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EFFECTS OF BIOCHAR PARTICLE SIZE ON PHYSICOCHEMICAL PROPERTIES OF SOIL AND MAIZE (*Zea mays L.*) PERFORMANCE

Joel M.F., Ogbe V.B., Amana S.M. and Jayeoba O.J.

Agronomy Department, Faculty of Agriculture, Nasarawa State University, Keffi, Shabu-Lafia Campus, Nigeria
**Corresponding Author Email: michaeljoel242@gmail.com; +234(0)8160250426*

Abstract
Reducing particle size is an easily adoptable strategy to reduce loss of nutrients due to more adsorption with correspondingly increased surface area compared to areas without biochar or soil treated with larger biochar particle sizes. Field experiment was conducted to determine the effect of biochar particle size on the physico-chemical properties of soil, growth and yield of maize. The treatments were biochar particle size of 5.3mm, 2mm, 1mm, 0.5mm and control. Soil samples were collected for the determination of physico-chemical properties of the soil before and after sowing. Data were also collected on growth and yield parameters and were analysed using Gen-stat. The results showed that biochar particle size of 0.5mm had the highest value in plant height (121.11cm), plant girth (2.177cm), number of leaves(14.80), leaf area (784.70cm^2) and yield parameters (cob length, cob girth, seed weight per cob and yield with values of 10.883cm, 3.640cm, 117.90g and 7094.17kg/ha respectively).Also, biochar particle size of 0.5mmhad the best in the physico-chemical properties in organic carbon (1.80), organic matter (3.10),Nitrogen (0.21), pH (6.7), CEC (4.81) and had the least value in EA (0.50) of the soil as compare to other treatments with the control having the least value of 1.72, 2.96, 0.12,6.3, 4.35 for O.C, OM, N, pH, CEC and the highest for EA(0.83). It can be concluded that biochar particle size of 0.5mm performed best with the highest improvement in the physicochemical properties of the soil, growth and yield parameters of maize.
Keywords: Biochar, Particle size, Maize, Physicochemical properties.

Introduction

Nigeria is currently the tenth largest producer of maize in the world, and the largest maize producer in Africa (IITA, 2012). It is estimated that seventy percent of farmers are smallholders accounting for 90 percent of total farm output (Cadini and Angelucci, 2013). Maize crop started as a subsistence crop in Nigeria and has gradually risen to a commercial crop on which many agro-based industries depend on as raw materials (Iken and Amusa, 2014). Maize is versatile as well as complete cereal crop providing food for human being and feed for animals, particularly in poor and arid lands which are cultivated in summer as well as spring season for fodder and grain purposes in many developing countries (Ali *et al*., 2016). It provides the majority of raw materials for the livestock and numerous agricultural products worldwide (Bello and Olaoye, 2009) and it contains vitamins and some essential nutrients for metabolic pathways (Orhun, 2013).

Emphasis of agricultural development has shifted from increasing productivity per unit area of land to feed the ever increasing population in the 20th century to sustainable land use, water and plant resources in the present century, while coping with climate change (Bhat *et al*., 2009). Globally, population is growing every day by 2050 it is anticipated to reach 9 billion (Haider *et al*., 2017). So, the food challenges, energy and freshwater upsurge progressively (Haider *et al*. 2017; Zabel *et al*., 2014).Depletion in soil organic matter and soil nutrients, decline in agricultural productivity and changes in climate due to anthropogenic activities are posing great threats to the sustainability of agricultural production in the tropical regions (Parry, 2007; Pender, 2009).Declining soil quality and loss in per capita land area demanded the increase in inorganic fertilizer use. However, the use of chemical or inorganic fertilizers for improving the agricultural yield and soil fertility is not a sustainable approach, as excessive use of inorganic fertilizers mainly nitrogen, has the ability to deteriorate soil environment and can also lead to the mineralization of organic matter (Liu *et al.,* 2010). One approach in successful management and sustainability of soil fertility and enhancement of productivity per unit area of land is the use of biochar. Biochar also known as agrichar, is a carbon-rich product derived from the thermal decomposition of a wide range of carbon-rich biomass materials, such as livestock manure, sewage sludge, crop residue, wood, and compost (Sohi *et al*., 2010; Yuan *et al*., 2011). Biochar as a soil amendment has received increased attention because of its many potential benefits to both environment and agriculture. Application of biochar improves soil physical properties such as bulk density, soil water holding capacity, permeability, soil structure, chemical properties such as nutrients availability, cation exchange capacity and retention, and biological properties such as microbial population, biomass and activities, thus ultimately increased crop yield (Lehmann *et al*., 2006; Herath *et al.,* 2013; Kumari *et al.,* 2014). The effects of biochar addition on soil physicochemical properties might vary in relation to the length of time of its incorporation into soil. A longer time was found to be more beneficial for improving soil properties because biological and abiotic processes that are both involved in biochar decomposition take time (Jien and Wang, 2013).

