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INFLUENCE OF SAWDUST BIOCHAR AND LIMING ON SOIL PROPERTIES AND MAIZE GROWTH INDICES

***Eunice Y. Thomas and Quineth, N. Aghaukwu**

Soil Resources Management Department, University of Ibadan, Ibadan
**Corresponding email address: thomaseunice.eunice@gmail.com ; Tel.: +2348077625414*

Abstract
Soil acidity is a great constraint to crop production globally and liming is the conventional method used for its remedy. However, lime is costly, scarce and had been reported to trigger CO_2 emission: a major contributor to global warming. Hence, the influence of sawdust biochar and lime on chemical and physical properties of soils and maize growth were evaluated. Oba super 2 hybrid maize was planted in acid soils collected from Lagos, Nigeria. Treatments tested were: control, biochar (5 and 10t/ha) and lime (1 and 2t/ha) arranged in a completely randomized design and replicated thrice. Data on soil particle size distribution and chemical properties were collected before and after planting and tested. Plant growth parameters were measured at two weeks intervals for eight weeks. The application of lime at 2t/ha and 1t/ha increased plant height (135cm) and stem girth (7.5cm), respectively, while number of leaves were increased (8.7) with the addition of biochar at 5t/ha. Biochar application at 10t/ha showed highest increase in soil pH (4.96 to77.9), organic carbon (2.65 to 5.8g/kg), zinc (26.7 to 53.6mg/kg) and iron. (46.62 to 301mg/kg) While soil magnesium (0.74 to 1.9 cmol/kg)) increased most at 5t/ha of biochar, lime increased available phosphorus (1.53 to 63.3mg/kg), manganese (7.68 to 13.8mg/kg) and copper (5.27 to 7.3mg/kg). Nitrogen and exchangeable acidity contents reduced across the treatments, especially when biochar was applied at 10t/ha. Nevertheless, biochar and lime showed no significant difference in soil chemical properties. The soil textural class remained the same after harvest with the addition of both lime and biochar, and an appreciable increase in the clay and silt fractions was observed. Therefore, biochar could be an alternative material for liming an acidic soil and can also enhance soil's chemical and physical properties.
Keywords: Biochar, lime, pH, maize and soil chemical properties

Introduction

Acidic soils are soils with a pH below 5.5 throughout the year (Vanderlinden, 2018). Acidic soils include Ultisol, Oxisols and Inceptisols (Spaargaren, 1989). The two major zones of acidic soils are Humid Northern Temperate Zones and the Humid Tropics. In Nigeria, acidic soils can be found in the Southeastern region of the country, Nasarawa, Kogi, some parts of Taraba State and Southwestern region (Lagos) (Fasina *et al*., 2015 and Ekele, 2019). Acid soils are low in pH, Cation exchange capacity, Organic matter, macro and micronutrients and water holding capacity. These soils are also characterized by high saturation of aluminum, manganese toxicity, and deficiency of calcium, magnesium, phosphorus and potassium, leading to low soil fertility and poor soil health (Hue *et al*. 1995; Slattery, 1999). Acidic soils can be managed by liming (incorporation of lime or dolomite), planting crops that are acid -tolerant, and practicing the process of slash and burn on the farm (Harter, 2007).

Biochar is a carbon-rich material obtained by pyrolysis of biomass from organic materials (decomposition of a material by applying high temperature in the absence of oxygen or any other reagents). It could be made from agricultural by-products such as bioenergy wastes, crops and forest residue, sewage, and other organic waste materials (Puhringer, 2016). Biochar could be

used to repair toxic environments to plant growth and human health by its ability to absorb toxic substances like manganese, aluminum, cadmium, and arsenic (Berek *et al*., 2011). Biochar has liming qualities as it increases the pH of acidic soils, and it aids soil water retention due to its high surface area and porosity. Biochar improves soil texture and aggregation, helps to decrease soil bulk density, and increases nutrient availability and the efficiency of nutrient use in the soil. Biochar enhances the uptake of nutrients in plant and improve soil properties (Chemical and physical), which positively affect soil productivity (Puhringer, 2016).
Maize (*Zea maize)* is an essential and highly consumed arable crop in Nigeria and is also used as livestock feed and as industrial raw material. The primary constraint to its production in most topical soils is soil acidification (Manna *et al*., 2007). Lime is generally used to correct soil acidity, but is not affordable and accessible. Hence, this study evaluated the influence of sawdust biochar and lime application on soil properties and maize performance.

