SOIL PHYSICAL AND CHEMICAL PROPERTIES OF TERMITE MOUND AND THEIR ADJACENT SOIL IN KASHERE AKKO LOCAL GOVERNMENT, GOMBE STATE NIGERIA.

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ABSTRACT
This study physical and chemical property of termite mounds in relation to their adjacent soils at the Faculty of Agriculture Teaching and Research Farm of University of Kashere. Five termitaria were selected at random in the study area. Twenty (20) composite soil samples were collected at the base of termitaria and adjacent soils at twenty four metres (24 m) away from termitaria at two depths (0 - 15 and 15 - 30 cm) and analyzed for physicochemical parameters. Results obtained shows no much difference between the termite mound and adjacent soil, with few exceptions were percent clay, soil pH, electrical conductivity (EC) and Exchangeable cations (Ca, Mg and Na) were significantly higher ($P < 0.05$) in termitaria compared to adjacent soil. The adjacent soil has higher percentage of sand compared to that of the termitaria. It can be concluded that termite mound soils is proving alternative to local farmers who cannot afford to buy expensive chemical fertilizers. It is recommended that termite mound soil should adapted by small holders farmers in the study area as an alternative to inorganic fertilizer.
Keywords: Adjacent soil, Termite mound, soil physical properties; soil chemical properties

INTRODUCTION

Soil is a dynamic natural body composed of mineral and organic materials and living forms in which plants grows, (Kalev and Toor, 2018). Soil is useful to living organisms as habitat, habitat support, food, shelter (Dhembare, 2013). Among these organisms that inhabit the soil is the termite. Termites are common biological agents that produce significant physical and chemical modifications to tropical and sub-tropical soils (Heikens *et al.*, 2001). They commonly build earthen mounds of various shapes and sizes forming an important feature of the tropical landscape (Chandra, 2018). However, Chandra (2018) opined that termites constitute an important component of soil fauna in tropical and sub-tropical regions, and they are considered as one of the most important natural modifiers of soil physical and chemical properties (Jouquet *et al.*, 2011). Termites are being considered to be one of the most destructive pests in the world (Temesgen and Emana, 2021), but termites mound soil are biological indicators of soil fertility (Enagbonma and Babalola, 2019) and utilized as an alternative to NPK fertilizers by subsistence farmers who are unable to afford mineral fertilizer because of its inflated cost in some parts of Africa (Abdeta Jembere *et al*., 2017). NitSoil is a dynamic natural body composed of mineral and organic materials and living forms in which plants grows, (Kalev and Toor, 2018). Soil is very important and useful to living organisms as habitat, habitat support, food, shelter (Dhembare, 2013). Among these organisms that inhabit and thrive in the soil is the termite. Termites can be described as common biological agents that produce significant physical and chemical modifications to tropical and sub-tropical soils (Heikens *et al*., 2001). Termites commonly build earthen mounds of different shapes and sizes there by forming an important feature of the tropical landscape (Chandra, 2018). However, termites constitute an important component of soil fauna in tropical and sub-tropical regions, and they are considered as one of the most important natural modifiers of soil physical and chemical properties (Jouquet *et al.*, 2011). Termites can be considered as one of the most destructive pests in the world (Temesgen and Emana, 2021), but termites mound soil are biological indicators of soil fertility (Enagbonma and Babalola, 2019) and utilized as an alternative to NPK fertilizers by subsistence farmers who are unable to afford mineral fertilizer because of its inflated cost in some parts of Africa (Abdeta Jembere *et al*., 2017). Nithyatharani and Kavitha (2018) reported that activities such as collection and transportation of living and dead plants, animal materials, soil particles, and burrowing by Termite's led to the improvement of soil physical and chemical properties and microbial population and diversity of the termite mound and their adjacent soils. Hyatharani and Kavitha (2018) reported that activities such as collection and transportation of living and dead plants, animal materials, soil particles, and burrowing by Termite's led to the improvement of soil physical and chemical properties and microbial population and diversity of the termite mound and their adjacent soils. However, such modifications have a great impact on the vegetation, through spatial and temporal effects (Afolabi *et al*., 2014). Termites are considered as ecosystem engineers built mounds, enhancing the content of organic carbon, clay and nutrients (Whiteford and Eldridge 2013). Comparative studies on termite mounds and the adjacent termite-unmodified control soils conducted by Sarcinelli *et al*. (2009) and Jouquet *et al*. (2016) they reported higher concentration of organic matter (OM) and mineral nutrients in termite mounds than in adjacent soil. This suggests mound materials as a soil fertility amendment in smallholder farming as their potential impact on agriculture is receiving increasing attention. Our work, therefore, attempts to discuss the unknown fertility status potentials of the base termite mound soil used in agricultural production by subsistence farmers in the study area as part of a traditional integrated nutrient management strategy. In this regard, the objective of the study was to compare physical and chemical properties of termite mounds in relation to their adjacent soils.

