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EVALUATION OF SOIL PHYSIO-CHEMICAL PROPERTIES UNDER A YOUNG *ALBIZIA LEBBECK* (RATTLE TREE) PLANTATION IN A SAVANNA ECOSYSTEM

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The use of agroforestry practice as a source of improving soil quality was studied with the aim of assessing the effect of six-year-old *Albizia lebbeck* on soil. The experiment was laid out on a randomised complete block design comprising of five treatments and three replicates at 0–15cm and 15–30 cm depths. The soil physio-chemical properties were estimated using standard analytical procedures. The result revealed increase in clay and decrease in silt and sand contents, down the depth. The silt clay ratio indicated young soil with high weathering potential. The control favoured macro-aggregate (0.881), while *A. lebbeck* and 10 t ha^{-1} green manure favoured micro-aggregate. Mean weight diameter showed that the control (0.910) was more stable than other treatments. Organic carbon, organic matter, total nitrogen and carbon to nitrogen ratio were not significantly influenced, while phosphorus was at 15–30 cm depth, influenced by *A. lebbeck.* Soil pH was slightly acidic but suitable for plant production, and change in pH was negative indicating the exchangeable capacity of the soil. All the soil quality indicators studied were low. Therefore, in choosing *A. lebbeck* as an alternative source of improving soil quality production, the factors evaluated should be tree age, incorporation method, soil stability and other cultural practices like tillage operation.

Keywords: *Albizia lebbeck*, savanna, ecosystem, green manure, soil nutrient, agroforestry

INTRODUCTION

Unsustainable soil fertility and productivity are the fundamental biophysical causes for the declining food production in sub-Saharan African countries in general, and Nigeria in particular (Sanchez et al. 1997). This is largely due to the inherent condition of the soils of Africa as well as the prevailing environmental conditions. Many Nigerian soils are highly weathered and leached, characterised by low levels of organic carbon (OC) and nitrogen (N) (Padwick 1983, Chude et al. 2011, Idoga 2014). The situation is further worsened by continuous cultivation without preserving the soil, erratic climatic conditions, poor agronomic practices and low return of organic residues into the soil, resulting to crop yield reduction and increased soil degradation (FAO 2017, Ayoubi et al. 2018)). Measures have been sought to furnish soil nutrients and improve productivity by practices such as shifting cultivation and bush fallow, as well as the use of compost, manure and chemical (inorganic) fertilisers. However, the supplies of organic manures are inadequate and the chemical fertilisers are costly (Young 1997). Thus, the associated yield reduction, soil acidity and nutrient imbalance constitute major constraints to these measures (Kang & Juo 1980).

In recent times, the use of green manure and agroforestry system for the improvement of environmental conditions and public health, as well as to reduce costs of fertilising crops have been advocated. According to Young (1997), agroforestry is a land-use practice where woody perennial and/or herbaceous plants are grown with or without livestock to derive both ecological and economic benefits from the tree and non-tree components of the system. Its greatest potential lies in its capacity to supply and maintain ground cover. The tree canopy supplies leafy materials through litterfall or pruning, in the form of green manure, to maintain surface cover. This plays an important role in maintaining desirable soil physical properties (higher water holding capacity, good permeability and greater erosion resistance), improve soil nutrient status, better micro-climate and improved rate of mineralisation. Tewari (1995) and Kareem (2015) reported higher yields obtained from agroforestry practices, as a result of the improved use of environmental resources and plant nutrients.

Kareem (2007) reported that nitrogen-fixing trees such as *Albizia lebbeck* could be incorporated into the agroforestry system as its pruning, in the form of green manure and mulch, provide an economical source of nitrogen. In addition, the high litterfall and the ease of decomposition of the *A. lebbeck* leaves contribute to the OC content of the soil, thereby, improving the soil quality. Imoro et al. (2012) reported the potential of *A. lebbeck* to reduce soil pH from highly alkaline (9.96) to slightly alkaline or neutral (7.24), and to increase nitrogen (0.10 to 2.38%), OC (1.21 to 1.87%) and phosphorus (P) (4.35 to 5.46 mg Kg^{-1}), compared to a control plot. However, according to Singh et al. (2004), the amount of nitrogen and phosphorus deposition through leaf fall and release of these nutrients largely depends on the age of the plantation. Presently, limited research has been done to evaluate the nutrient status of soil under the *A. lebbeck* plantations. Thus, this research aims to evaluate the effect of *A. lebbeck* green manure on the physio-chemical properties of the soil in a plantation where the *A. lebbeck* trees are planted in rows.

