

*Full Length Research Paper*

# **Effect of biochar application on selected soil properties in Southwestern Nigeria**

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**This study investigated the effect of biochar on dispersible clay and soil chemical properties. The treatments consisted of four rates of milled biochar (0, 450, 900 and 1344 kg/ha) arranged in a Completely Randomized Design with four replicates. Surface (0-15 cm depth) soil of Iwo (Sandy loam) and Egbeda (Loamy sand) soil series were collected from the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria. 1 kg of each soil sample was thoroughly mixed with milled biochar at different rate and maintained at field moisture capacity for a period of 12 weeks in the screen house. Soil particle size distribution, bulk density, dispersible clay, soil pH, soil organic carbon and available phosphorous were determined. Data obtained were subjected to analysis of variance; Duncan's New Multiple Range Test was used to separate significant means at  $p \leq 0.05$ . It was revealed from the results that biochar addition at rate 450 and 1344 kg/ha appeared to be more beneficial and adequately improved soil pH, organic carbon and available phosphorous. Biochar at 900 kg/ha significantly reduced dispersible clay. It was concluded that short term biochar amendment did not improve soil quality of loamy sand.**

**Keywords:** Biochar, dispersible clay, soil organic carbon, available phosphorus, soil pH.

## **INTRODUCTION**

Biochar has been reported to be widely considered as soil amendment. It boosts soil fertility and improved soil quality (Mukherjee and Lal, 2013). Its addition into the soil raised soil pH, increased moisture holding capacity, attracted more beneficial microbes and fungi, improved cation exchangeable capacity (CEC), and retained nutrients in soil. Also, biochar as soil amendment improves carbon sequestration capacity of the soil (Yadav et al., 2017). Preventing the loss of water and nutrient is one of the environmental benefits of biochar

application to the soil. Olakayode et al. (2019) reported that biochar are more beneficial to adequately improved water movement in the soil. Yang et al. (2018) reported that biochar have a strong affinity for organic contaminants, therefore it helps to prevent toxic substances from contaminating the environment. Jiang et al. (2019) reported that adding biochar to soil increased nutrient availability, soil pH, organic carbon and crop yield.

Physical properties of soil have direct influence on soil

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productivity and crop production; they determine soil water holding capacity, aeration and strength which affect root activity (Rattan et al., 2015). Organic matter content of the soil has great effect on physical properties of the soil. It improves soil structure, increases soil porosity and enhances nutrient and water retention. All these result into improved root growth and crop yield. Nutrients are held and made available for plant uptake by clay minerals and soil organic matter. Usually, application of organic materials such as compost and manure into soil enhance nutrients retention capacity. Biochar has been reported to be more effective than other organic materials in retaining and making nutrients available to plants (Li et al., 2014). Its surface area and complex pore structure are habitat to bacteria and fungi which are beneficial to plant (Jin et al., 2014; Li et al., 2014). Also, the higher content of ash/minerals in biochar may contribute to its stability in soils (Han et al., 2018; Yang et al., 2018).

Various soil properties affect the ability of the soil to optimally support growth of plants either directly or indirectly by interfering with plant-soil interactions, reactions and processes. These properties can generally be grouped as either physical or chemical. Some of the physical properties include soil bulk density, texture, structure, porosity, hydraulic conductivity, etc., while some of the chemical properties include pH, organic carbon, cation exchange capacity (CEC), etc. Improvement in soil physical properties will minimize the risks of degradation in agricultural soils caused by traditional management techniques such as tillage. Biochar has been found to alleviate soil compaction by decreasing bulk density, which increases porosity and enhances favorable soil processes (Akhtar et al., 2014). Application of biochar as a soil amendment reduces tensile strength and penetration resistance.

