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EFFECTS OF DIFFERENT AGGREGATES OF BAOBAB (*ADANSONIA DIGITATA* L.) TREES ON SOIL IN A SAVANNA ZONE OF GHANA

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ABSTRACT

The influence of three different aggregates of baobab stands on soil was investigated at Doba in a semi-arid area of northern Ghana with the aim of examining the different basal areas of the trees on some soil physico-chemical properties. A purposive sampling technique was used to select the baobab trees in natural stands categorized into highly-clumped, moderately-clumped and isolated stands and each stand type replicated three times. Each stand type was located within 20 m x 20 m of land with the clumped trees forming closed canopies. Soil samples were randomly collected from two depths (0-10 and 10-20 cm) under the canopies and outside the canopies of the baobab stands using auger and bulked on local site basis. Soil samples were air-dried, ground and sieved to pass through a 2-mm sieve and some physico-chemical properties determined using standard laboratory methods. The results indicated that the physical parameters especially, bulk density and gravimetric moisture content were similar under the three baobab stands whilst some chemical properties showed variations. The bulk densities of soils under the isolated, moderately-clumped and the highly-clumped stands were 1.76 ± 0.03, 1.68 ± 0.06 and 1.70 ± 0.01 g m^{-3}, respectively. The organic carbon, total nitrogen and exchangeable potassium contents of the soils under the three baobab canopies were higher than those of the soils of the nearby site. The study concludes that the baobab trees have improved the chemical properties of soils under their canopies.

Keywords: Baobab, canopy, loamy-sand, physico-chemical, soil, stand.

INTRODUCTION

Agricultural land-use activities pertaining to food crop production in the Kasena-Nankana East District of the Upper East Region in the semi-arid zone of Ghana are based on small land holdings system, which incorporates indigenous woody species as a component. Woody species, especially trees, play multiple functions in the system. The functional and service roles of trees and shrubs in the land-use system cannot be down played especially, considering the general semi-arid nature of the area.

Trees are generally known to perform multiple functions as far as soil productivity is concerned and many reports confirm enhanced soil properties under trees in the semi-arid areas. For example, Kellman (1979) reported a higher concentration of calcium, magnesium and potassium in soils under *Byrsonima crassifolia* canopy as compared to the soils in tree-less Savanna sites. Belsky *et al*. (1989) also reported higher levels of organic matter, available phosphorus, available calcium and potassium under *Adansonia digitata* in a semi-arid Savanna environment as compared to the open grassland. Kessler (1992) also reported an improved availability of water in soils under *Vitellaria paradoxa* and *Parkia biglobosa* canopies in a semi-arid Savanna, attributing this to a decrease in actual evapo-transpiration and a better infiltration under the canopy soils. Furthermore, Kater *et al.* (1992) reported significant higher levels in carbon, available potassium and magnesium under *Vitellaria paradoxa* and *Parkia biglobosa* as compared to the tree-less sites in Sahelian-savanna soils. Also, according to Akpo *et al*. (2005) organic matter level was two times higher in the surface soils under tree canopies than in the open in a semi-arid area.

Other evidences of soil improvement qualities of trees are reported elsewhere (Frost and Edinger, 1991; Schlesinger *et al*., 1996; Finzi *et al*., 1998). According to Lal and Greenland (1979) the presence of trees generally maintains or improves soil physical properties such as structure, porosity, moisture retention and erosion resistance. Also, trees tend to moderate the effect of leaching through the addition of bases to the soil surface

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(Stromgaard, 1991; Matthews *et al.*, 1992). Soil pH has also been reported to be reduced under *Acacia nilotica* and *Eucalyptus tereticornis* in the topsoil from pH 10.5 to 9.5over a five-year period (Gill and Abrol, 1986; Grewal and Abrol, 1986; Singh *et al.*, 1988).