MATERIALS AND METHODS

Study site

The study was carried out in the Teaching and Research Farm of the Department of Agricultural Extension and Management, Federal College of Forestry, Bauchi Road, Jos, Plateau State, Nigeria. The Jos Plateau lies between latitude 8° 50' N and 10° 10' N and longitude 8° 22' E and 9° 30' E (Udo 1978). The Jos is located in the Northern Guinea Savanna Zone, but has distinctive features that differ from the rest of the Zone (Keay 1959). The average elevation is about 1200 m above sea level with its surrounding plains having an elevation of about 600 m above sea level. The state is bounded by low plains; Bauchi plains at the Northeast, Jama'a plains at the Northwest and Benue lowlands at the South (Keay 1951, Hill 1978, Eziashi 1995). The mean annual rainfall is 1400–2000 mm and the annual temperature ranges between 10 and 32 °C (FCF 2015). The soil is sandy, light to darkish colour, well-drained and aerated, and classified mainly as ultisols.

Experimental site description

The site was established initially to study the effect of rattle tree (*A. lebbeck)* on soil properties and productivity of Irish potato (*Solanum tuberosum*) in Jos Plateau, Nigeria (Kareem 2007). Five treatments were used with three replicates, each laid out in randomised complete block design (RCBD). The treatments were:

Treatment 1: green manure (as mulch) at 5 tonnes $hectare^{-1}$ without tree rows of *A. lebbeck*
Treatment 2: tree rows of *A. lebbeck* and 5 tonnes $hectare^{-1}$ of green manure
Treatment 3: tree row of *A. lebbeck* without green manure
Treatment 4: tree row of *A. lebbeck* and 10 tonnes $hectare^{-1}$ of green manure
Treatment 5: control, without green manure or tree rows of *A. lebbeck*

The *A. lebbeck* seedlings were planted in rows at 15 cm depth having inter-tree row spacing of 2 m, for treatments 2, 3 and 4. Green manure of *A. lebbeck* was incorporated at land preparation two weeks before planting the test crop for treatments 2 and 4, and in treatment 1 green manure of *A. lebbeck* was applied as leaf mulch. This was evenly spread on the alley two weeks before planting, at the rate of 5 tons ha^{-1}. Okonkwo et al. (1995) and Oloyede (1994) suggested the use of forest tree foliage as green manure for improving productivity. Details of land preparation and demarcation, as well as raising of *A. lebbeck* seedlings, preparation, application and quantities of green manure of *A. lebbeck* used have been outlined (Kareem 2007, Kareem 2015).

The experimental layout was maintained for this study and soil was sampled at two depths (0–15 cm and 15–30 cm). These depths were chosen to cover the active root depth of the young tree, in line with the SERA 17 guidelines for agronomic and environmental sampling (Vadas et al. 2005). At least three sample points were established in each replicate, at each depth, and using a soil auger, bulked and composite samples were taken. A total of 30 samples were taken from the field for laboratory analysis.

Determination of soil parameters

Soil samples collected from the three replicates in each treatment/plot at 0–15 cm and 15–30 cm depths were analysed in the laboratory for particle and wet aggregate size distribution, soil organic carbon (SOC), total nitrigen (TN), soil pH and P. Particle size distribution was determined by the hydrometer method using sodium hexametaphosphate as a dispersing agent (Gee & Or 2002). The textural classes were determined with the aid of the USDA textural triangle. Silt clay ratio (SCR) was also calculated to evaluate clay migration, stage of weathering, and soil susceptibility to detachment and transportation (Yakubu et al. 2008). Wet aggregate size distribution was determined by the slaking method (Elliott 1986). The aggregate size stability characterised by mean weight diameter (MWD) was defined according to van Bavel (1950) as:

$$\text{MWD} = \sum_{i=1}^{n} x_i \, \omega_I \qquad [1]$$

where x_i = mean diameter of any particular size range of aggregate separated by sieve, ω_I = weight of aggregate in the size range as a fraction of the total dry weight of sample.

The SOC was analysed by the Walkley/Black procedure (Nelson & Sommers 1982). The percentage of organic matter (OM) content in the samples was calculated by multiplying the value of SOC by the conventional van Bammeller factor of 1.724. The TN was determined by the macro Kjeldahl method (Bremner 1996). The ratio of carbon to nitrogen was also calculated to determine mineralisation and immobilisation of nitrogen as an indication of OM decomposition stages (Ukaegbe et al. 2015). Soil pH in water and calcium chloride was determined in a 1:2.5 solution (soil:distilled water and calcium chloride) and was measured by the glass electrode pH meter (Mclean 1982). Change in pH (ΔpH) was calculated to determine the exchangeable capacity of the soil:

$$\Delta\text{pH} = \text{pH}(\text{CaCl}_2) - \text{pH}(\text{H}_2\text{O}) \qquad [2]$$

Phosphorus was extracted using the Bray II method as outlined in Olsen (1982).