The effect of biochar on soil improvement has also been linked to biochar particle size, which influences soil physicochemical properties as well as soil erosion (Jien and Wang, 2013; Liu *et al*., 2016).Particle size is expected to strongly influence interactions between soil and biochar, since smaller biochar particles will necessarily have greater physical contact with soil particles (Sigua *et al.,* 2014; Chen *et al*., 2017). One predicted consequence is that smaller biochar particles will result in more rapid pH equilibration of soil-biochar mixtures and potentially higher pH values (Chen *et al*., 2017; Zheng *et al*., 2010). There is also evidence that biochar with smaller particle sizes can increase nutrient and organic compound sorption (Xie *et al.,* 2015).Thus, the objectives of this study were to determine the effects of different biochar particle sizes on some soil physical and chemical properties as well as maize performance.

Materials and Methods

Brief description of the study area

The study was conducted at the Faculty of Agriculture Demonstration Farm, Nasarawa State University, Keffi, located at Shabu - Lafia, Nasarawa State, Nigeria. It lies on latitude 08° 33'N, longitude 08^0 32'E at an altitude of 181.53m above sea level. The area is located in southern – guinea savannah characterized by a sub-humid tropical climate with wet and dry seasons. The mean annual temperature is 28.75^0Cwith mean minimum and maximum temperatures of 24.5^0Cand 33^0C, respectively. The relative humidity fluctuates between 43.2% and 86.3%with average rainfall ranging from 1,138.0 mm to 1,595.7mm per annum (Jayeoba, 2013).

Land Preparation and Field Layout

The experimental plots were marked out after land clearing and tilled manually using hoe. Each plot measured 4 x 3m and separated from one another with a space of 1m by block and replicate. The net and gross plot areas of the field were $180m^2$ and$264m^2$, respectively. Each plot consisted of five ridges maintained at 0.75m apart.

Experimental Design and Treatment Layout

The experiment was laid out in randomized complete block design with five treatments replicated thrice. The treatments were different biochar particle sizes represented as T_1 (Zero application) as the control, T_2 (0.5mm), T_3 (1.0mm), T_4 (2.0mm) and T_5 (5.3 mm). The experiment constituted a total of 15 plots.

Soil Quality Determination

Soil samples were collected from ten randomly selected points within the experimental site at 0-30cm depth using soil auger and bulked to form a composite sample. It was sub sampled using coning and quartering, air-dry and sieved through a 2mm sieve. The subsamples were used for physicochemical analysis in the Agronomy Laboratory, Faculty of Agriculture, Nasarawa State University, Keffi, Shabu-Lafia campus. The particle size was determined using the hydrometer method (Boyoucous, 1951). Textural classes were determined using USDA textural triangle. Total nitrogen was determined by regular Macro-Kjeldhal digestion technique (Jackson, 1964), while organic matter content was determined using titration method (Nelson *et al*., 1996). Soil pH was determined using pH meter while exchangeable bases were determined using 1N NH4OAC extractant method (Thomas, 1982) and cation exchange capacity (CEC) was estimated by summation of the exchangeable bases. The soil water content was determined gravimetrically at a depth of 0 - 30 cm. Moisture storage data was collected at 4, 8, and 12weeks after sowing (WAS) from each treatment. Soil samples were collected using an auger, weighed and oven dried at 105˚C for 48 hours. It was weighed again to a constant weight to determine the soil water content.

Biochar Preparation and Application

The biochar of specified tree, black locust (*Robinia pseudoacacia*) was obtained from a commercial market in Lafia town Nasarawa State and then grounded and sieved into different particle sizes (5.3mm, 2mm, 1mm and 0.5mm) and incorporated into the soil at 5t /ha each except for the control plots, where no biochar was added

Crop Establishment and Maintenance

Two Samaz 16 maize seeds were sown per hill on the 1st of July, 2019 at a spacing of 30× 75cm between plants and rows, respectively at 2 – 5cm depth. The seedlings were thinned to one plant per hill two weeks after germination and missing stands were supplied. Split doze fertilizer application was done using the band placement method at a rate of 200 kg/ha NPK (15:15:15) at two weeks after planting and top dressed before tasselling. Weeding was done manually using hoe as at when due to keep the farm weed free. The green cobs were harvested at physiological maturity and dried.