The soil is a three-phase system of solid, liquid and gaseous components, each of which has its own physical and chemical properties, and are in an equilibrium or transient-state relationship. The liquid and gaseous phases are fairly homogeneous but the solid phase is heterogeneous. The solid phase consists of a range of different sized inorganic particles of silica, silicate clay, metal oxides and other minor components, all in varying degrees of association with different types of organic matter (Bannister, 1976).

The parklands in the semi-arid zone of Ghana are characterized by scattered and clumped trees/ shrubs dotted in the open fields. Many research activities are concentrated on the scattered trees to the neglect of the few clumped woody species that also probably have ecological impacts. The effect of clumped trees/shrubs on soil properties in semi-arid zone in Ghana has not been investigated or reported in literature so far. However, studies elsewhere have reported enhanced soil properties under scattered tree canopies. Furthermore, there is no information on whether increased tree density leads to enhanced soil properties. This study therefore, sought to examine the effects of three different aggregates (especially basal area) of baobab stands on some soil physical and chemical properties at Doba in a Savanna area of northern Ghana.

MATERIALS AND METHODS

Study area

The study was conducted at Doba, a community near Navrongo in the Kasena-Nankana East District of the Upper East Region of Ghana, a semi-arid zone. The study area is located on latitude 10º 54' N and longitude 01º 06' W. The vegetation of the area is Sudan savanna with short grasses interspersed with common tree species like *Vitellaria paradoxa*, *Ceiba pentandra*, *Adansonia digitata* and *Parkia biglobosa* (Taylor, 1960). Agriculture and other human activities did not permit the establishment of natural climax vegetation, but fire pro-climax vegetation is predominant in the area with a few species of fire-tolerant trees growing over a continuous understory of grass cover.

The climate of the area is influenced mainly by two air masses that affect the West African sub-region. Namely; the North East Trade winds and the Tropical Maritime winds. A clear-cut rainy season from May to October with a monomodal pattern and a dry season from November to April are the main features of the climate. The mean annual rainfall is between 750 and 1100 mm, with high temperatures throughout the year. The area also experiences abundant sunshine throughout the year, with mean relative humidity values (measured at 0600 GMT) ranging between 35 and 95% (Ghana Meteorological Service, unpublished data).

Selection of experimental baobab trees

A purposive sampling technique was used to select baobab trees in the natural stands based on three aggregation regimes of the stands into highly-clumped trees, moderately-clumped trees and isolated trees. These classifications were based on the results of tree inventory and reconnaissance survey carried out in the study area.The highly-clumped baobab trees consisted of six trees situated within 20 m x 20 m land area with closed canopy and the moderately-clumped trees were made up of three baobab trees situated within 20 m x 20 m land area. The isolated trees consisted of a single baobab situated within an area of 20 m x 20 m in which no other tree was found. The three tree stands were identified at three different sites and these served as replicates.

Determination of selected tree parameters

Tree height was determined by the use of a clinometer and the crown diameter was measured by determining the average diameter of the vertical projections of canopies in North-South and East-West directions (Peiler, 1994) using surveyor’s tape. The basal area at breast height was calculated whilst, the proportion of the crown occupied by foliage and branches was visually appraised.

Determination of light intensity under the baobab stands

The canopy area(s) beneath each baobab stand category was first divided into north, south, east and west cardinal points using a compass. Then, light intensities in the four cardinal points beneath the canopies were randomly determined using a hand-held light level Sensor Meter (E 30280/1 DK, Philip Harris Shenstone-England) with the aid of field assistants. This was measured at the same time (simultaneously) in all the different categories of baobab stand canopies. The measurements were taken at the hours between 11.45 am and 12.15 pm, duration of 30 minutes.