Clay dispersion is the precursor for selective washing away of clay particles by agents of erosion, this results into severe deterioration of the soil. This dispersion is affected by several soil physical, chemical and biological properties. Despite the relative availability of biochar in Nigeria, its effectiveness to ameliorate clay dispersion and other soil properties has not been properly evaluated. This research was conducted to examine the effect of biochar on selected soil chemical properties and dispersible clay.

## MATERIALS AND METHODS

Bulk top soil (0 - 15 cm) samples of Iwo (Sandy loam) and Egbeda (Loamy sand) soil series, which are both Ultisols were obtained from different uncultivated land at the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, Nigeria (Latitudes 7° 32'N and 7° 33'N and Longitudes 4° 32'E and 4° 34'E). The soils were classified as Ultisol due to the presence of kandic horizon (USDA Soil Taxonomy, 2017). It has a finer texture at subsoil horizon that is about 18 cm thick or more below the coarser-textured surface horizon. The soil moisture regime of Ile-Ife area is ustic. The vegetation over the soil was cleared before the soil was

collected. Bulk top soil (0-15 cm) samples were obtained randomly in the field with a spade and mixed together.

Bulk samples of both Iwo and Egbeda soil series collected were air-dried, and sieved through a 6.7 mm sieve so as to preserve aggregates. Another fraction of the soil was also sieved through a 2 mm mesh number, from which antecedent physical and chemical properties of the soil were determined. These include soil pH, organic carbon, available phosphorous, bulk density, field moisture capacity and dispersible clay index. The charcoal used for the experiment was crushed into fine particles to increase its surface area for better reaction within the soil and then, was also sieved using 0.5 mm mesh number.

Perforated plastic cups (868 ml), plugged with cotton wool at the bottom to allow free water drainage were filled with 1 kg air-dried soil and thoroughly mixed with four rates of milled wood biochar (0, 450, 900 and 1344 kg/ha soil). This was done for the two soil types (Iwo and Egbeda series) and each treatment had four replications and subsequently labeled. The experiment was laid out in a randomized complete block design with four replicate consisting of the following: Soil only (Control) (C<sub>1</sub>), Soil + 450 kg biochar/ha soil of biochar (C<sub>2</sub>), Soil + 900 kg biochar/ha soil of biochar (C<sub>3</sub>), Soil + 1344 kg biochar/ha of soil biochar (C<sub>4</sub>). Each cup was maintained at 70% field moisture capacity throughout the course of the 12 weeks' experiment.

The particle size distribution of the soil was determined by the modified hydrometer method used by Oyebiyi et al. (2018), while the soil textural triangle was used to classify the soils into textural classes.

The soil pH was determined by digital pH meter (Walk lab Ti 9000) in a soil-water suspension ratio of 1:2 in 0.01 M CaCl<sub>2</sub>. Soil organic carbon content was determined by wet digestion method using potassium dichromate (K<sub>2</sub>Cr<sub>2</sub>O<sub>7</sub>) as oxidizing agent in the presence of concentrated sulphuric acid (H<sub>2</sub>SO<sub>4</sub>). The percent organic carbon was determined by titrating the solution with 1 N ferrous ammonium sulphate solution. Available phosphorus was determined using the Bray-1 method and read at 660 nm wavelength. Dispersible clay was determined using centrifuge machine and spectrophotometer at 660 nm to measure the turbidity. A standard curve was plotted with the concentrations of the standards against the absorbance readings and this was used to determine the concentrations of clay in the samples (Pojasok and Kay, 1990).

$$\% \text{ Clay} = \frac{\text{soil value}}{0.2} (100)$$

The data obtained were subjected to analysis of variance, Duncan's New Multiple Range Test was used to separate significant means at  $p \leq 0.05$ .