Materials and Methods

Description of Soil Samples Collection Site

Soil samples were taken randomly at 0-30 cm depth from selected farm lands Lagos (Nigeria) on Latitude 6° 26’ 59.39” to 27° 5’5.24” N and Longitude 3° 9’ 54.18” to 3° 10’ 4.99”. Agricultural activities in the location include the propagation of pawpaw, plantain, cocoyam, palm tree and yam.

Description of Experimental Site

The experiment was done at the screen house situated at Department of Agronomy, University of Ibadan now Soil Resources Management Department, Faculty of Agriculture, Oyo state, Nigeria.

Materials Used

Hybrid maize seeds, Oba Super 2 were procured from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria while sawdust biochar was obtained from the department of Agronomy. Lime (Calcium carbonate ($CaCO_3$) was collected from the department of Agronomy’s soil chemistry laboratory.

Analysis of Soil and Saw Dust Biochar

Soil samples were sieved using sieves with 2 mm and 0.5 mm diameter, depending on the parameters to be analyzed after air drying. Soil pH was read with a pH meter after mixing the soil with distilled water a ratio of 1:2 (Thomas, 1996). Total nitrogen was determined using the Kjeldahl method (Bremner, 1996). Walkley Black dichromate wet oxidation method was used for the percentage of organic matter and organic carbon (Walkley and Black, 1986). Bray P (II) solution was used to extract available phosphorus from the soil sample and, its concentration was determined with a spectrophotometer (Olsen and Sommers, 1982). Potassium chloride solution was used to extract the 2 mm sieved soil sample, and the filtrate was titrated against 0.01M Sodium hydroxide (NaOH) to determine exchangeable acidity (Logan *et al*., 1985). Mehlich (III) was employed to extract manganese, copper, zinc and iron (micronutrients) and calcium, magnesium, potassium and sodium (exchangeable bases) from soil samples and values obtained were read off on Atomic Absorption Spectrophotometer and the Flame Photometer (Lindsay and Norvell, 1978). As described by Gee and Or (2002), soil particle size distributions were determined.

Treatments and Experimental Design

The experiment consisted of five treatments: T1: Biochar (5t/ha), T2: Biochar (10t/ha), T3: Lime (1t/ha), T4: Lime (2t/ha) and T5: control (No biochar or lime added) replicated thrice with 2blocks in a completely randomized block design.

Planting, biochar and lime application

Biochar at 5 and 10t/ha and lime at 1 and 2t/ha were incorporated into the soils in the pots two weeks before planting. The hybrid maize seeds were sown with three seeds per pot after which the soil was watered. Weeding was done anytime weeds were observed.

Data Collection

Data on maize growth parameters (plant height, number of leaves and stem girth) were collected at two weeks intervals. Stem girth was measured with the aid of a Vernier Caliper. Counting of leaves was done manually. A meter rule was used to measure the plant height (from the ground level to the apex of the longest leaf). Fresh weight (t/ha) - the shoot, root and total fresh plant weight were measured on a sensitive scale after harvest. Dry weight (t/ha) of plant root and shoot were measured from their constant weight obtained after oven-drying at 70^{o}C

Statistical Analysis

Data collected were subjected to analysis of variance using SPSS (SPSS, 2011) software version 20 and the mean values generated were separated using LSD at significant level of 5%.