Soil sampling under and outside canopies of baobab stands

In order to investigate possible differences between soil properties under the canopies of the three baobab stands, soil samples were randomly collected at two depths (0-10 and 10-20 cm) under the canopies of the isolated, moderately-clumped and highly-clumped baobab stands using soil auger. The soil samples were bulked and sub-sampled on local site basis and sent to the laboratories of the Savanna Agriculture Research Institute (SARI) of the Council for Scientific and Industrial Research (CSIR) for analyses. The samples for bulk density were taken using metallic cylinders (100 cm^3 core sampler). Samples were also randomly taken from beneath the canopies for moisture content determination in the laboratory. Corresponding soil samples were also randomly collected from the control plots i.e. area without the influence of tree stands for laboratory analyses.

Determination of soil physico-chemical properties

Soil bulk density and texture were determined with methods of Blake and Hartge (1986) and Boyoucos (1962), respectively. Soil pH was determined in soil-water (1:2.5) suspension and measured by glass electrode pH meter. Soil organic carbon and total nitrogen were determined by the Walkley and Black procedure as described by Nelson and Sommers (1982) and Kjeldahl digestion and distillation procedure as described in the Soils Laboratory Staff (1982). Soil available phosphorus was determined by Bray-1-method (Bray and Kurtz, 1945). Exchangeable potassium was extracted by neutral acetate technique and measured by flame photometry. Cation exchange capacity (CEC) was measured using ammonium acetate at pH 7 whilst, soil gravimetric moisture content was determined using the oven-dry method at 105°C.

Data analysis

Normality of the data was tested before analyses and the data were analyzed using one-way analysis of variance (ANOVA) as well as paired t-test for comparison of means between the soil depths.

RESULTS

Characteristics of selected trees

The mean heights amongst the three different baobab stands were not significantly different (F = 0.90, df = 2, P = 0.418). The mean crown diameters amongst the three different baobab stands also did not show variation (F = 1.734, df = 2, P = 0.196) (Table 1).

Table 1. Characteristics of the three baobab stands.

Stand type	Height (m)	Crown diameter (m)	Proportion of crown volume occupied by foliage.	Basal area (m^2/ha)	Light intensity under canopies (10^3 lux)
Isolated baobab stands	14.2 ± 2.20^a	22.3 ± 2.59^a	0.89 ± 0.08^a	5.68 ± 1.06^a	4.59 ± 0.12^a
Moderately- clumped stands	11.3 ± 1.06^a	15.5 ± 2.19^a	0.90 ± 0.03^a	6.09 ± 0.23^a	4.62 ± 0.10^a
Highly- clumped stands	11.5 ± 0.81^a	16.3 ± 1.42^a	0.92 ± 0.06^a	21.67 ± 2.44^b	4.64 ± 0.11^a

Means in the same column accompanied by the same superscript do not differ significantly (Tukey, P < 0.05).

The proportion of crown volume occupied by foliage of the three different baobab stands did not show significant difference (F = 1.270, df = 2, P = 0.461) and similarly, the light intensity received under the three baobab stands also showed no significant differences (F = 1.319, df = 9, P = 0.321). However, the basal area of the three different baobab stands showed significant differences (F = 11.595, df = 9, P = 0.009), indicating that the highly-clumped stands had the highest basal area and the isolated baobab stands had the least basal area among the three stand types (Table 1).

Physical properties of soil under the canopies of the three baobab stands

There were no significant differences (F = 2.786, df = 12, P = 0.110) in the soil bulk density beneath the canopies of the three baobab stands as well as in the control plots. The trend of the mean values of soil bulk density in the three baobab stands and the control plots was similar (Table 2). The gravimetric soil moisture contents under the canopies of the three baobab stands and the control plots did not show significant difference (F = 1.865, df = 12, P = 0.214).