## RESULTS AND DISCUSSION

Table 1 shows antecedent physical and chemical properties of the soil. The particle size distribution of the soils confirmed that Iwo series is sandy loam while Egbeda series is loamy sand contained. The bulk density of the soils is below the critical level of 1.63 g/cm<sup>3</sup> (USDA, 2018); the field moisture capacity contents were 21 and 16% for Iwo and Egbeda soil, respectively. The dispersible clay for Iwo series was 0.007% and that of Egbeda was 0.012%. The organic carbon (OC) contents of both Iwo and Egbeda series were 2.7 and 4.3 g kg<sup>-1</sup>, respectively. The soil pH was moderately acidic (6.0) in Iwo series and slightly acidic (6.4) in Egbeda series. The

**Table 1.** Antecedent physical and chemical properties of the soil used for the experiment.

Parameter	Iwo series	Egbeda series
Sand (g kg <sup>-1</sup> )	781.6	841.6
Silt (g kg <sup>-1</sup> )	66.8	46.8
Clay (g kg <sup>-1</sup> )	151.6	111.6
Texture	Sandy loam	Loamy sand
Soil bulk density (g/cm <sup>3</sup> )	1.14	1.12
Field moisture capacity (%)	21	16
pH in 0.01 M CaCl <sub>2</sub>	6.0	6.4
Organic carbon (g kg <sup>-1</sup> )	2.7	4.3
Available P (mg kg <sup>-1</sup> )	12.6	12.7
Dispersible clay (%)	0.007	0.012

**Table 2.** Changes in dispersible clay contents of Iwo and Egbeda Soil series over a period of 12 weeks.

Parameter	Rate (kg/ha)	Weeks					
		2	4	6	8	10	12
Iwo D_Clay (%)	Control	0.010 <sup>b</sup>	0.016 <sup>a</sup>	0.025 <sup>a</sup>	0.009 <sup>a</sup>	0.022 <sup>b</sup>	0.007 <sup>a</sup>
	450	0.008 <sup>b</sup>	0.015 <sup>a</sup>	0.025 <sup>a</sup>	0.011 <sup>a</sup>	0.018 <sup>b</sup>	0.008 <sup>a</sup>
	900	0.029 <sup>a</sup>	0.015 <sup>a</sup>	0.028 <sup>a</sup>	0.007 <sup>a</sup>	0.029 <sup>a</sup>	0.007 <sup>a</sup>
	1344	0.009 <sup>b</sup>	0.015 <sup>a</sup>	0.027 <sup>a</sup>	0.009 <sup>a</sup>	0.019 <sup>b</sup>	0.008 <sup>a</sup>
Egbeda D_Clay	Control	0.005 <sup>a</sup>	0.006 <sup>a</sup>	0.007 <sup>a</sup>	0.019 <sup>a</sup>	0.008 <sup>a</sup>	0.012 <sup>a</sup>
	450	0.005 <sup>a</sup>	0.006 <sup>a</sup>	0.007 <sup>a</sup>	0.019 <sup>a</sup>	0.015 <sup>a</sup>	0.013 <sup>a</sup>
	900	0.004 <sup>a</sup>	0.006 <sup>a</sup>	0.007 <sup>a</sup>	0.019 <sup>a</sup>	0.012 <sup>a</sup>	0.012 <sup>a</sup>
	1344	0.004 <sup>a</sup>	0.005 <sup>a</sup>	0.008 <sup>a</sup>	0.019 <sup>a</sup>	0.013 <sup>a</sup>	0.012 <sup>a</sup>

Means with the same letter on a column are not significantly different ( $P < 0.05$ ) according to Duncan's New Multiple Range Test.

available phosphorous of both Iwo and Egbeda series were 12.6 and 12.7 g kg<sup>-1</sup>, respectively.

### Effects of biochar amendment on dispersible clay contents

Table 2 shows the effects of the treatments on soil dispersible clay index after 2 to 12 weeks of addition. In Iwo series, the 900 kg/ha addition of biochar significantly decrease the dispersible clay at weeks 2 and 10. This could be as a result of negative surface charge of biochar which attracts cations (Usman et al., 2015); these cations serve as bridge between biochar and clay particles. There was no significant difference among the treatments at the end of weeks 4, 6, 8 and 12. For Egbeda series there were no significant difference between dispersible clay content of the treatments throughout the 12-week period of the experiment. However, treatment 450 kg/ha increased the dispersible clay content at weeks 10 and 12 but not significantly. This may be due to the fact that the soil is already rich in carbon. This was in line with the findings of Yao et al. (2013) who reported that clay

dispersion depends on the soil amendment.