Results and Discussion

The pre-experimental chemical and particle size distribution of soils and the chemical properties of sawdust biochar used are shown in table 1. The low pH value (4.96) in the soil was an indication that it is a strong acid soil (Vanderlinden, 2018). Acid soils usually have hydrogen and aluminum ions dominating the soil solution matrix with the absence of basic nutrient elements needed for plant growth. In acids soils, microbial activities are usually, limited leaving a negative effect on soil structure and biochemical activities (Blanchart, 1999, and Sullivan *et al*. 2017). The soil organic matter contents (4.57%) were high when compared with those reported for soils in Southwestern Nigeria (FMANR, 1990). Soil organic carbon (2.65%) was low compared with values obtained from some parts of the Southwestern Nigeria (Soremi *et al*., 2017), while the soil texture was sandy loam. Available phosphorus (1.53 mg/kg), total nitrogen (0.08%), potassium (0.16cmol/kg) and magnesium (0.74cmol/kg) were low according to the rating of Espinoza *et al* (2006). Surprisingly, the soil calcium (18.91cmol/kg) was moderate. This may result from bush burning activities that occasionally occur on the farm after harvest. The low available phosphorus content in the soils confirms the report of (Dawit *et al*., 2002) that acids soils were deficient in available Phosphorus. Continuous cultivation and high rainfall that are common occurrence at the sample location can also be responsible for the low basic cation content in the soil. Agboola and Ayodele (1987) findings corroborated this report. The low soil pH could also be responsible for the low total nitrogen and potassium in the soils. Sodium (0.65cmol/kg), manganese (7.68mg/kg), zinc (26.7mg/kg), copper (5.27mg/kg) and, iron (46.62) values were above the critical levels suggested by Ayodele *et al*., (2008) for Southwestern soils. Exchange acidity (0.5cmol/kg) content in the soil is low. This would be expected because of the low basic nutrient in the experimental soils and the fact that the soil is strongly acidic with a low pH. Soil texture (loamy sand) is suitable for some crops like maize, groundnut, potato and grapes (USDA, 1987).

Biochar's pH (7.4) was slightly alkaline as shown in table 1. Biochar had been reported to be commonly alkaline what makes them have liming effect on acids soils (Jiang *et al*., 2012). The biochar's organic carbon content was high at 17.84%. This should be expected because the feedstocks are usually high in carbon. Total Nitrogen (0.64%) content in biochar was low. This was due to their gaseous emission during pyrolysis, as reported by Leng *et al*. 2020 that the N content of biochar decreases with increasing pyrolytic temperature through gaseous emission. Available phosphorus (1.9mg/kg) was low, and this could be attributed to the biomass from the wood used in preparing the biochar. It has been reported that animal-based biochar will have a higher P content than those from wood-based feedstock (Brantley *et al*., 2016; Bu *et al*., 2017, Li and Shangguan 2018; Xiao *et al*., 2018). Calcium, magnesium, potassium and sodium contents of biochar were 7.33, 0.32, 0.44 and 0.125mg/kg, respectively. These values were low compared to those obtained from animal manure biochar, as reported by Xiao *et al*. (2018) and Brantley *et al*. (2016). The difference in the nutrient values in biochar were attributed to the sources of the biomass used for biochar production. It has been reported that biochar produced from animal manure has higher secondary nutrients than those from wood biomass and crop residue (Hossain *et al*., 2020). Micronutrients content in the biochar were 145mg/kg (Mn), 1,193mg/kg (Fe), 24.5mg/kg (Zn) and 24.5mg/kg (Cu). The values were high and corroborated the findings of Hossain *et al*., (2020) that biochar contain significant micronutrients.

Table 1: Selected Physical and Chemical Characteristics of Soil and Biochar

Nutrient	Soil	Biochar
pH	4.96	7.4
Exchangeable Acidity (cmol/kg)	0.50	-
Total Nitrogen	0.08	0.64
Organic Carbon (%)	2.65	17.84
Organic Matter (%)	4.57	-
Available P (mg/kg)	1.53	1.9
Exchangeable cations (cmol/kg)		**mg/kg**
Ca	18.91	7.33
Mg	0.74	0.32
Na	0.65	0.13
K	0.16	0.44
Micronutrients (mg/kg)		
Mn	7.68	145
Fe	46.62	1,195
Cu	5.27	24.5
Zn	26.7	111
Particle size Analysis (%)		
Sand	92.75	-
Silt	4.09	
Clay	3.16	
Textural Class	**Loamy sand**	

Number of Leaves of Maize

There was an increase in the number of leaves from weeks 1-8 as shown in figure1. However, mean number of leave was not significantly difference with each treatment throughout the eight (8) weeks of planting. Biochar applied at 5t/ha, notwithstanding, gave the highest mean number of leaves (8.7) at the eighth week. This result was similar to the work of Ndor (2014) where no significant effects of woody biochar used on the number of leaves of both Oba 98 and Sam maize 18 maize varieties at different week intervals were recorded.

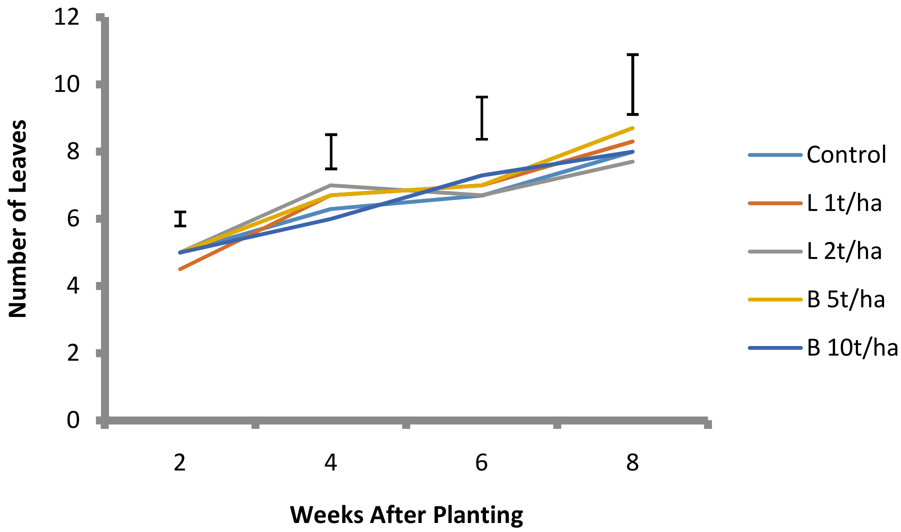

FIGURE 1: APPLICATION OF LIME AND SAW DUST BIOCHAR AS IT AFFECT NUMBERS OF LEAVES OF MAIZE PLANT

L1t/ha –Lime applied at 1t/ha,   L2t/ha – Lime application

B 5t/ha – Biochar application at 5t/ha,   B10t/ha- Biochar application at 10t/ha

Maize Plant Height (cm) in Soil amended with Lime and Biochar

Plant height showed a continuous linear increase from the second to the eighth week (Figure 2). At the fourth and sixth weeks of treatments application, no significant difference in plant heights was recorded. However, significant differences in plant height were noticeable in the second and eighth week, between the treatments. A substantial difference from other treatments in maize height was also observed with 5t/ha of biochar treatments at the sixth week, while 2t/ha of lime recorded the highest plant height (135.5cm) at 8 weeks after planting. This finding was similar to the report of Mensah and Frimpong, 2018; Rabileh *et al*., 2015 that there was an increase in plant height when biochar or lime was added to acid soils where maize was grown in a pot experiment. The research seemingly indicated that a combined treatment of acid soil with biochar and lime at the application rates of 5t/ha and 2t/ha, respectively, could increase the height of maize between 6 to 8 weeks after planting.