Also, sand content of the soils in both 0 – 10 cm (F = 0.655, df = 12, P = 0.602) depth and 10 -20 cm (F = 0.016, df = 12, P = 0.997) depth beneath the canopies of the three baobab stands and the control plots showed no significant differences. However, sand content in the soil between the two depths (i.e., 0-10 and 10-20 cm) under the isolated stands showed significant difference (t = 47.467, df = 5, P = 0.000). Also, sand content between the two depths under the moderately-clumped stands (t = 61.272, df = 5, P = 0.000) and highly-clumped stands (t = 33.046, df = 5, P = 0.000) showed differences, respectively. In the control plots, sand content of the soils from the two depths showed differences (t = 26.103, df = 5, P = 0.000).

Similarly, the silt contents of the soils in both 0 -10 cm (F = 1.040, df = 12, P = 0.426) depth and 10 - 20 cm (F = 0.344, df = 12, P = 0.795) depth beneath the canopies of the three baobab stands and the control plots did not differ. Contrarily, the silt content between the two depths under the isolated (t = 7.522, df = 5, P = 0.001), moderately-clumped (t = 10.880, df = 5, P = 0.000) and the highly-clumped stands (t = 6.540, df = 5, P = 0.001) as well as in the control plots (t = 8.108, df = 5, P = 0.000) showed differences.

Clay contents of the soils in both the 0 – 10 cm (F = 2.078, df = 12, P = 0.182) depth and the 10 -20 cm (F = 0.224, df = 12, P = 0. 877) depth beneath the canopies of the three baobab stands and the control plots did not show significant differences. The clay content of the soils however, showed differences at the two depths under the isolated (t = 4.449, df = 5, P = 0.007), moderately-clumped (t = 5.044, df = 5, P = 0.004), highly-clumped stands (t = 3.036, df = 5, P = 0.029) and the control plots (t = 2.246, df = 5, P = 0.057). The clay content of the soils in the 0 -10 cm depth followed the trend control> highly-clumped > moderately-clumped > isolated stands but in the 10 -20 cm depth, the trend was: control> highly-clumped > isolated > moderately-clumped stands (Table 2).

Table 2. Physical parameters of soil under the canopies of the three baobab stands.

Soil properties	Depth (cm)	Level of aggregation			
		Isolated stands	Moderately clumped	Highly-clumped	Control plot
Bulk density (gm^{-3})	-	1.76 ± 0.03[a]	1.68 ± 0.06[a]	1.70 ± 0.01[a]	1.81±0.03[a]
Moisture (%)	-	16.17±1.51[a]	15.94±3.99[a]	18.76±5.76[a]	9.51±2.27[a]
Sand (%)	0-10	87.80 ± 2.74[a]	85.49 ± 1.49[a]	83.19 ± 3.92[a]	87.18±0.97[a]
	10-20	83.18 ± 1.84[b]	84.23 ± 2.64[b]	83.00 ± 4.04[b]	83.52±7.02[b]
Silt (%)	0-10	10.45± 2.73[a]	12.35± 1.66[a]	14.51± 3.74[a]	8.65±0.41[a]
	10-20	12.34 ± 1.78[b]	11.72 ± 1.81[b]	11.89 ± 2.16[b]	9.62±2.44[b]
Clay (%)	0-10	1.75± 0.40[a]	2.16± 0.39[a]	2.31± 0.56[a]	4.17±1.26[a]
	10-20	4.48 ± 0.65[b]	4.05 ± 0.92[b]	5.11 ± 2.28[b]	7.19±5.30[b]
Textural class	0-10	Loamy sand	Loamy sand	Loamy sand	Loamy sand
	10-20	Loamy sand	Loamy sand	Loamy sand	Loamy sand

Means within a row and with the same superscript are not significantly different. Also, among sand, silt and clay, means in the same column accompanied by the same superscript do not differ significantly.

Chemical properties of soil under the canopies of the three baobab stands.