MATERIALS AND METHODS

The study was carried out at the Faculty of Agriculture Teaching and Research Farm of Federal University of Kashere Akko Area of Gombe State, Nigeria. It is located at Latitude 9◦ 46' 0"N and Longitude 10◦ 57' 0" and 431 above sea level. There are numerous termites' mounds in the area. The study area lies in the Dry sub-humid Azare - Gombe -Yola Plain of Nigeria (FPDD, 2012). It experiences an average annual rainfall of 850mm and the annual mean temperature range between 30˚C to 32˚C (Ibrahim and Muhammad, 2021). And the vegetation of the area is characterized by grasses, shrubs and few trees and is forming part of the Limestone and Shale of the Pindiga formation (Ibrahim and Muhammad, 2021). The soil of the study area falls within the Leptosols, Cambisols and Luvisols from Limestone and Shale of the Pindiga formation (Ibrahim *et al.,* 2021b). It is deep, whitish, clay loam and free from concretions and stones (Ibrahim *et al.,* 2021c). It is well drained, with good moisture-holding capacity. The economic activities of local communities of the study area are characterized by mixed farming systems that involve arable crops and livestock subsistence farming (Ibrahim *et al*. 2021a). Constraints to agricultural practices are low soil fertility, land degradation, lack of access to modern technology and marketing. Termite mounds are widespread in the study area and farmers bitterly complain the damage of termites.

Samples and sample collection

Twenty (20) composites soil samples from termite mound base and their adjacent soils were collected at two depths (0 - 15 and 15 - 30 cm). The adjacent soils were collected at twenty four (24) metres away from the termite mound. The samples were collected into polythene bags, labelled and taken to the Soil Science laboratory for analysis. The samples collected were air dried, grinded with mortar and pestle, mixed well and passed through 2-mm mesh sieve.

Laboratory analysis

Particle size analysis were performed using the hydrometer method (Gee and Or 2002). Bulk density was determined by the method described by Grossman and Reinsch (2002) and calculated using the formulae

$$\text{Bulk density (Db.) } (g/cm^3) = \frac{\text{mass of ovendried sample}}{\text{volume of sample}}$$

Soil pH (H_2O) and electrical conductivity (EC) was measured using pH-meter and conductivity meter in a 1:2.5 soil water ratio (VanReeuwijk, 1993 and Raina *et al.,* 2007). Soil organic carbon was determined by the Walkley Black combustion method (Nelson and Sommers, 1996). Total nitrogen was analyzed by the modified Kjeldahl oxidation method where salicylic acid was added during digestion to include nitrate-N and nitrite-N (Okalebo *et al*., 2002), whereas available Phosphorus was determined by Bray 1 method (Bray and Kurtz, 1945). Exchangeable Ca^{2+}, Mg^{2+}, Na^+ and K^+ were determined by extraction with 1 N NH_4OAC. K^+ and Na^+ in the extract was determined with a flame photometer, while Ca^{2+} and Mg^{2+} were determined using an atomic absorption spectrophotometer following the procedures outlined by Udol *et al*. (2009).

Data analysis

Data collected were subjected to Analysis of Variance (ANOVA) using SAS package version 9.0 of Statistical Analysis Software package as described by SAS (2002).

RESULTS AND DISCUSSION

Selected physical properties of termites mound soil and adjacent soil

Selected physical property of termites mound soil and adjacent soil analyzed from composite soil samples are shown in Table 1. Results revealed that the textural class of soil under termite mound was clay loam while the adjacent soil was sandy clay loam (Table 1). This implies that termite mound have great impact on soil texture of the study area and also, indicates there is similarity in parent material of the soil. Relatively higher sand content was recorded in adjacent soils in the upper 0 to15 cm depth while silt content was recorded in termite mound soils in the upper 0 to15 cm depth (Table 1). On the other hand, higher content of clay was recorded in 15 to 30 cm depth of both in termite mound soils and adjacent soils. The percentage of sand was higher in all samples than the percentages of silt and clay while the percentage of clay is higher than that of silt in all the samples. This type of situation was also reported by Afolabi *et al*. (2014). As indicated in (Table 1), the clay percentage increased with depth in both termite mound soils and adjacent soils while the sand decreases with depth compared to adjacent soils. Contrary to the pattern observed for the sand and clay fractions, silt fraction decreases with depth in termite mound compared to adjacent soils were it increases with depth. Similar higher clay fractions in termite mound compared to adjacent soils were reported by Tilahun *et al*. (2021) and Oliveira *et al*. (2012).