Data analysis

The data collected from the experiment were analysed using analysis of variance (ANOVA) for randomised complete block design. Duncan multiple range tests (DMRT) were used to rank the treatment means while the least significant difference (LSD) at $p < 0.05$ was used to determine the probability level of significance. The coefficient of variation (CV) expressed as the magnitude of variability was ranked according to Shukla et al. (2004) into different classes: low (< 15%), medium (15–35%), and high (> 35%). Statistical analysis was carried out in R (2021) and Microsoft Exel (2016) software.

RESULTS AND DISCUSSIONS

Physical properties of soils in the studied area

The particle size distribution of the studied area at 0–15 cm depth (Table 1) was significantly different ($\rho < 5\%$) across the three soil fractions (clay, silt and sand). *Albizia lebbeck* and 10 t ha^{-1} of green manure (ALTGM) recorded the highest clay and silt contents (20%), while green manure alone (GM) recorded the least clay content (11.33%) and *A. lebbeck* and 5 t ha^{-1} of green manure (ALFGM) had the least silt content (12.67%). Sand content was highest in ALFGM (74.66%) area and least in the ALTGM (60.00%) area. The soil textural triangle shows that the soil is sandy loam in nature while the silt clay ratio (SCR) was significantly similar among the five treatments. In the same vein, a significant difference was observed in the aggregate size distribution (Table 1) except in the micro aggregate size (< 0.05 mm) which was significantly the same across the treatments.

Table 1 The physical properties of the study area at 0–15cm depth

Treatment	Particle size distribution				SCR	Aggregate size distribution			
	Clay (%)	Silt (%)	Sand (%)	Textural class		2–0.25 mm	0.25–0.05 mm	< 0.05 mm	MWD
Green manure alone	11.33^{c}	16.00^{ab}	72.67^{ab}	Sandy loam	1.47^{a}	0.731^{bc}	0.027^{b}	0.003^{a}	0.762^{ab}
Albizia lebbeck and 5 t ha^{-1} of green manure	12.67^{c}	12.67^{b}	74.67^{a}	Sandy loam	1.00^{a}	0.803^{ab}	0.026^{b}	0.003^{a}	0.832^{ab}
Albizia lebbeck alone	18.67^{ab}	19.33^{a}	62.00^{ab}	Sandy loam	1.03^{a}	0.658^{c}	0.033^{a}	0.004^{a}	0.695^{b}
Albizia lebbeck and 10 t ha^{-1} of green manure	20.00^{a}	20.00^{a}	60.00^{b}	Sandy loam	1.00^{a}	0.653^{c}	0.038^{a}	0.004^{a}	0.695^{b}
Control	15.33^{bc}	18.00^{ab}	60.00^{b}	Sandy loam	1.24^{a}	0.881^{a}	0.025^{b}	0.004^{a}	0.910^{a}
p-value	4.10**	6.84*	14.34*		0.69^{ns}	0.130	0.005**	0.001^{ns}	0.138**
CV	25%	24%	14%		32%	15%	21%	16%	14%

SCR = silt clay ratio, 2–0.25 mm = macro-aggregate, 0.25–0.05 mm = meso-aggregate, < 0.05 mm = micro-aggregate, MWD = mean weight diameter, CV = coefficient of variation, ** = significant at $\rho < 1\%$, * = significant at $\rho < 5\%$ and ns = non-significant

Macro-aggregate size (2–0.25 mm) highest value was observed in control (0.881) and the least value was obtained under ALTGM (0.653), while meso-aggregate (0.25–0.05 mm) values was in reverse order, ALTGM had the highest value (0.038) and control the least value (0.025). It was also observed that control had the highest value of MWD (0.910) with a trend ALFGM (0.832) > GM (0.762) > AL (0.695) and ALTGM (0.695). The result of the CV is presented in Table 1, indicating that sand, macro-aggregate (2–0.25 mm), and MWD ranked low, while clay, silt and SCR, meso-aggregate (0.25–0.05m) and micro-aggregate (< 0.05 mm), ranked medium.

The results of the particle size distribution and aggregate size distribution at 15–30 cm depth are presented in Table 2. The clay and sand contents are significantly different at ρ-value < 5% while the silt content is similar across the five treatments. *Albizia lebbeck* alone (AL) recorded the highest clay percentage (25.33%) and the least sand percentage (58.67%), while ALFGM recorded the least clay percentage (16.67%) and the highest sand percentage (73.33%). The subsurface soil is also sandy loam in nature. The SCR was less and significantly the same across the treatments. The aggregate size distribution showed no significant different in the macro-aggregate (2–0.25 mm), meso-aggregate (0.25–0.05 mm) and the mean weight diameter, while a significant difference was observed in the micro-aggregate at ρ-value of 5%. The control had the highest value of 0.0062 while ALFGM had the least value of 0.0026. Results of the coefficient of variation (CV) showed that sand content, macro-aggregate, meso-aggregate and MWD ranked low, while clay content, silt content and SCR ranked medium, and micro-aggregate ranked high.

The result of the comparison of the topsoil to subsoil physical properties (Figure 1) showed that clay fraction consistently increased with depth across the treatments, while silt and sand fractions decreased with depth. The soil is sandy loam both at the top and sub-surfaces which is an indication of the extent of soil formation of the study area. The silt/clay ratios were also higher on the top which is due to increased clay content in the subsoil than in the topsoil. The aggregate size distribution had an irregular distribution pattern among the treatments. Under the macro-aggregate and MWD, the GM, ALFGM and control had higher values in the topsoil, while AL and ALTGM had higher values in the subsoil. Meso-aggregate consistently recorded higher values in the subsoil and micro-aggregate had higher values in topsoil treatments (GM, ALFGM, AL and ALTGM), and higher values in the subsoil for control.

Table 2 The physical properties of soil sampled at depth 15–30 cm

Treatment	Particle size distribution				SCR	Aggregate size distribution			
	Clay (%)	Silt (%)	Sand (%)	Textural class		2–0.25 mm	0.25–0.05 mm	< 0.05 mm	MWD
Green manure alone	18.67^{ab}	12.67^{a}	68.67^{ab}	Sandy loam	1.47^{a}	0.709^{a}	0.037^{a}	0.0028^{b}	0.750^{a}
Albizia lebbeck and 5 t ha^{-1} of green manure	16.67^{b}	10.00^{a}	73.33^{a}	Sandy loam	1.00^{a}	0.727^{a}	0.034^{a}	0.0026^{b}	0.764^{a}
Albizia lebbeck alone	25.33^{a}	16.00^{a}	58.67^{b}	Sandy loam	1.03^{a}	0.705^{a}	0.035^{a}	0.0027^{b}	0.743^{a}
Albizia lebbeck and 10 t ha^{-1} of green manure	21.33^{ab}	14.00^{a}	64.67^{ab}	Sandy loam	1.00^{a}	0.681^{a}	0.039^{a}	0.0033^{ab}	0.724^{a}
Control	23.33^{ab}	16.00^{a}	60.67^{ab}	Sandy loam	1.24^{a}	0.709^{a}	0.032^{a}	0.0062^{a}	0.746^{a}
p-value	7.22**	6.58^{ns}	13.19**		0.69^{ns}	0.109^{ns}	0.009^{ns}	0.003*	0.105^{ns}
CV	22%	28%	13%		16%	8%	14%	54%	7%

SCR = silt clay ratio, 2–0.25 mm = macro-aggregate, 0.25–0.05 mm = meso-aggregate, < 0.05 mm = micro-aggregate, MWD = mean weight diameter, CV = coefficient of variation, ** = significant at $\rho < 1\%$, * = significant at $\rho < 5\%$ and ns = non-significant

The increasing pattern of clay content with depth could be attributed to vertical migration of clay, predominant *in situ* pedogenetic formation of clay in the subsoil, and destruction of clay in the surface horizon, synthesis of secondary clay and the weathering of primary minerals (Chadwick & Grahm 2000, Buol et al. 2003, Chukwu 2013, Sekhar et al. 2014, Kebede et al. 2017, Adegbite et al. 2019, Lelago & Buraka 2019, Osujieke et al. 2020). The decreasing pattern of silt and sand content with respect to depth across the treatments are probably due to parent material rich in quartz mineral, and geological processes of soil materials degradation by biological/agricultural activities, clay migration through eluviation and illuviation, or surface erosion by runoff or their combinations (Malgwi & Abu 2011). The rate of variation could be associated with a similarity in the parent material and climatic factors in the soils of Nigeria (Osujieke et al. 2020). The current findings were in agreement with the results reported by Chikezie et al. (2009) but contradicted the findings of Imadojemu et al. (2017) in the soils of Northeast Nigeria. The silt/clay ratio is used as a yardstick to evaluate clay migration, stage of weathering and age of parent material of soils (Young 1976, Yakubu et al. 2008). The SCR of less than 1.00, as obtained in the subsoil, could mean that these soils had undergone ferralitic pedogenesis, while the topsoil recording SCR of more than 1.00 is an indication of a young soil. The SCR above 0.15 is an indication of young parent material and above 0.2 is an indication of high weathering potentials (Ayolagha 2001). The SCR of the studied area is above 0.2 as reported by Northern Nigeria researchers (Yakubu et al. 2008, Idoga 2014, Osujieke et al. 2020). This could be related to the isohyperthermic temperature regime of the area which encourages high, intense weathering and textural composition of the soil.

The result of the aggregate size distribution suggested that control had more macro aggregate at 0–15 cm depth than other treatments, while treatments of *A. lebbeck* and 10 t ha^{-1} of green manure recorded the highest micro aggregate. This is because macro aggregates are highly susceptible to disruption by tillage operation, thereby, making them more dependent on cultural practices. The low structural stability (MWD) of studied soil may be attributed to the disturbance by cultivation operations, which disrupt aggregates and expose the occluded and physically-protected OM pools to rapid decomposition (Ayoubi et al. 2012, Zeraatpisheh et al. 2021).

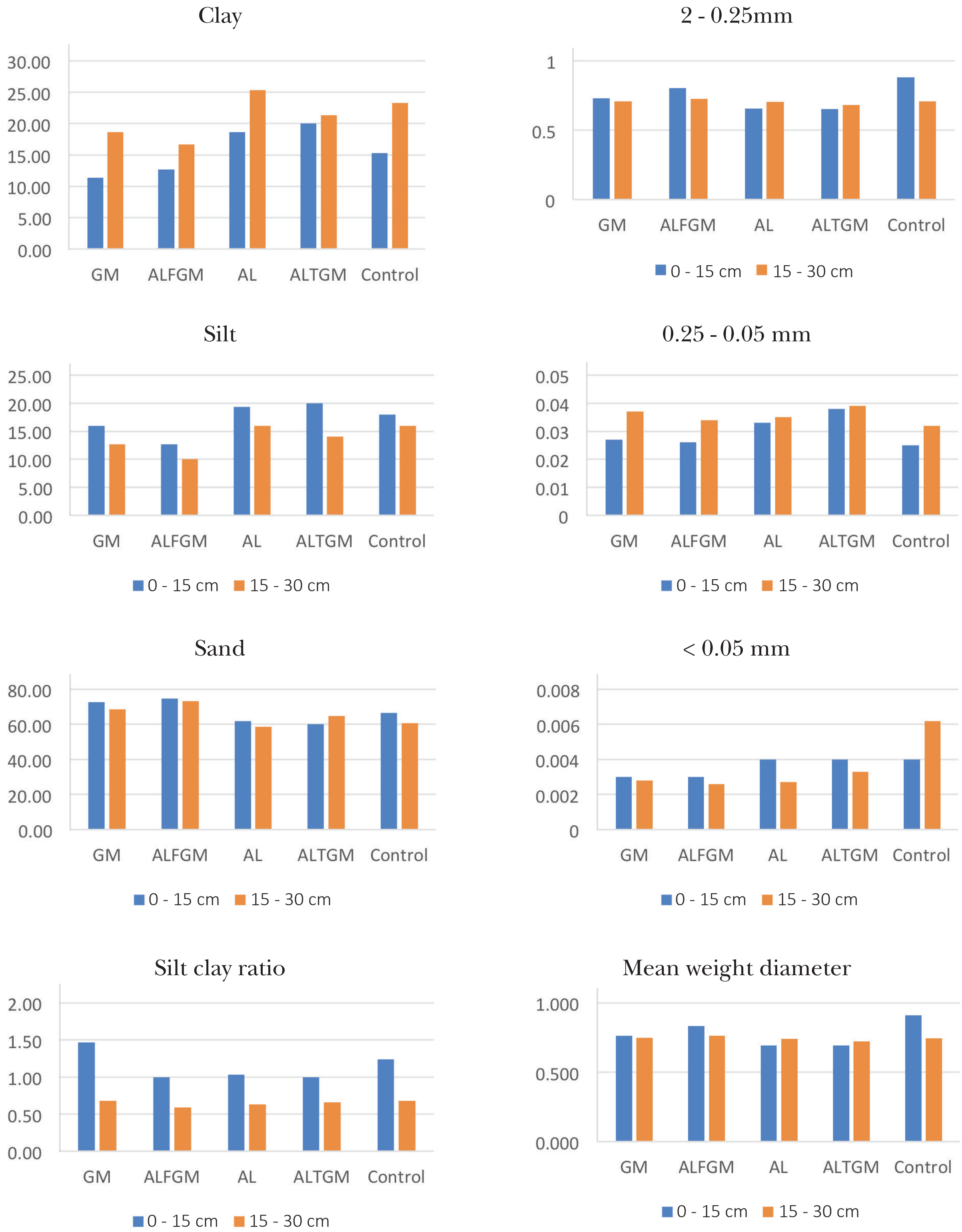

Figure 1 Comparison of the mean values of physical properties of soil at 0–15 cm and 15–30 cm depths GM = green manure, ALFGM = *Albizia lebbeck* and 5 t ha^{-1} green manure, AL = *Albizia lebbeck*, ALTGM = *Albizia lebbeck* and 10 t ha^{-1} green manure

Chemical properties of soils in the studied area

The results of chemical properties at 0–15 cm depth are presented in Table 3. The OC, OM, TN, carbon to nitrogen ratio (C:N) and P are significantly the same with their coefficient of variation ranked medium according to Shukla et al. (2004) ratings. The soil reaction (pH in water and calcium chloride) was significantly different with of low variation of 2% across the treatments. Selected soil chemical characteristics at 15–30 cm depth are indicated in Table 4. The OC, OM, N, C:N and pH(H_2O) were similar among the five treatments. Soil pH in calcium chloride ($CaCl_2$), ΔpH and phosphorus recorded significant differences at different probability levels. Their variations also differ; pH in water and $CaCl_2$ ranked low, OC, OM and ΔpH ranked medium while N, C:N and P ranked high, according to Shukla et al. (2004) ratings. Comparing the soil properties of the two soil depths (Figure 2), results showed that OC, OM and N decreased with depth except under GM which increased with depth. The C:N recorded high values on the top surface soil under GM, AL and ALTGM with high values in the subsurface soil under ALFGM and control. Soil pH had high values on the topsoil under GM and ALFGM, equal values under AL and ALTGM, and high values in the subsurface soil. The P values decreased consistently with depth among the five treatments.

Table 3 The chemical properties of soil samples at depth 0–15 cm

Treatment	OC (%)	OM (%)	TN (%)	C:N	pH(H_2O)	pH($CaCl_2$)	ΔpH	P (ppm)
Green manure alone	0.71^{a}	1.23^{a}	0.070 ^{a}	11.20^{a}	5.90^{a}	4.80^{b}	-1.10c	10.79^{a}
Albizia lebbeck and 5 t ha^{-1} of green manure	0.75^{a}	1.29 ^{a}	0.076 ^{a}	10.81^{a}	5.87^{a}	4.80^{b}	-1.07^{bc}	9.34^{a}
Albizia lebbeck alone	0.93^{a}	1.60 ^{a}	0.064 ^{a}	14.64^{a}	5.63^{b}	4.77^{b}	-0.87^{ab}	7.00^{a}
Albizia lebbeck and 10 t ha^{-1} of green manure	0.92^{a}	1.59 ^{a}	0.070 ^{a}	13.89^{a}	5.63^{b}	4.87^{ab}	-0.77^{a}	8.17^{a}
Control	0.62^{a}	1.07 ^{a}	0.064 ^{a}	12.47^{a}	5.67^{b}	5.00^{a}	-0.67^{a}	7.00^{a}
p-value	0.31^{ns}	0.54^{ns}	0.041^{ns}	10.46^{ns}	0.14**	0.17*	0.20**	5.33^{ns}
CV	24%	24%	30%	40%	2%	2%	22%	34%

OC = organic carbon, OM = organic matter, TN = total nitrogen, C:N = carbon nitrogen ratio, pH(H_2O) = pH in water, pH($CaCl_2$) = pH in calcium chloride, ΔpH = differences in pH, P = phosphorus, CV = coefficient of variation, ** = significant at $\rho < 1\%$, * = significant at $\rho < 5\%$ and ns = non-significant