There were differences (F = 4.340, df = 12, P = 0.043) in the organic carbon content of the soil at the depth of 0 - 10 cm between the three baobab stands and the control plots (Table 3). The results showed that the organic carbon content of the soil in the 0 -10 cm depth of the highly-clumped stands was higher than that of the control plots. However, the three stands types were similar (F= 0.174, df = 9, P = 0.845). Also, in the 10 – 20 cm depth, the organic carbon content of the soil under the highly-clumped stands was higher (F = 4.728,df = 12, P =0.035) than that of the control plots while, the three stand types showed no differences (F = 3.140, df = 9, P = 0.117). In addition, the organic carbon content of the soils from the two depths (i. e., 0-10 cm and 10-20 cm) under the isolated (t = 4.345, df = 5, P = 0.007), moderately-clumped (t = 5.195, df = 5, P = 0.003) and the highly-clumped stands (t = 6.402, df = 5, P = 0.001) as well as in the control plots (t = 4.574, df = 5, P = 0.006) showed differences. The results showed that the surface soils contained more organic carbon than the subsurface soils irrespective of location (Table 3).

Total nitrogen (N) content of the soils from the 0 - 10 cm depth under the canopies of the three baobab stands and the control plots showed significant difference (F = 5.820, df = 12, P = 0.021). The results showed that the soils under the isolated and highly-clumped stands contained more total N than that under the controls. On the other hand, total N content of the soils from the 10 - 20 cm depth under the three baobab stands and the control plots did not show any significant differences (F = 0.283, df = 12, P = 0.836). Also, the total N content from the two depths (i. e., 0-10 cm and 10-20 cm) under the isolated (t = 22.723, df = 5, P = 0.000), moderately-clumped (t = 12.104, df = 5, P = 0.000) and the highly-clumped stands (t = 9.170, df = 5, P = 0.000) showed differences. On the contrary, the total N content of the surface soils from the control plots was not significantly different (t = 1.804, df = 5, P = 0.131) from that of the subsurface soils.

There were no differences in the soil available phosphorus (P) in both the 0 - 10 cm (F = 1.627, df = 12, P = 0.258) depth and 10 - 20 cm (F = 1.552, df = 12, P = 0.275) depth under the three baobab stands and the control plots. However, the available P showed differences at the two depths under the isolated (t = 3.220, df = 5, P = 0.023), moderately-clumped (t = 4.108, df = 5, P = 0.009), highly-clumped stands (t = 4.423, df = 5, P = 0.007) and the control plots (t = 10.082, df = 5, P = 0.000), respectively.

Exchangeable potassium (K) contents of the soils from the 0 - 10 cm depth under the canopies of the three baobab stands were significantly different (F = 15.764, df = 12, P = 0.001) from that of the control plots. On the contrary, the K content of soils from 10 – 20 cm of the control plots was not significantly different (F = 1.465, df = 12, P = 0.295) from that of the three baobab stands. Furthermore, the exchangeable K showed differences at the two depths under the isolated (t = 7.463, df = 5, P = 0.001), moderately-clumped (t = 4.237, df = 5, P = 0.008), highly-clumped stands (t = 4.165, df = 5, P = 0.009) and the control plots (t = 7.031, df = 5, P = 0.001), respectively.

The plots did not show any significant difference in cation exchange capacity (CEC) either at the 0 - 10 cm (F = 0.434, df = 12, P = 0.734) depth or 10 - 20 cm (F = 0.563, df = 12, P = 0.654) depth. Contrarily, the CEC showed significant differences between the two depths under the isolated (t = 11.010, df = 5, P = 0.000), moderately-clumped (t = 4.979, df = 5, P = 0.004), highly-clumped stands (t = 8.668, df = 5, P = 0.000) and the control plots (t = 9.783, df = 5, P = 0.000), respectively.