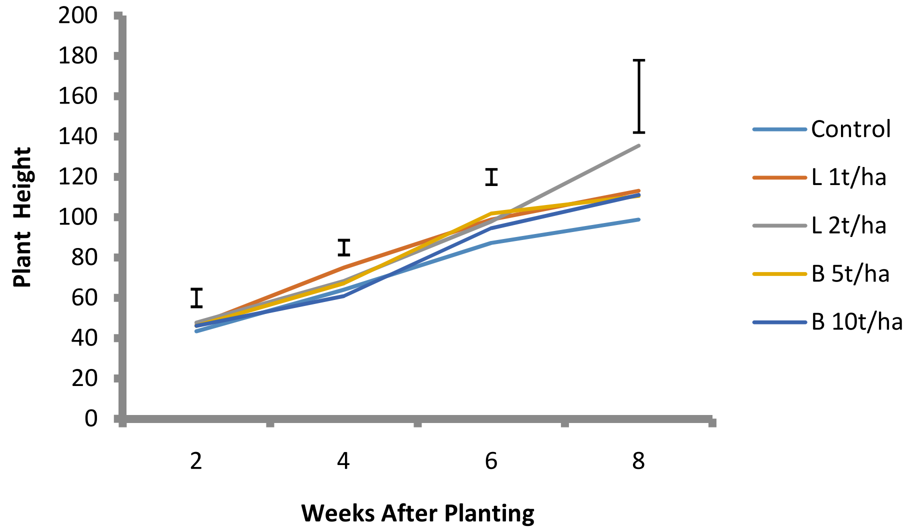

FIGURE 2: APPLICATION OF LIME AND SAW DUST BIOCHAR AS IT AFFECTS THE HEIGHT OF MAIZE PLANT

Maize Stem Girth (cm) in soil amended with Lime and Biochar
Figure 3 shows the mean stem girth of maize at different rates of lime and biochar applications in the soil. Maize stem girth was not significantly different from all the treatments from week 1 to 8 after planting. However, an increase in stem girth (0.2- 1.2cm) was observed from weeks 2-8. At 2t/ha lime application had the highest mean growth (1.2cm) in stem girth. This was contrary to the discovery of Mensah and Frimpong (2018) that reported the highest increase in maize stem girth of maize when 2% biochar was applied.

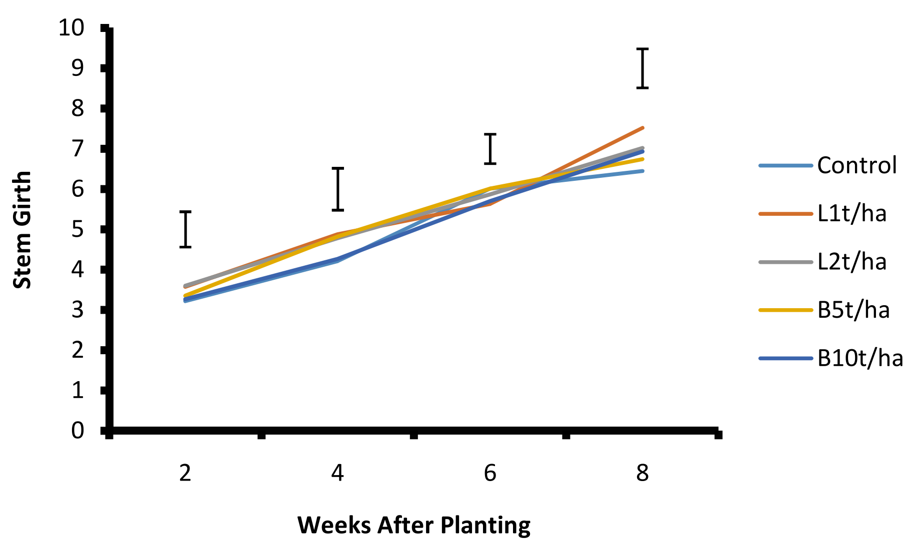

FIGURE 3: APPLICATION OF LIME AND SAW DUST BIOCHAR AS IT AFFECT THE STEM GIRTH OF MAIZE PLANT

Dry Weight

Maize mean dry weight under the different treatments and control are as shown in table 2. The treatment's mean dry weights (root and shoot) did not differ significantly. The highest dry root weight (6.2) value was recorded at 5t/ha biochar was similar to the findings of Rabileh *et al*. (2015) that when 5t/ha of biochar was applied in the pot experiment where maize was grown, dry weight matter increases. Whereas, lime applied at 2t/ha had the highest shoot dry weight (9.3). Both biochar and lime have been reported to have a significant increase in plant shoot and root biomass (Yao *et al*., 2019).