Maize Growth and Yield Parameters

Growth parameters data were collected at 4, 6, and 8 WAS on five randomly selected plants from each plot and recorded. Plant height was measured from the soil surface to the terminal bud using a meter rule and the mean recorded. The plant girth was measured using a vernier calliper and the numbers of leaves on each selected plant was counted manually and their means recorded. The leaf area was determined by multiplying the manually measured length and maximal width of tagged plants with a shape factor, k, empirically determined to be 0.75 for maize. The cob length was measured from the base of the cob to its tip while cob girth was measured using a vernier calliper and their mean recorded. The seed weight from each cob of selected plant was weighed and the cob obtained from the net plot was also weighed and the yield expressed in kg per hectare and the mean recorded, respectively.

Statistical Analysis

The measured data was analysed by analysis of variance for complete randomized block design (RCBD) using Gen-Stat package. The differences among the treatments were determined using least significant differences.

Results

Table 1 shows the physical and chemical properties of the soil samples before application of biochar. The soil contained very high proportion of sand (89%) and low in clay content (7.6%). Also, the soil contains low rates of nitrogen (0.21%), and organic matter (2.99%). The exchangeable cations were low with the exception of magnesium that was moderate (1.48Cmol/kg) with a very low cation exchange capacity (4.33 Cmol/kg). The soil was slightly acidic (6.23).

Table 1: Physical and chemical properties of soil before sowing at 0-30cm Depth

Parameters	0-30cm
Physical composition	
Clay (%)	7.6
Silt (%)	3.4
Sand (%)	89
Texture	Loamy Sand (LS)
Chemical composition	
pH (H2O)	6.23
N (%)	0.21
% Organic carbon	1.74
% Organic matter	2.99
K (Cmol/kg)	0.29
Ca (Cmol/kg)	2.40
Mg (Cmol/kg)	1.48
Na (Cmol/kg)	0.16
EA (Cmol/kg)	0.83
CEC (Cmol/kg)	4.33

Table 2 show the effect of biochar particle size on the soil physicochemical properties. The results revealed that application of 0.5mm particle size biochar recorded the highest values in organic carbon (1.80), organic matter (3.10), Nitrogen (0.21), pH (6.7), CEC (4.81)and had the least value in EA (0.50) while control had the least value of 1.72, 2.96, 0.12,6.3, 4.35 for OC, OM, N, pH, CEC and the highest for EA (0.83), respectively. In terms of the physical properties, there were no differences in their textural class but field added with biochar had a higher value of 8.2 for clay with the control having a lower value of 7.6

Table 2: Effect of Biochar on Soil Physical and Chemical Properties after Application

Particle size (mm)	Sand (%)	Silt (%)	Clay (%)	Textural class	pH (H_2O)	OC (%)	OM (%)	N (%)	Exchangeable bases (Cmol/kg) Ca	Mg	K	Na	CEC (Cmol/kg)	EA
5.3	88	3.8	8.2	LS	6.3	1.75	3.01	0.14	2.38	1.52	0.29	0.16	4.35	0.83
2	88	3.8	8.2	LS	6.4	1.76	3.03	0.14	2.43	1.58	0.36	0.21	4.58	0.67
1	88	3.8	8.2	LS	6.4	1.78	3.06	0.14	2.43	1.59	0.36	0.21	4.59	0.67
0.5	88	3.8	8.2	LS	6.7	1.80	3.10	0.21	2.50	1.70	0.39	0.22	4.81	0.50
control	89	3.4	7.6	LS	6.2	1.72	2.96	0.12	2.36	1.46	0.28	0.15	4.25	0.84

LS= Loamy Sand; OC= Organic Carbon; OM= Organic Matter; N= Nitrogen; CEC= Cation Exchange Capacity; EA= Exchangeable Acidity

Table 3 shows the effects of biochar particle sizes on plant height. At 4 and 6 WAS, the treatments were significantly different (P<0.05) from each other except for the control and 5.3mm particle size that were at par (P>0.05) while at 6 WAS all the treatments were significantly different (P<0.05) from each other. Biochar particle size of 0.5mm had the highest plant heights (21.61 cm, 90.70 cm and 121.11cm) at 4, 6 and 8 WAS, respectively followed by 1.0 mm biochar particle size which had values of 16.87 cm, 67.53 cm and 110.29 cm at 4, 6 and 8 WAS, respectively. Biochar particle size of 5.3mm had the least value (9.47cm) at 4 WAS while control had the lowest plant heights value of 27.87 and 59.17 cm at 6 and 8 WAS.

