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Extractable Iron and Aluminum Distribution in *Macrotermitinae Nigeriensis* Infested Guinea Savanna Alfisol

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Abstract: The nature, amount and distribution of iron (Fe) and aluminum (Al) oxides in a soil affects its charge characteristics and ion adsorption especially Phosphorus (P) sorption. Termites remove materials for termite nest construction and repairs from diverse locations but predominantly from the B-horizons of the profile which leads to the modification of soil properties and characteristics. The objective of the study was to determine the effect of termite infestation on the forms and distribution of Fe and Al oxides, hydroxides and oxyhydroxides in the soil. Two pedons with termite mounds (plot 1 and 2) and one without signs of present or previous termite mounds (plot 3) was sampled according to genetic horizons in both Mokwa and Kontagora area in the Niger State area of Nigeria (total of 6 pedons). Three mounds per plot was also broken and sampled. The termite species identified was *macrotermitinae nigeriensis*. The soils were classified as Arenic Kandiustox . The crystalline form of Fe and Al was higher than the amorphous forms in both the pedons and mounds. The crystalline form of Fe increased with depth in the non-infested soils of Mokwa but not in the infested. This increase with depth was also observed in plots plot 1 and 3 (infested and non-infested, respectively) and not in plot 2 of Kontagora. An indication of build up of crystalline form of sesquioxides on the surface of the infested soils. The means of crystalline and amorphous forms of Fe in the mounds were 7.39 and 11.27g kg^{-1}, respectively in Kontagora and 7.60 and 10.84 g kg^{-1}, respectively in Mokwa, while those of Al were 9.56 and 7.78 g kg^{-1}, respectively in both Kontagora and Mokwa. These values fell within the range observed in the pedons especially on the surface and the surbsurface horizons. The observation in the infested soils of plot 1 and 3 of Mokwa and plot 2 of Kontagora created an indication that termite infestation may have affected the distribution of sesquioxides especially Fe oxides. This observed increase in the crystalline form of Fe oxides in the surface soil could lead to progressive deterioration of soil physical and chemical properties.

Key words: Macrotermitinae nigeriensis, pedoturbation, sesquioxides oxides, guinea savanna

INTRODUCTION

Termites feed on both organic and inorganic components of the soil and use same for construction and repair of nests (Venugopal, 1999). Consequences of these are sorting and rearrangement of the soil components and subsequently modification of the soil properties and characteristics especially of the uppermost horizons (Jouquet *et al.*, 2004, 2005; Ndiaye *et al.*, 2004). Pedoturbating effect of termites on soil lead to the exposure of the soil material removed from the lower horizons (especially B-horizons) to the vagaries of the atmospheric conditions and diverse reaction possibilities. Soils of the tropical region are dominantly alfisols, ultisols and oxisols and the dynamics of sesquioxides (mainly iron and Aluminum oxides) are progressively the major determining factors for formation of these soils in association with clay migration and content. Iron (Fe) and aluminum (Al) found in the soil are released during weathering and development and reprecipitated as amorphous and crystalline oxides, hydroxides and oxhydroxides. Crystalline form is the predominant form of Fe in alfisols which dominate the soils of savanna region of Nigeria (Jones and Wild, 1975; Jou *et al.*, 1974). The crystalline form of Al-oxides is thought to be substituted into crystalline Fe-oxides such as geothites and heamatite

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(Holgren, 1967). The effect of such substitution is the structural distortion of crystalline Fe oxides with implications for anion retention and surface area (Schwertmannn and Herbillon, 1992). There is higher P sorption per unit area for Al-substituted geothites compared pure geothites. Also, crystalline form of Fe oxides has been found to increase with soil age at the expense of amorphous. This is measured as the ratio of amorphous iron (Fe_o) to crystalline (Fe_d). Ideally, this ratio is less than unity and decreases with soil age. Also, low Fe_o/Fe_d ratio indicated high degree of crystallinity. According to Alendader and Cady (1962), the feature that distinguishes plinthites and account for hardness are greater degree of crystallinity and a continuity of the crystalline phase. Therefore, the nature, amount and distribution of Fe oxides in a soil especially tropical, significantly affect its properties, such as charge characteristics, ion adsorption particularly phosphorus (Ojanuga, 1985; Torrent, 1987; Torrent *et al*., 1990).

The objective of this study was to determine the effect of termite infestation on the forms and distribution of Fe- and Al-oxides in the soils of Guinea Savanna regionof Nigeria.