Table 2: The influence of Lime and Saw dust biochar on maize root and shoot dry weight

TREATMENTS	DW (ROOT)	DW (STEM)
Control	4.02	6.8
Lime Application Rates		
1t/ha	4.4	7.8
2t/ha	4.3	9.3
Biochar Application Rates		
5t/ha	6.2	7.8
10t/ha	3.2	7.4
LSD	4.01	2.68

Means with the same letter(s) are not significantly different from each other at 5% level of significance

Effects of Saw Dust Biochar and Lime on Soil Chemical Properties and Particle Size after Harvest

The pH of the soils increased significantly across all treatments from the initial value of 4.96 to 7.6 for both $CaCO_3$ treatments, 7.9 for the Biochar treatment at 5 t/ha and 7.8 for biochar treatment at 10 t/ha (table 3). Similar findings were obtained by Glaser *et al*., 2002, Biederman and Harpole (2013). This increase in pH may also be due to the liming impact of biochar due to its ash accretion (Nigussie *et al*., 2012). Secondly, it has been reported that the functional groups of biochar, that after decarboxylation, consumes proton, could also be responsible for the increase in soil pH (Wang *et al*., 2014). The soil percentage total nitrogen, decreased by 0.03% which was significantly different from the initial 0.08% recorded in across all treatments (table 1). This is an indication that nitrogen can easily be leached from the soil (Parnes, 2013). Biochar application has been reported to have no direct effect on soil nitrogen though it helps to prevent nitrogen from leaching from topsoil due to its high adsorptive capacity (Clough *et al*., 2013). Furthermore, the C: N ratio of biochar is usually very high which could encourage the possibility of nitrogen being immobilized (Lone *et al*., 2015)

Biochar treatments also increased the organic carbon content (5.8g/kg) in the soil, even though this was not significantly different among all the treatments. Njoku *et al.,* (2016) also confirmed that the incorporation of biochar could increase the soil's organic carbon. The rise in organic carbon can be linked to the increase in pH over a short time, which gives soil microbes an enabling environment that help to decompose crop residues (Abewa, 2013). The reduction in the soil concentration of calcium, potassium, magnesium and sodium after harvest in control soil compared with treatments could be linked to the uptake and leaching of the nutrients (Parnes, 2013). Although nutrient was not significantly different from each other, biochar applied at 5t/ha still recorded the highest Ca, Mg and sodium, while 10t/ha gave the highest potassium content in the soil after harvest.

With the different treatments, available phosphorus (63.3mg/kg) significantly increased after harvest. This is consistence with the finding of DeLuca *et al*. (2006). The increased phosphorus exceeded the critical range of 8mg/kg to 12mg/kg for tropical soils (Enwezor *et al.*, 1989). Application of lime at 1 and 2t/ha in acid soils increased soil phosphorus, according to Abewa *et al*., 2013. The precipitation of soil aluminum and iron as Al $(OH)_3$ and Fe $(OH)_3$ could be triggered by the liming ability of biochar in acid soils, and this could also lead to an increase in phosphorus availability (Tisdale *et al*., 2002). An increase in soil pH after plant harvest, triggered by the application of biochar, could also be responsible for this increase because phosphorus will be available between the pH of 6.0 - 7.0 (Abewa *et al*., 2013). The application of both biochar and lime had no significant difference in soil micronutrients except for copper (7.3mg/kg) when lime was applied at 1t/ha, however the increase in micronutrient contents in the soil after harvest (Mn, Fe, Cu and Zn), were observed with high accumulation of iron across all treatments. The lime application, however recorded the highest micronutrient contents.