Bulk density

The bulk density (Pb) did not differ significantly (Table 1). Soil bulk density did not differ between the termite mound and adjacent soils, regardless of the sampling layer soil bulk density were higher ($p<0.05$)

in the adjacent soil than in the termite mound soils. Across the termite mound and adjacent soil, bulk densities were at the normal value (< 1.45g/cm^3) for ideal plant growth. The relatively higher bulk density values recorded for surface soils of termite mound and adjacent soils might be associated with the effect of SOM content. Furthermore, the higher bulk density of soil in termite mound and adjacent soil might be due to the practice of ploughing in adjacent soil and activities of termites, which tends to lower the quantity of soil organic matter. Similarly, Brady and Weil (2017) opined that the continuous exposure of the soil surface to the direct impact of raindrops as well as continuous cultivation might have also contributed to the higher bulk density. In contrast to these findings, Arshad *et al*. (2010) observed that the termite mounds had higher bulk density than the surrounding soil, probably because termites repack soils with their saliva to form hard protective layers against open air and temperature fluctuation in the termite mounds soil. Girma (2020) opined that bulk density is among the physical parameters used to evaluate the physical fertility status of soil. According to the Bohn (2001) rating scale, bulk density values of the soil in the study area were not too compact to limit root penetration and to restrict water and air movement.

Table 1: Physical Properties of Termites Mound and Adjacent Soils

Depth **(cm)**	Sand **(%)**	Silt **(%)**	Clay **(%)**	BD **(g/cm^3)**	Textural Class
			Termite mound		
0-15	40.3^b	27.4^a	32.3^b	1.34^a	Clay Loam
15-30	44.3^a	17.4^b	38.3^a	1.32^a	Clay Loam
Mean	42.3	22.4	35.3	1.33	Clay Loam
Se±	1.70	2.7	1.99	0.01	
			Adjacent soil		
0-15	56.3^a	18.4^b	25.3^b	1.40^a	Sandy Clay Loam
15-30	46.3^b	23.0^a	30.7^a	1.44^a	Sandy Clay Loam
Mean	54.3	23.9	21.9	1.42	Sandy Clay Loam
Se±	2.70	1.18	1.62	0.17	

Bd = Bulk density. Means followed by the same letters (s) within the same column and treatment are not significantly different at 5 % level of probability using LSD. Duncan's Multiple Range Test (DMRT)

Some chemical properties of mound soil and adjacent soil

Some selected chemical properties of termite mound soil and adjacent soil analyzed from composite soil samples are shown in Table 2. The pH (H2O) of termites mound were significantly different in relation to the surrounding soil, while these values did not differ ($p>0.05$) between the sampling depths in both termites mound and adjacent soils (Table 2). The result is in agreement with study conducted by Brossard *et al*. (2007). The soil pH could be categorized as slightly acidic under termites mound whereas that of adjacent soils was moderately acidic, following the classification described by Brady and Weil (2002). Compared with soil from adjacent soil, the termites mound soil showed higher pH. This result corroborate with those values reported by Chandra Sekhar Reddy (2018); Seibert *et al.* (2007); Temesgen and Emana (2021) that termite modify soil pH value due to the accumulation of OM, which in turn increase soil pH value in their nests. In contrast to Soil pH value (H2O), significant variation was observed ($p<0.05$) in the termites mound, adjacent soils and their sampling depth in EC (Table 2). This result agrees with Abe and Wakatsuki (2011) who found significantly higher soil EC value in the nest body than in the neighboring soil. Generally, the electrical conductivity (EC) of termite soils (average 364.0 µs/cm) is significantly higher than those of adjacent soils (average 201.5 µs/cm). This might be as a result of weathering of minerals, and mineralization of organic matter in this study area Chandra Sekhar Reddy (2018). The conductivity of soil of the termitaria to be Similar, higher electrical conductivity from adjacent soil compared to adjacent soils were reported by Aiki *et al.* (2013) and they attributed it to the nature of materials termites move in to their nest during nesting and scavenging for food.