MATERIALS AND METHODS

Study site: Giant termite mounds are common features of the rural landscape of Niger State. These mounds are particularly numerous and cover Mokwa, Gbako, Bida, Agaie, Kontagora, Magama and Wushishi Local Government Areas of Niger State, Nigeria measuring about 51,756.96 km^2. It is located between latitudes 8° 30'N and 11°N and longitudes 4° 30'E and 6° 30'E . The soils of the area are dominantly Alfisols (USDA) and Luvisol (FAO/IUSS, 2006). The environmental conditions of the study area include precipitation (1175 mm year^{-1}), temperature (28°C), sunshine period (3.8 h in August to 8 h in November), wind velocity (44 km day^{-1} in January to 133 km day^{-1} in April), evapotranspiration (about 2149 mm). The soil moisture regime is ustic and soil temperature regime is hyperthermic. The area falls within the Southern Guinea savanna region covered with either wooded bush land or wooded grassland. The study area is on a relatively flat terrain with slope of less than 4%. Parent material is Nupe sandstone. The soil texture class of B-horizon of the pedons is dominantly sandy loam, with clay that ranged between 102 and 182 g kg^{-1}. The soils are classified as Arenic Kandiustox according to Soil Survey Staff (2006).

Mokwa in the south and Kontagora in the northern part of the infestation zone were chosen for the study. In each location, three (100 m × 100 m) plots were selected for study. Two plots (plot 1 and 2) had termite mounds while the third (plot 3) had neither sign of present nor previous occurrence of mound. The entire plots studied had been under similar land use but presently cropped to maize and relay cropped with cowpea. None of the plots had been cropped for more than 5 years.

Six, representative profile pits were established at the rate of one per plot. Soil samples were collected according to genetic horizons FAO/IUSS (2006), 3 representative termite mounds were also sampled per infested plot. Termite mound population was counted manually and termite sample collected for identification. Termite mound and soil samples were bagged and labeled, air-dried, partially ground and made to pass through 2 mm sieve. Dithionite Citrate Bicarbonate (DCB) extractable and ammonium oxalate soluble iron and aluminium oxides (Fe_2O_3 and Al_2O_3) were determined as described by Mckeague and Day (1966), respectively. Clay content was determined using Bouyoucous hydrometer method.

RESULTS AND DISCUSSION

Generally, the mounds found in the area were dominatly large sized constructed by Macrotermitinae nigeriensis Sjostedt. the texture of the mounds was generally sandy loam and brownish red (5YR 5/6) in colour. Mounds in Mokwa were much large in size than those in Kontagora whle density was higher in Kontagora. Themean density, height and base diameter of mounds were, 8 per ha, 4.89 and 3.06 m, respectively in Mokwa and 10 per ha, 2.93 and 1.88 m, respectivley in Kontagora. The mean intertemiterial distance was 26.82 and 17.19 m for Mokwa and Kontagora, respectively.

Table 1 and 2 shows the distribution of crystalline (Fe_d and Al_d) and amorphous (Fe_o and Al_o) forms of Fe and Al oxides and clay content of the termite-infested (pedon 1 and 2), non-infested (pedon 3) and termite mounds in both Kontagora and Mokwa. In pedon 1 and 2 of Kontagora, amorphous Fe oxides were 8.44 and 8.00 g kg^{-1} on the surface horizon, respectively and 7.11 and 9.78 g kg^{-1}, respectively in the subsoil (B-horizon). The crystalline form was both 8.89 g kg^{-1} for pedon 1 and 2, respectively in the surface horizon, but 13.33 and 9.78 g kg^{-1}, respectively in the subsoil (B-horizon). The amorphous form of Fe oxides in the infested was 8.00 and 8.89 g kg^{-1} while crystalline form was 9.78 and 10.67 g kg^{-1} on the surface and subsurface soils, respectively.

In Mokwa, the amorphous and crystalline forms of Fe oxides on the surface of the soils were 8.89 and 9.78 g kg^{-1} in pedon 1, 8.89 and 9.78 g kg^{-1} in 2 and 8.44 and 8.89 g kg^{-1} in pedon 3. Those of subsurface soil were respectively 6.22 and 7.56 g kg^{-1} in pedon 1, 6.67 and 8.00 g kg^{-1} in pedon 2 and 7.11 and 13.33 g kg^{-1}

Table 1: The distribution of amorphous and crystalline forms of Fe and Al oxides and clay content in the pedons and termite mounds in Kontagora

Horizondesignation	Depth (cm)	Al_o	AL_d	Fe_o	Fe_d	Al_o/Al_d	Fe_o/Fe_d	Clay $g\ kg^{-1}$	Fe_d/clay
		---------------------------g kg^{-1}			-------------------------------				
Termite infested (Plot 1)									
Ap	0- 20	7.27	8.63	8.44	8.89	0.84	0.95	62	0.14
AB	20-60	4.09	4.54	7.11	11.56	0.90	0.62	32	0.14
Bt	60-200	8.18	8.63	7.11	13.33	0.95	0.53	172	0.05
Termite infested (Plot 2)									
Ap	0-20	8.18	8.63	8.00	13.33	0.95	0.60	52	0.17
AB	20-60	7.73	8.63	8.00	10.12	0.90	0.79	32	0.27
BA	60-90	4.09	6.36	6.22	9.78	0.64	0.64	32	0.19
Bt	90-200	5.45	6.82	9.78	9.78	0.80	1.00	182	0.03
Termite infested (Plot 3)									
Ap	0-25	7.73	12.27	8.00	9.78	0.63	0.82	32	0.38
AB	25-40	6.45	6.82	8.89	10.67	0.95	0.83	62	0.11
BA	40-85	6.36	6.36	8.00	10.23	1.00	0.78	62	0.10
Bt	85-200	6.82	6.82	8.89	10.67	1.00	0.83	132	0.04
Termite mound									
		9.56	7.78	7.39	11.27	0.82	0.66	47.0	0.24

o = amorphous d = crystalline

Table 2: The distribution of amorphous and crystalline forms of Fe and Al oxides and clay content in the pedons and termite mounds in Mokwa

Horizon designation	Depth (cm)	Al_o	AL_d	Fe_o	Fe_d	Al_o/Al_d	Fe_o/Fe_d	clay $g\ kg^{-1}$	Fe_d/clay
		---------------------------g kg^{-1}			------------------------------				
Termite infested (Plot 1)									
Ap	0-10	7.73	9.09	8.89	9.56	0.85	0.93	62	0.15
AB	10-35	5.91	6.36	9.78	10.23	1.08	0.96	62	0.10
BA	35-115	4.09	6.82	10.67	12.00	1.67	0.89	32	0.21
Bt	115-145	4.09	6.82	6.22	7.56	1.67	0.82	102	0.07
Termite infested (Plot 2)									
Ap	0-20	6.82	8.18	8.89	9.78	1.20	0.91	42	0.19
AB	20-62	5.45	5.91	10.67	12.89	0.92	0.83	32	0.16
BA	62-150	4.54	5.91	8.00	8.89	0.77	0.90	42	0.14
E	150-200	6.36	9.09	6.67	8.00	0.70	0.83	42	0.22
Non-infested (Plot 3)									
Ap	0-20	7.27	8.63	8.44	8.89	0.84	0.95	42	0.21
AB	20-60	4.09	4.54	7.11	11.56	0.90	0.62	42	0.11
Bt	60-200	8.18	8.63	7.11	13.33	0.95	0.53	122	0.07
Termite mound									
		9.56	7.78	7.60	10.84	0.82	0.71	79.5	0.14

o = amorphous d = crystalline

in pedon 3. The amorphous form of Al oxides were 7.73 and 6.82 g kg^{-1} on the surface of pedon 1 and 2, respectively and 4.09 and 6.36 g kg^{-1} in the subsurface horizon of the infested (pedon 1 and 2, respectively). The crystalline form was 9.09 and 8.18 g kg^{-1} on the surface of pedon 1 and 2, respectively. In the non-infested pedons, amorphous and crystalline form was 7.17 and 8.63 g kg^{-1} on the surface and 8.18 and 8.63 g kg^{-1} respectively in the subsurface horizons of the pedons.

The mean amorphous form of Fe and Al oxide was 7.39 and 9.56 g kg^{-1}, respectively in Kontagora and 7.60 and 9.56 g kg^{-1}, respectively in Mokwa. The mean crystalline form of Fe- and Al-oxides was 11.27 and 7.78 g kg^{-1}, respectively in Kontagora and 10.84 and 9.78 g kg^{-1} Mokwa.

In the non-infested plots of each location, the crystalline (Fe_d) form of Fe increased with depth as a normal process for formation of argilic horizon for alfisols and ultisols (Soil Survey Staff, 2006). They have been found to be associated with clay (co-migration of the oxides with clay) according to Ogunsola *et al.* (1998), Agbenin (2003). The contrary was noticed in the infested plots where those (Fe_d) of the upper horizons were found to be higher (Mokwa plot 1 and 2, Kontagora plot 3). This could be attributed to the activity of termite as they remove soil material from the lower portions in the profile (preferentially B-horizons) for construction of their mounds. Some termite species ingest these materials for nutrition while others moisten the soil material with saliva before utilization for mound construction these materials when suddenly exposed to the atmospheric environment triggers oxidation reduction reaction and subsequent increase in the crystalinity of the mound material. These materials were continually eroded and redistributed on the upper positions in the profile leading to the increase in the crystalline form of Fe on the surface horizons. This has been seen as the effect of termites on the surrounding soils. The buildup of crystalline form of Fe oxides will lead to deterioration of soil characteristics and constitute management problems because they affect phosphorus sorption, soil reaction, soil structure and other physical and chemical properties.

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