Table 3: Chemical Properties of Soil after Harvest

Treatments	pH	TN	OC	Ca	Mg	K	Na	P	Mn	Fe	Cu	Zn
		%	(g/kg)		(cmol/kg)					(mg/kg)		
Control	7.7	0.05	5.05	6.0	1.4	0.1	0.6	44.1	9.3	278	6.5	48.4
Lime												
1t/ha	7.6	0.03	5.6	6.4	1.7	0.1	0.6	59.7	13.8	301	7.3	53.6
2t/ha	7.6	0.05	5.6	5.3	1.6	0.1	0.5	63.3	12.6	254.5	7.1	47.2
Biochar												
5t/ha	7.9	0.03	5.5	8.2	1.9	0.1	1.0	36.1	7.2	124.4	3.9	23.8
10t/ha	7.8	0.01	5.8	5.9	1.7	0.2	0.5	43.8	7.5	255.5	4.4	70.3
LSD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.8	NS

Particle size distribution was not significantly different with applying both lime and biochar as shown in table 4. Hence, the textural class remains loamy sandy, although an appreciable increase was noticed in the clay and silt fractions. The application of lime and biochar increased soil organic carbon content after harvest, though no significant differences were observed. The highest increase with the application of 10t/ha could due to carbon from the saw dust biochar. This benefits the overall soil health improvement (Abewa *et al*., 2013). There was a reduction in exchangeable acidity and the treatments applied did not show any significant difference after harvest. This is similar to the discovery of Chintala *et al*. (2013) that gave an account of a non-significant decrease in exchangeable acidity, when biochar and lime were applied during an incubation study. However, the proportion of decrease was pronounced under biochar application than lime. This decrease could be due to the increase in soil pH, which caused cations to be released to displace the exchangeable Al^{3+} and H^{+} in the soil exchange complex, thereby decreasing the exchangeable soil acidity (Chan *et al*., 2008; Warnock *et al*., 2007; Yuan *et al*., 2011)

Table 4: Physical and Chemical Properties of Soil after Harvest

Treatments	Particle Size Distribution (%)			Textural Class	Exchangeable Acidity (cmol/kg)	Organic Matter (%)
	Sand	**Silt**	**Clay**			
Control	92.0	4.4	3.6	Loamy Sand	0.2	8.7
$CaCO_3$						
1t/ha	92.4	4.5	3.1	Loamy Sand	0.3	9.7
2t/ha	92.6	4.3	3.1	Loamy Sand	0.3	9.6
Biochar						
5t/ha	91.6	4.5	3.9	Loamy Sand	0.2	9.5
10t/ha	92.5	4.3	3.2	Loamy Sand	0.2	10
LSD	0.3	0.2	0.1		0.1	1.0
Remark	NS	NS	NS		NS	NS

Conclusion and Recommendations

Plants in pots with biochar treatments had the highest cumulative maize growth rate. However, significant maize growth was observed when biochar 5 t/ha and 10 t/ha were added than Lime ($CaCO_3$) treatments and the control experiment. The soils without biochar and lime treatments had the lowest cumulative growth in maize. The application of lime treatments influenced the growth of maize significantly but not as much as biochar treatments at 5 t/ha and 10 t/ha. Hence, biochar at 10 t/ha and 5 t/ha may be applied to acidic soils before maize production to enhance soil fertility and crop growth. The Chemical properties of the soil improved from their initial state after harvest. The pH after the application of lime to soil also increased. Biochar application increased soil organic matter content after harvest than Lime. It is apparent that biochar could compare favorably well with lime as it enhanced the growth of maize and improved the chemical and physical properties of acid soils. Especially, when applied at 5 t/ha and 10 t/ha. Consequently, biochar could be used in place of lime to raise the pH of acidic soils.

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