Table 3: Effect of Biochar Particle Size on Maize Height (cm)

Treatment	4 WAS	6 WAS	8 WAS
Control	10.55[d]	27.87[d]	58.35[e]
0.5 mm PS	21.61[a]	90.70[a]	121.11[a]
1.0 mm PS	16.87[b]	67.53[b]	110.29[b]
2.0 mm PS	13.57[c]	37.76[c]	82.29[c]
5.3 mm PS	9.57[d]	28.97[d]	73.81[d]
Mean	14.43	50.57	89.17
Significant	<0.001***	<0.001***	<0.001***
SEM	0.431	0.517	0.693
$LSD_{0.05}$	1.404	1.687	2.259
CV (%)	5.20	1.80	1.30

PS= Particle Size, SEM= Standard Error of Mean; LSD= Least Significant Difference; CV= Coefficient of Variation; WAS= Week after Sowing; *= Significant At 5%,**

Table 4 shows the effect of biochar particle size on plant girth. Analysis of variance showed that there was a high significant difference (P<0.05) in plant girth among treatment means from 4 to 8WAS. Biochar particle size of 0.5mm had the highest plant girth with values 1.633, 1.877 and 2.177cm at 4, 6 and 8 WAS and was followed by biochar particle sizes of 1.0 mm and 2.0 mm, respectively. Control had the lowest plant girth values of 0.777, 1.043 and 1.193cm at 4, 6 and 8 WAS, respectively. However, at 4 WAS, 5.3mm was at par to 2.0 mm particle size and control while at 6 and 8 WAS, it was similar to the control.

Table 4: Effect of Biochar Particle Size on Maize Girth (cm)

Treatment	4 WAS	6 WAS	8 WAS
Control	0.777[d]	1.043[d]	1.193[d]
0.5 mm PS	1.633[a]	1.887[a]	2.177[a]
1.0 mm PS	1.317[b]	1.390[b]	2.047[b]
2.0 mm PS	0.940[c]	1.420[c]	1.667[c]
5.3 mm PS	0.880[cd]	1.090[d]	1.294[d]
Mean	1.109	1.577	1.675
Significant	< 0.001***	< 0.001***	< 0.001***
SEM	0.0490	0.0520	0.0317
$LSD_{0.05}$	0.1598	0.1694	0.1035
CV (%)	7.70	6.60	3.30

PS= Particle Size, SEM= Standard Error of Mean; LSD= Least Significant Difference; CV= Coefficient of Variation; WAS= Week after Sowing; *= Significant At 5%,**

Table 5 shows the effect of biochar particle size on number of maize leaves**.** It shows that the treatments were significantly different (P<0.05) from each other except for the control and 5.3 mm PS that were similar (P>0.05) at 4 WAS while at 6 WAS all the treatments were significantly different (P<0.05) from each other except for 0.5 and 1.0 mm PS that were similar. At 8 WAS, 0.5 mm PS was significantly different from the others while 1.0 mm PS was at par with 2.0 mm PS but significantly different from the 5.3 mm PS which is at par with 2.0 mm PS and there was significant different from the others. Biochar particle size of 0.5mm had the highest number of leaves at 4, 6 and 8 WAS with values 8.290, 12.17 and 14.80, respectively while control had the lowest number of leaves at 6 and 8 WAS and biochar of particle size of 5.3mm had the least value (5.50) at 4 WAS.

Table 5: Effect of biochar particle size on number of maize leaves

Treatment	4 WAS	6 WAS	8 WAS
Control	5.80[d]	8.08[d]	12.37[d]
0.5 mm PS	8.29[a]	12.17[a]	14.80[a]
1.0 mm PS	7.43[b]	11.43[a]	13.73[b]
2.0 mm PS	6.60[c]	10.34[b]	13.33[bc]
5.3 mm PS	5.50[d]	9.13[c]	12.82[c]
Mean	6.704	10.23	13.41
Significant	<.001***	<.001***	<.001***
SEM	0.0999	0.237	0.263
$LSD_{0.05}$	0.3257	0.771	0.859
CV (%)	2.60	4.00	3.40

PS= Particle Size, SEM= Standard Error of Mean; LSD= Least Significant Difference; CV= Coefficient of Variation; WAS= Week after Sowing; *= Significant At 5%,**