Organic carbon, total nitrogen and Available phosphorus (AP)

It was further noted that organic carbon of the termite mounds and adjacent soil at different depths were not significantly different ($p < 0.05$) (Table 2). There was also a decreasing trend in soil OC from surface and subsurface of termites mound to adjacent soils. This result agreed with the findings of Ackerman *et al.* (2007) and Menichetti *et al*. (2014) who reported an elevated OC on termite mounds than adjacent soil and they relate it to termite feeding habit and the type of materials used for mound construction. Jouquet *et al.* (2002) and Roose Amsaleg *et al.* (2004) reported that termite activities increases the content of organic matter in the soils .Similar to organic carbon, total nitrogen did not differ significantly (Table 1). It was further noted that total nitrogen of the termite mounds and adjacent soil at different depths were not significantly different ($p < 0.05$) (Table 2). This result agreed with that of Menichetti *et al*. (2014) who reported an elevated TN on termite mounds than adjacent soil. The low termite mound material with organic carbon and total N contents for both soil types agreed with Adekayode and Ogunkoya (2009), furthermore, Kaschuk *et al*. (2006) and Tilahun *et al.* (2012) reported, no significant difference between termites mound soil and adjacent soils organic carbon and total nitrogen content. Significant variation was observed ($p<0.05$) in the termites mound, adjacent soils and their sampling depth in available phosphorus (AP) (Table 2). There was also an increasing trend in soil AP from surface and subsurface of termites mound to adjacent soils. AP content was higher at surface soil than those in the subsurface soil at both termites mound and adjacent soils. In a comparison of the AP contents in termite mounds and surrounding soil, similar results were reported by López-Hernández *et al*. (2006) in their study they reported higher AP content in termite mound soil compared to adjacent soils, which might be due to the incorporation of feces in the mound material. However, in another study conducted by Oliveira *et al*. (2012) noted that the higher P content in termites mound is related to the amount of clay in the mound construction, that prevent the loss of available P. Hernandez *et al*. (2006) opined that termite feeding habit and materials used for construction of mound plays a vital role on phosphorus sorption as well as affecting availability of phosphorus for plant uptake.

Exchangeable bases

Generally, the soil at the study site showed slightly acidic to moderately acidic status and medium contents of bases (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}) as per Kparmwang *et al*. (2001). The exchangeable bases contents of the termite's mounds were not significantly different from the exchangeable bases contents of the adjacent soils (Table 2). These soil characteristics with poor fertility status are common in tropical savanna soils in West Africa (Abe *et al*., 2010; Abe *et al*., 2011). In contrast, soil from termite mounds has been reported by different authors contain higher plant nutrients compared to adjacent soil from where they were collected (Frageria and Baligar, 2004; Dhembare, 2013). In line with this study in most cases nutrient contents of the mounds were not significantly different from the adjacent soils.

Table 2: Some Selected Chemical Properties of Termites Mound and Adjacent Soils

Depth (cm)	pH (H_2O)	EC (µs/cm)	OC (%)	TN (%)	AP (mg/kg)	Ca^{2+}	Mg^{2+} (Cmol (+/kg))	K^{+}	Na^{+}
					Termites Mound				
0-15	6.52_a	378.1^a	0.84^a	0.05^a	9.39^a	3.45^a	0.85^a	0.22^a	0.14^a
15-30	6.41_a	349.9^b	0.69^a	0.04^a	7.15^b	3.13^a	0.77^a	0.11^a	0.13^a
Mean	6.50	364.0	0.76	0.45	8.11	3.29	0.81	0.16	0.14
Se±	0.28	4.47	0.24	0.31	0.72	0.47	0.24	0.28	0.28
					Adjacent Soils				
0-15	5.87^a	184.9^b	0.62^a	0.04^a	8.89^a	2.29^a	0.69^a	0.20^a	0.11^a
15-30	5.63^a	218.1^a	0.66^a	0.04^a	6.91^b	2.18^a	0.63^a	0.18^a	0.12^a
Mean	5.80	201.5	0.64	0.04	7.92	2.24	0.66	0.19	0.12
Se±	0.41	4.84	0.36	0.01	0.65	0.28	0.20	0.10	0.10

pH(H_2O) = Soil pH in water, EC = Electrical conductivity, OC = organic carbon, TN = Total Nitrogen, AP = Available phosphorus, Ca^{2+} = Calcium, Mg^{2+} = magnesium, K^{+}, Potassium, Na^{+} = Sodium. Means followed by the same letters (s) within the same column and treatment are not significantly different at 5 % level of probability using LSD

CONCLUSION

This study has compared the physical and chemical properties of termite mound and their adjacent soil. Results obtained shows that adjacent soil has higher percentage of sand compared to that of the termitaria, but the percentage of clay is higher in termitaria compare to the adjacent soil, where it increases it infiltration capacities and thus promote microbial metabolism. However, termite activities significantly influence the soil textural properties. Generally the chemical properties between the termitaria and the adjacent soils show variation which can be attributed to termite activities and continues cultivation in the adjacent soils. Further research need to be done on the types of species of termites and their role in enriching the soil nutrient and their ability in combating erosion.

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