### Effects of biochar addition on soil pH, organic carbon content and available phosphorous

The effect of treatment on soil pH and organic carbon content over a period of 6 and 12 weeks and available phosphorous at week 12 only are shown in Table 3. Soil pH of the two soil series was not significantly influence by biochar application except in the 12th week of Iwo series where biochar significantly increased the soil pH. Shareef and Zhao (2017) reported that application of charcoal (biochar) increased soil pH, and also decreased Al concentration in acid soils.

At the end of weeks 6 and 12 of Iwo series, biochar applied at rate 1344 kg/ha significantly ( $P < 0.05$ ) increased the soil organic carbon contents. The higher organic carbon content would provide better living condition for soil microbes and these can partly improve the effect of biochar on soil structure (Luo et al., 2016). Surprisingly, biochar addition at week 6 had no significant effect on organic carbon content of Egbeda soil series.

**Table 3.** Effects of biochar addition on soil pH, organic carbon content and available phosphorous contents of Iwo and Egbeda soil Series at the end of 6 and 12 weeks.

Parameter	Rate (kg/ha)	Iwo series		Egbeda series	
		Weeks			
		6	12	6	12
SOC (%)	Control	0.438 <sup>b</sup>	0.453 <sup>b</sup>	0.983 <sup>a</sup>	1.218 <sup>a</sup>
	450	0.490 <sup>ab</sup>	0.940 <sup>c</sup>	0.943 <sup>a</sup>	1.023 <sup>c</sup>
	900	0.435 <sup>b</sup>	0.880 <sup>d</sup>	0.860 <sup>b</sup>	1.148 <sup>ab</sup>
	1344	0.563 <sup>a</sup>	1.210 <sup>a</sup>	0.943 <sup>a</sup>	1.083 <sup>cb</sup>
pH	Control	5.200 <sup>a</sup>	5.175 <sup>b</sup>	6.575 <sup>a</sup>	6.475 <sup>a</sup>
	450	5.350 <sup>a</sup>	5.300 <sup>ab</sup>	6.525 <sup>a</sup>	6.500 <sup>a</sup>
	900	5.325 <sup>a</sup>	5.425 <sup>ab</sup>	6.525 <sup>a</sup>	6.325 <sup>a</sup>
	1344	5.300 <sup>a</sup>	5.500 <sup>a</sup>	6.650 <sup>a</sup>	6.500 <sup>a</sup>
P (g kg <sup>-1</sup> )	Control	-	12.63 <sup>b</sup>	-	12.68 <sup>a</sup>
	450	-	13.23 <sup>ab</sup>	-	12.02 <sup>a</sup>
	900	-	13.25 <sup>ab</sup>	-	12.85 <sup>a</sup>
	1344	-	14.56 <sup>a</sup>	-	12.50 <sup>a</sup>

Means with the same letter on a column for each parameter are not significantly different ( $P < 0.05$ ) according to Duncan's New Multiple Range Test.

**Table 4.** Effects of biochar addition on organic carbon sequestration in Iwo and Egbeda series over a period of 6 and 12 weeks.

Week	OC sequestration (%)
6	21.66 <sup>a</sup>
12	13.50 <sup>b</sup>

Means with the same letter in a column are not significantly different ( $P < 0.05$ ) according to Duncan's New Multiple Range Test. OC = Organic carbon, % = Percentage.

Whereas, the control (without biochar) at week 12 was significantly ( $P < 0.05$ ) higher than those with treatments.

Available phosphorous content was increased as the rate of biochar increases in Iwo soil series. