1981). A Checklist of Insects Injurious to the Oil Palm in Nigeria. *Journal of the Nigerian Institute for Oil-Palm Research*, 59- 64.

Bandiya HM, Yahaya MA, Shindi HA, Danjumma BJ (2016). A survey of mound- building termites in four local government areas of Sokoto State, North- western Nigeria. *Scholarly Journal of Biological Science.* 5(2): 71- 73.

Bignell DE, Eggleton P, Nunes L, Thomas KL (1997). Termites as Mediators of Carbon Fluxes in Tropical Forest, Budgets for Carbon dioxide and Methane Emissions. In: Watt, A. D., Stock, N. and Hunter, M. D. (eds.). *Forests and Insects.* Chapman and Hall, London. pp. 109- 134.

Black CA (1965). *Methods of Soil Analysis.* Monograph no. 9. American Society of Agronomy, Madison, Winsconsin, USA. p.770.

Donovan SE, Eggleton P, Bignell DE (2001). Gut Content Analysis and a New Feeding Group Classification of Termites. *Ecological Entomology*, 26: 356- 366.

Edwards R, Mill A (1986). *Termites in Buildings: Their Biology and Control.* Rentokil Ltd., East Grinstead. p. 263.

Eggleton P, Homathavi R, Jones DT, MacDonald J, Jeeva D, Bignell DE, Davies RG, Maryati M (1999). Termite Assemblages, Forest Disturbance and Greenhouse Gas Fluxes in Sabah, East Malaysia. *Philosophical Transactions of the Royal Society*, 354: 1791- 1802.

Fall S, Brauman A, Chotte JI (2001). Comparative Distribution of Organic Matter in Particle and Aggregate Size Fractions in the Mounds of Termites with Different Feeding Habits in Senegal: *Cubitermesniokoloensis* and *Macrotermes bellicosus*. *Applied Soil Ecology*. 17: 131- 140.
Ghilarov MS (1962). Termites of USSR, Their Distribution and Importance. In: *Termites in the Humid Tropics*, *New Delhi Symposium*, *UNESCO, Paris.* pp. 131-135.
Goodland RJA (1965). On termitaria in a Savanna ecosystem. *Canadian Journal of Zoology*, 43: 641- 650.
Greaves T (1962). Termites in Australian Forest. *Proceedings of the 11th International Congress of Entomology*, *Vienna*. Pp. 238- 240.
Harris WV (1955). Termites and the Soil. In: McEkevan, D. E. (ed.). *Soil Zoology*. Butterworths, London. Pp. 62- 72.
Holt JA, Lepage M (2000). Termites and Soil Properties. In: Abe, T., Bignell, D. E., and Higashi, M. (eds.). *Termites: Evolution, Sociality, Symbiosis and Ecology*. Kluwer Academic, Dordrecht, The Netherlands. pp. 389- 407.
Hussain AA (1963). Biology and Control of the Dubas Bug (Homoptera: Tropiduchidae) Infesting Date Palms in Iraq. *Bulletin of Entomological Research*, 53: 737- 745.
Jackson ML (1962). *Soil Chemical Analysis*. Prentice- Hall, New York. pp. 9- 16.
Jouquet P, Bottinelli N, Lata JC, Mora P, Caquineau S (2007). Role of the Fungus- growing Termite *Pseudacanthotermes spiniger* (Isoptera, Macrotermitinae) in the Dynamic of Clay and Soil Organic Matter Content: An Experimental Analysis. *Geoderma*, 139: 127- 133.
Jouquet P, Mamou L, Lepage M, Velde B (2002). Effect of Termites on Clay Minerals in Tropical soils: Fungus Growing Termites on Weathering Agents. *European Journal of Soil Sciences*, 53(4): 521-528.
Jouquet P, Tessier D, Lepage M (2004). The Soil Structural Stability of Termite Nests: Role of Clays in *Macrotermes bellicosus* (Isoptera: Macrotermitinae) Mound Soils. *European Journal of Soil Sciences*, 40: 23- 29.
Kozlova AV (1951). Accumulation of Nitrates in Termites Mounds in Turkmenia. *Pochvovedemic*, 10: 626-631.
Landon JR (1991). *Booker Tropical Soil Manual*. Longman Scientific & Technical, Hong Kong. p. 474.
Lawton JH, Bignell DE. Bloemers GF, Eggleton P, Hodda ME (1996). Carbon Flux and Density of Nematodes and Termites in Cameroun Forest Soils. *Biodiversity and Conservation*, 5: 261- 273.
Lee KE, Wood TG (1971). *Termites and Soils*. Academic Press, London and New York. 251 pp.
Logan JWM, Cowie RH, Wood TG (1990). Termites (Isoptera) Control in Agriculture and Forestry by Non- Chemical Methods: A Review. *Bulletin of Entomological Research*, 80(3): 309-330.
Malaka SLO (1973). Observations on Termites in Nigeria. *The Nigerian Fields*, 38(1): 24-40.
Meyer VW, Braack LEO, Biggs HC, Ebersohn C (1999). Distribution and Density of Termite Mounds in the Northern Kruger National Park, with Specific Reference to those Constructed by Macrotermes (Holmgren) (Isoptera: Termitidae). *African Entomology*, 7(1): 123- 130.
Obi JC, Ogunkun AO (2009). Influence of Termite Infestation on the Spatial Variability of the Soil Properties in the Guinea Savanna region of Nigeria. *Geoderma*, 148: 357- 363.
Page ACP, Miller RH, Keeney DR (1982). Methods of Soil Analysis. Vol. 2, 2nd ed. American Society of Agronomy, Madison, Winsconsin.
Pleysier JL (1990). *Soil Sampling and Sample Preparation*. IITA Research Guide. 2nd ed. (revised). International Institute of Tropical agriculture (IITA), Ibadan, Nigeria. p. 27.
SAS (Statistical Analysis System) (2003). SAS Release 9.1 for Windows, SAS Institute Inc. Cary, NC, USA.
Stoops G (1964). Application of Some Pedological Methods to the Analysis of Termites Mounds. In: *EtudusSurless Termite Afirs*. Bunollon, A. (ed.). Leopoiduills University, Leopoldville. pp. 379-598.
Tureta ZM, Yabo MA, Kiryo H (2006). Sokoto State. [Internet] Available from: <http://www.sokoto-state.com/index.html>
Umeh VC, Ahonsi S, Kolade JA (1998). Insect Pests Encountered in a Citrus Orchard in Nigeria. *Fruits*,53(6): 397-408.
Umeh VC, Ivbijaro MF (1997). Termite Abundance and Damage in Traditional Maize-cassava Intercrops in Southwestern Nigeria. *Insect Science and its Application*,17:315-321.
Umeh, V. C., Ivbijaro, M. F. and Ewete, F. K. (1999). Relationship Between Characteristics of *Macrotermes* spp. Mound Materials and their Surrounding Soils. *Insect Science and its Application*,19: 251-255.
Vashista BR, Sinha AK (2005). *Botany for Degree Students. Part II : Fungi.* S. Chand & Company Ltd. Ram nagar, New Delhi, India. p. 676.
Wood TG, Johnson RA, Ohiagu CE (1980). Termite Damage and Crop Loss in Nigeria: A Review of Termite Damage to Maize and Estimation of Damage, Loss of Yield and *Microtermes* Abundance at Mokwa. *Tropical PestManagement*, 26: 241-253.