There were differences (F = 5.424, df = 12, P = 0.025) in soil pH in the 0 - 10 cm depth under the three baobab stands and the control plots. The soil pH value under the moderately-clumped sites was lower than that in the control plots. However, there was no difference (F = 2.154, df = 12, P = 0.172) in the soil pH in the 10 - 20 cm depth under the three baobab stands and the control plots. The result further showed that differences exist at the two depths under the isolated (t = 253.000, df = 5, P = 0.000), moderately-clumped (t = 57.375, df = 5, P = 0.000), highly-clumped stands (t = 233.739, df = 5, P = 0.000) and the control plots (t = 561.253, df = 5, P = 0.000), respectively. The results also showed that the trend of the mean pH values in the 0 – 10 cm depth under the three baobab stands and the control plots was: highly-clumped > isolated > control> moderately-clumped stands but the trend in the 10 -20 cm depth was: isolated > highly-clumped > control> moderately-clumped stands (Table 3).

Table 3. Chemical parameters of soil under the canopies of the three baobab stands.

Soil properties	Depth (cm)	Level of aggregation			
		Isolated stands	Mod-clumped	Highly-clumped	Control plot
Org. Carbon (%)	0-10	1.75 ± 0.14^{ab}	1.81 ± 0.42^{ab}	2.01 ± 0.35^{a}	0.65 ± 0.18^{b}
	10-20	0.58 ± 0.04^{ab}	1.04 ± 0.23^{ab}	1.25 ± 0.24^{a}	0.40 ± 0.14^{ab}
Total Nitrogen (%)	0-10	0.19 ± 0.01^{ac}	0.15 ± 0.03^{ab}	0.21 ± 0.04^{ac}	0.07 ± 0.01^{b}
	10-20	0.16 ± 0.00^{a}	0.16 ± 0.00^{a}	0.17 ± 0.00^{a}	0.26 ± 0.18^{a}
Available P (mg/kg)	0-10	18.93 ± 9.68^{a}	27.81 ± 9.60^{a}	9.17 ± 2.40^{a}	9.50 ± 1.63^{a}
	10-20	12.02 ± 3.18^{a}	20.64 ± 8.32^{a}	7.40 ± 3.33^{a}	8.70 ± 1.13^{a}
Ex'able K(cmol$^{(+)}$/kg)	0-10	155.00 ± 12.30^{a}	161.00 ± 11.07^{a}	144.67 ± 10.82^{a}	60.67 ± 13.01^{b}
	10-20	89.00 ± 9.83^{a}	57.33 ± 22.63^{a}	46.33 ± 9.75^{a}	60.33 ± 14.21^{a}
CEC (cmol$^{(+)}$/kg)	0-10	6.39 ± 0.31^{a}	5.75 ± 1.72^{a}	7.08 ± 0.68^{a}	5.70 ± 0.60^{a}
	10-20	5.66 ± 1.13^{b}	6.73 ± 2.16^{b}	4.56 ± 0.45^{b}	4.77 ± 0.93^{b}
pH, 1:2.5 (g/ml)	0-10	6.28 ± 0.02^{a}	5.92 ± 0.16^{b}	6.37 ± 0.03^{a}	6.27 ± 0.02^{a}
	10-20	6.37 ± 0.03^{b}	6.27 ± 0.02^{b}	6.32 ± 0.04^{b}	6.28 ± 0.02^{b}

Means within a row and with the same superscript are not significantly different (Tukey, P < 0.05).

DISCUSSION

Physical properties of soils under the canopies of the three baobab stands

In general, the bulk density values in this study were high under the canopies of the three baobab stands as well as in the control plots. The bulk density values ranged from 1.68 ± 0.06 g cm^{-3}under the moderately-clumped stands to 1.81 ± 0.03 g cm^{-3} in the control plots in this study. According to Arshad *et al.* (1996) the ideal bulk density value for loamy-sand soil should be less than 1.60 g cm^{-3} and value of 1.69 g cm^{-3} may affect plant root growth and bulk density greater than 1.80 g cm^{-3} would restrict root growth. Anthropogenic activities such as leaf plucking, gathering of fruit and medicinal products from the baobab trees by man could contribute to the high soil bulk density values near the trees. High bulk densities might also be due to compaction of the soils by domestic animals especially cattle that roam, rest and graze near the baobab trees for litter and falling fruits as well as in the control plots. Intense heat from the sun in the area could also lead to high soil bulk densities generally. Also, bulk density values of soils under the clumped stands were comparatively lower than those of the isolated stands and the control plots. This result was probably due to the intense shading of the clumped baobab stands which ameliorated the microclimate under the canopies since the general weather conditions particularly, solar radiation in the area is very intense throughout the year and could possible contribute to the hardening or compaction of the soils in the control plots and the isolated stands more than under the clumped stands.