Table 4 Showing the chemical properties of soil samples at depth 15–30 cm

Treatment	OC (%)	OM (%)	TN (%)	C:N	pH(H_2O)	pH($CaCl_2$)	ΔpH	P (ppm)
Green manure alone	0.73^{a}	1.25^{a}	0.09^{a}	10.29^{a}	5.67^{a}	4.53^{c}	-1.13^{c}	8.17^{a}
Albizia lebbeck and 5 t ha^{-1} of green manure	0.69^{a}	1.19 ^{a}	0.05^{a}	15.41^{a}	5.73^{a}	4.77^{b}	-0.97^{bc}	7.29^{ab}
Albizia lebbeck alone	0.61^{a}	1.06 ^{a}	0.05^{a}	13.45^{a}	5.63^{a}	4.77^{b}	-0.87^{ab}	5.92^{ab}
Albizia lebbeck and 10 t ha^{-1} of green manure	0.56^{a}	0.96 ^{a}	0.05^{a}	11.94^{a}	5.63^{a}	4.83^{b}	-0.80^{ab}	5.54^{ab}
Control	0.55^{a}	0.96 ^{a}	0.04 ^{a}	15.81^{a}	5.73^{a}	5.03^{a}	-0.70^{a}	4.38^{b}
p-value	0.21^{ns}	0.36^{ns}	0.06^{ns}	9.38^{ns}	0.21^{ns}	0.13**	0.22**	3.65*
CV	19%	19%	63%	36%	2%	4%	20%	46%

OC = organic carbon, OM = organic matter, TN = total nitrogen, C:N = carbon nitrogen ratio, pH(H_2O) = pH in water, pH($CaCl_2$) = pH in calcium chloride, ΔpH = differences in pH, P = phosphorus, CV = coefficient of variation, ** = significant at $\rho < 1\%$, * = significant at $\rho < 5\%$ and ns = non-significant

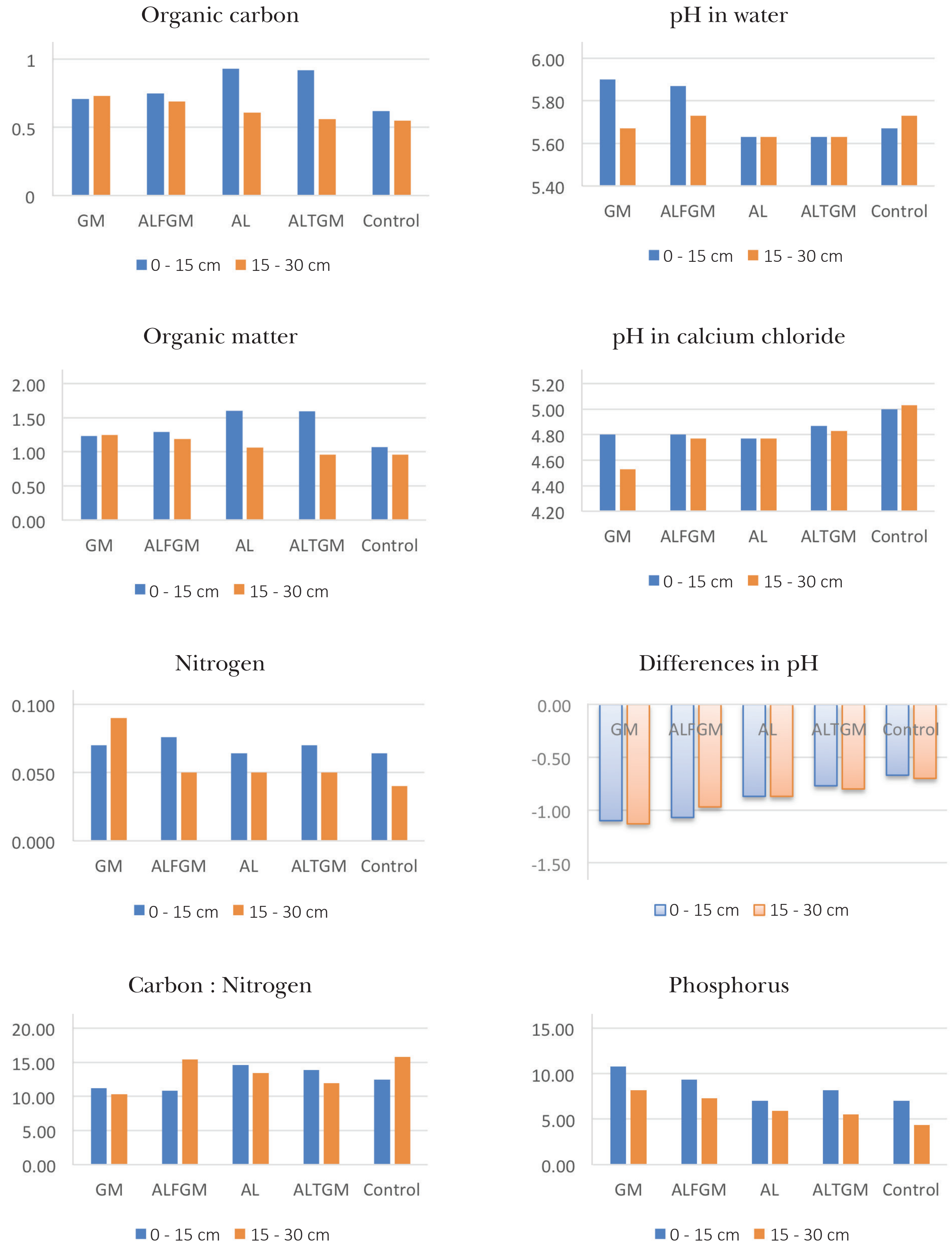

Figure 2 Comparison of the mean values of chemical properties of soil at 0–15 cm and 15–30 cm depths GM = green manure, ALFGM = *Albizia lebbeck* and 5 t ha^{-1} green manure, AL = *Albizia lebbeck*, ALTGM = *Albizia lebbeck* and 10 t ha^{-1} green manure

The high values of OC, OM and N observed at the topsoil in ALFGM, AL, ALTGM and control were due to the presence of organic materials and root activities. The high values observed in GM at depth 15–30 cm could be due to the method of incorporation of the green manure which occurs at that depth (Paustian et al. 1997). Generally, the OC and OM were ranked low according to the ratings of Chude et al. (2011). This could be attributed to the availability of organic material, the level of the mineralisation/decomposition of OM, and intensive and continuous cultivation which forced oxidation of OC, and thus resulted in a reduction of N. Hence, the least values of OC and OM observed in control are in accordance with the findings of Idoga (2014). The medium (OC and OM) and high (N) rates of variation are dependent on the rate of volatilisation, crop removal and plant uptake. The result is also in concurrence with the findings of Feller (1993) who recorded that environmental factors determine OM contents and variation in tropical soils. The C:N of about 10:1 has been suggested for relatively better decomposition rate and improved availability of nitrogen to plants, with the possibilities of incorporating crop residues into the soil without the adverse effect of nitrogen immobilisation (Yerima 1993). The C:N of the studied soils varied with depth and only GM (10.29: 1) falls within the suggested values at 15–30 cm depth. Other treatments (ALFGM, AL, ALTGM and control) could provide nitrogen above microbial needs, indicating high microbial activities for humification and mineralisation of organic residues (Foth 1990). This further explained the low levels of OC and TN recorded in the studied area, in contrast with the findings of Adegbite et al. (2019) in derived savanna and Lelago and Buraka (2019) in agricultural land. A high rate of variation may not be unconnected to amounts of organic materials and methods of incorporation.

The soil reaction (pH) was rated slightly acidic according to Chude et al. (2011). However, AL and ALTGM were the most acidic (5.63) when measured in water, and AL in calcium chloride for both depths. In general, pH within the ranges of 5.5–7.0 (H_2O) and 4.5–7.5 ($CaCl_2$) are optimum for overall availability of plant nutrients, as suggested by Brady and Weil (2002) and Charman and Murphy (2000). The pH difference (ΔpH) was negative in both depths, an indication of soil colloid with appreciable silicate clay minerals and the exchangeable capacity of the soil. Topsoil phosphorus is usually greater than that in subsoil because of the added phosphorus sorption, greater biological activity and accumulation of organic material in the topsoil, hence, GM had more P. Phosphorus was low in all the treatments when compared with the ratings of Chude et al. (2011). The variations among the treatments could be attributed to the distribution of organic materials and P fixation. The results of P are in line with the findings in the soils of North Central Nigeria (Idoga 2014, Osujieke et al. 2020).

CONCLUSION

Assessment of *A. lebbeck* influence on soil physio-chemical properties revealed that the soils of the studied area were formed on similar parent material, though with a significant influence on the clay, silt and sand contents. The SCR indicated a young soil that had undergone ferralitic pedogenesis with high weathering potentials. The aggregate size distribution showed the extent of damage caused by tillage operation to soil stability; control had more stability at the top surface than other treatments despite having low OC. The OC, OM and TN were not affected by *A. lebbeck*, while the C:N showed that the soil could provide nitrogen above microbial needs. Soil pH was slightly acidic and suitable for plant production and the ΔpH was negative, indicating the exchangeable capacity of the soil. The P was also low across the treatments, irrespective of depths. All the soil quality indicators (aggregate stability, OC, OM and TN) were low, thereby revealing the low effect of *A. lebbeck* on soil physio-chemical properties in the savanna ecosystem. Therefore, in choosing *A. lebbeck* as an alternative source of improving soil health and quality production, these factors amongst others should be carefully evaluated, the age of the tree, method of incorporation, stability of the soil and other cultural practices like tillage operations.

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