Table 6 shows the effect of biochar particle size on soil water holding capacity. Biochar particle size of 0.5mm had the highest values from 4 to 12 WAS with values of 6.30, 7.10 and 7.5cm^3, respectively and control had the least values of 2.70, 6.33, and 6.80 cm^3,, respectively. At 4 WAS, it was shown that 0.5 mm PS treatment was significantly different (P<0.05) from the others that were at par. At 8 WAS, 0.5 mm PS was at par with 1.0 mm and significantly different from the others while 1.0 mm PS and 2.0 mm PS were significantly different from the control but at par with 5.3 mm which was also at par with the control. At 12 WAS 0.5 mm PS and control were significantly different from each other but at par with other treatments.

Table 6: Effect of biochar particle size on soil water holding capacity

Treatment	4 WAS	8 WAS	12 WAS
Control	2.70^{b}	5.33^{c}	5.70^{b}
0.5 mm PS	6.30^{a}	7.10^{a}	7.50^{a}
1.0 mm PS	2.74^{b}	6.83^{ab}	6.97^{ab}
2.0 mm PS	2.83^{b}	6.73^{b}	6.90^{ab}
5.3 mm PS	2.76^{b}	6.67^{bc}	6.85^{ab}
Mean	3.47	6.53	6.78
Significant	$< 0.001^{***}$	$< 0.001^{***}$	$< 0.001^{***}$
SEM	0.0922	0.1035	0.0820
$LSD_{0.05}$	0.3007	0.3377	0.2674
CV (%)	4.60	2.70	2.10

PS= Particle Size; SEM= Standard Error of Mean; LSD= Least Significant Difference; CV= Coefficient of Variation; WAS= Week after Sowing; *= Significant At 5%,**

Table 7 shows the effect of biochar particle size on yield parameters that biochar particle size of 0.5mm had the highest cob length, cob girth, seed weight per cob and yield with values of 19.99cm, 4.94cm, 225.4g and 7094.17kg/ha respectively while control had the lowest cob length, cob girth, seed weight per cob and yield with values, 10.833cm, 3.640cm, 108.80g and 5194.17kg/ha respectively. It was shown that the treatments were significantly different (P<0.05)from each other for cob length, seed weight per cob and yield while 0.5 and 1.0 mm PS were significantly different from 5.3 mm PS and control which are at par and all the treatments at par with 2.0 mm PS.

Table 7: Effect of biochar particle size on yield parameters

Treatment	Cob length (cm)	Cob girth (cm)	SWPC (g)	Yield (kg/ha)
Control	10.883^{e}	3.640^{b}	108.80^{e}	5194.17^{e}
0.5 mm PS	19.997^{a}	4.940^{a}	225.40^{a}	7094.17^{a}
1.0 mm PS	17.503^{b}	4.597^{a}	204.10^{b}	6375.00^{b}
2.0 mm PS	15.547^{c}	4.260^{ab}	150.40^{c}	5994.17^{c}
5.3 mm PS	11.373^{d}	3.690^{b}	117.90^{d}	5525.00^{d}
Mean	4.225	15.061	161.30	7.244
Significant	$<.001^{***}$	$<.001^{***}$	$<.001^{***}$	$<.001^{***}$
SEM	0.0471	0.2101	2.390	0.1062
$LSD_{0.05}$	0.1535	0.6851	7.800	0.3465
CV (%)	1.90	2.40	2.60	2.50

PS= Particle Size, SEM= Standard Error of Mean; LSD= Least Significant Difference; CV= Coefficient of Variation; WAS= Week after Sowing; *= Significant At 5%, SWPC= Seed Weight Per Cob**