In general, the top soils under the canopies of the three baobab stands contained high amounts of sand, ranging from 82.16 ± 3.95 % to 87.80 ±2.74 % and the amount decreased with depth. These results conform to Bashir and Amare (1991) results in semi-arid area in Kenya, who obtained mean sand fraction under trees canopies to be 86 %. The higher amounts of sand in the top soils could probably be linked to long-term soil forming processes including water and wind erosions that occur predominantly in semi-arid areas. Furthermore, Akpo *et al.* (2005) also reported that in a semi-arid area, sand fraction of a soil showed no particular trend with soil depth but under the shade of trees, soils contained more sand than those in the open. The finding in the present study did not agree with that of Akpo *et al.* (2005) because sand fraction decreased with soil depth and did not show any particular trend under the trees and the control plots.

Also, the silt contents ranged from 8.65 ± 0.41 % to 14.51 ± 3.74 % in the soils of the study area while, clay contents ranged from 1.75 ± 0.40 % to 7.19 ± 5.30 %. In this study, the silt content of the soils did not show any trend with soil depth but the clay content increased with depth. Akpo *et al.* (2005) also reported that in a semi-arid vegetation, all the soils that were sandy in texture, contained small amounts of silt and clay ranging from 12 to 18 % and the amount of clay in the soil increased with depth while, the amount of silt decreased with depth. The present findings agreed partially with that of Akpo *et al*. (2005) because the clay content in the soil increased with soil depth but the silt content did not decrease with the soil depth generally.

Chemical properties of soils under the canopies of the three baobab stands

In general, the trend in the chemical properties of the soils particularly, organic carbon, total nitrogen and available phosphorus contents among the three baobab stands did not show differences. The differences occurred between the two depths (i.e. 0-10 cm and 10-20 cm) under each stand type. The similarity in the chemical properties of the soils under the three baobab stands might be due to the fact that the species were the same and the degree to which a tree influences the productivity of soils may not be dependent on the density or the number of trees but the quality of the litter inputs. Bashir and Amare (1991) found no significant difference in soil organic carbon, potassium, calcium, phosphorus and pH under eight different tree densities in a study in semi-arid Kenya. The present finding, to some extent, agrees with some of the results of Bashir and Amare (1991). This result might be attributed to the fact that trees produce nutrients under their canopies through litter fall together with additions from sources such as pumps from the deeper layers and trapping with the aid of their rooting systems (Akpo *et al*., 2005).