Discussion

From the study it was observed that biochar of 0.5mm performed best in enhancing the physical and chemical properties of the soil followed by other treatments with the control having the least values. This is consistent with the findings of Park *et al.* (2011) who stated that improvement in soil's physico-chemical properties by biochar amendment and its potential to impart plant friendly environment to soil is with increased surface area through reduced biochar particle size. Glab *et al.* (2016) reported that total porosity increased with biochar addition in loamy and sand soil, with an increase in biochar size from 0.5mm to 2mm. Concerning particle size, it is a considered effective factor in biochar properties which has potential interactive effects between soil and biochar, because smaller biochar particles will basically have greater physical features with soil aggregates (Chen *et al*., 2017). Further, there is evidence that biochar with minor particle sizes can increase nutrient and organic compound sorption (Xie *et al*., 2015). The ability of biochar to improve the quantity of nutrients can be attributed to its large amount of carbon and its large specific surface area, porosity and amount of negative surface functional groups. All of these factors produce an enhanced soil cation exchange capacity (Mukherjee *et al*. 2011) that can reduce nutrient leaching while increasing the quantity of the elements in the soil (Biederman *et al*. 2013).Several research studies have found that biochar addition to soil increases total C (Van Zwieten *et al*. 2010), total N, pH, CEC, available P, and exchangeable cations (e.g. Ca, Mg, Na, and K) in soil (Chan *et al*. 2008).Similarly, Major *et al.*(2010) found that biochar addition increases available Ca, Mg, and pH in soil. Also, Ndor *et al.* (2015) reported increase in CEC and some basic cations in degraded soil of Lafia. The effect of biochar in increasing soil pH in highly weathered tropical soils had been reported (Glaser *et al*., 2002). Then Ndor *et al*., (2017) confirmed the use of lime and biochar for amending soil acidity in soils of southern guinea savannah of Nigeria. Also, Major *et al* (2010) reported that biochars can be beneficial to acidic soils, because biochar act as a liming agent to increase the soil pH, and decrease exchangeable Al.

Biochar application may provide positive changes to the soil's physical characteristics such as decreasing the soil strength and increasing the soil's field capacity (Chan *et al*. 2007, 2008). Laird *et al*. (2010) reported that biochar amended soils retained greater water holding capacity and no effect was detected regarding saturated hydraulic conductivity. Similar soil-water parameters were studied by Asai *et al*. (2009), and it was discovered that applying biochar to upland rice paddies, improved soil water permeability and water holding capacity. From this study, it was verified that finer fractions increased water retention. For example, the particle size (0.5mm) was probably responsible for an increase of moisture (Glab *et al.* 2016).This increase occurred because small biochar particles often have more micro pores than large biochar particles, holding more water than large particles (Blanco-Canqui *et al.* 2019). The increase in water retention with a decrease in particle size (especially in 0.5 mm) was also reported by Ibrahim *et al.* (2017).

It was observed that biochar particle size of 0.5mm performed best with the highest plant height. It also had the highest number of leaves, largest girth and leaf area from 4 to 8WAS. This is consistent with the findings of Hardy *et al.* (2015) which stated that there was a significant improvement due to more exposed surface area with reduced particle size of the biochar that might have enhanced nutrients adsorption and release for crop growth. Glaser *et al.* (2002) reported that application of biochar removed all the constraints that limit plant growth as well as enhanced the fertilizers use efficiency hence increased plant biomass. Steiner *et al.* (2007) also report that finer sizes of biochar application improved nitrogen availability in soil and transport in plant, enhancing photosynthesis and increasing plant biomass. Smaller biochar feedstock particles enhance the release rate of volatile organic materials and syngas and the biochars having smaller particle sizes might have greater plant nutrient availability thereby improving growth parameters (Sigua *et al*., 2014). The large surface area of finer biochars resulted in increased CEC, which may prevent nutrient leaching (Lehmann and Joseph, 2009). By increasing CEC, applied fertilizers can be adsorbed to the surface area and thereby used more efficiently by plants (Steinbeiss *et al*., 2009). Significant decrease in leaching of applied fertilizers after biochar addition has been reported (Lehmann *et al*. 2003). Furthermore, improved plant uptake of N, P and K has been documented (Ndor, 2016). The yield performance of biochar particle size of 0.5mm had the highest cob length, cob girth, seed weight per cob and yield with values of 10.883cm, 3.640cm, 117.90g and 7094.17kg/ha. This is in accordance with the findings of Blackwell *et al*. (2010) who reported that smaller sizes of biochar increased yield due to the fact that it provided better supply of water to plants. This is due to its large surface area, ability to retain moisture and nutrients (Lehmann *et al.,* 2003). Uzoma *et al.* (2011) also reported that biochar application appreciably improved the grain yield of maize. The results of this research also agreed with the findings of Liang *et al.*, 2014) who reported the importance of biochar particle size in improving yield due to its associated improvement in soil physical properties (bulk density and water storage).

Conclusion

From the result obtained from this study, it can be concluded that biochar particle size of 0.5mm performed best with the improvement in the physicochemical properties of the soil and highest in the growth and yield parameters of maize. Biochar amendment should be grounded to smaller sizes before application in order to get better growth and yield of maize. Biochar has very promising potential for the further development of sustainable agriculture production. Hence, may be adopted in maize production

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