The results of the study also showed higher amounts of organic carbon, total nitrogen and exchangeable potassium under the baobab stands than from the control plots. These findings agreed with the reports by Belsky *et al*. (1989) who had reported higher levels of organic matter and potassium under *Adansonia digitata* (Baobab) in a semi-arid Savanna environment. Similarly, Kellman (1979) had reported a significantly higher concentration of potassium in soils under *Byrsonima crassifolia* canopies than areas without trees in a Savanna environment. Furthermore, Kater *et al.* (1992) found significant higher amounts of organic carbon and available potassium under *Vitellaria paradoxa* and *Parkia biglobosa* as compared to the tree-less sites in Sahelian-savanna soils. All these go to support the general assertions and findings that trees enhance the productivity of soils by adding humus-rich materials to the soils beneath their crowns. Many researchers have also reported horizontal gradient from the tree trunks to the periphery in terms of soil enhancement properties of trees (Bernhard-Reversat, 1982; Belsky *et al*., 1989; Weltzin and Coughenour, 1990). Thus, trees enhance soil properties is in consistent with results obtained in other semi-arid regions of the world (Radwanski and Wickens 1967; Belsky *et al.,* 1989). Increases in chemical properties of soils and for that matter fertility under trees seem to be related to tree litter and organic matter accumulation under trees (Bernhard-Reversat, 1982). Other ways of increasing nutrients under trees could be through precipitation (Kellman, 1979), redistribution of nutrients from lower to upper horizons (Charley and Cowling, 1986) and the droppings of domestic and wild animals resting under the trees. Treca *et al.* (1996) reported that birds recycled 12.8 kg of nitrogen per hectare and 0.9 kg of phosphorus per hectare and also produced 186 kg ha^{-1} of organic matter from the grasses utilized by their nests under tree canopies.

The mean soil pH values in the 0-10 cm depth under the canopies of the three baobab stands ranged from 5.92 ± 0.16 to 6.37 ± 0.03 while they ranged from 6.27 ± 0.02 to 6.37 ± 0.03 in the 10-20 cm depth. Belsky *et al*. (1989) reported a mean pH value for soils under baobab trees in a semi-arid Savanna in Kenya to be 6.3. The results of this study agreed with that of Belsky *et al*. (1989), implying that soils under baobab canopies might be slightly acidic to almost neutral. Also Peiler (1994) reported mean pH values under the canopies of *Vitellaria* and *Parkia* trees in a Savanna zone as 6.2 and 6.0, respectively. These results could be attributed to the ecosystem characteristics in which the general soil types influence the pH level. For example, in the Savanna soils of Ghana especially the Ochrosols, soil reaction ranges from near neutral to neutral, in the A horizon, becoming slightly to moderately acidic with depth (Obeng, 1971).

In this study, the total N content of the soils decreased with depth under both isolated and highly-clumped stands whilst, under the moderately-clumped stands, a reverse trend occurred. Akpo *et al*. (2005) also reported that nitrogen content of soils under tree shade tend to decrease with depth. Thus, the findings in the present study partly agree with the trend observed by Akpo *et al*. (2005) that nitrogen content decreased with soil depth under trees shade.The decomposition of litter provided by the tree canopies and other organic materials could result in higher topsoil total N content. The present study showed that while the distribution of total N in the soils under the isolated and the highly-clumped stands agreed with those of Akpo *et al*. (2005), those of the soils under the moderately-clumped baobab stands did not.

The mean CEC values of the soils which ranged from 4.56 ± 0.45 c mol (+) kg^{-1} to 7.08 ± 0.68 c mol (+) kg^{-1} under the canopies of the three baobab stands could be described as optimum since the CEC of soils in the area especially, the Savanna Ochrosols range between 1.0 and 15.0 c mol (+) kg^{-1}. Release of nutrients from the tree litter to the soil could also explain the CEC values obtained under the canopies. Trees in general tend to moderate the effects of leaching through the addition of bases to the soil. Thus, cations such as K^+ and Ca^{2+} would be readily available in the soils under the canopies of the baobab stands.

CONCLUSION

From the results of this study, baobab trees enhanced the chemical properties of the soils under their canopies than in the control plots. Thus, soil fertility enhancement properties of baobab trees have been shown by the results of this study. The soils under the canopies of the three baobab stands showed higher values of organic carbon, total N and exchangeable K than in the control plots. The soils in the study area under the various baobab stands canopies and in the control plots, were slightly acidic to almost neutral. The soils contained very high amounts of sand making them predominantly loamy sand in texture under both the canopies of the three baobab stands and in the control plots.

The bulk density of the soils in the study area was generally high but did not appear to adversely affect root growth as natural vegetation and cultivated crops were found growing near and under the various baobab stands.

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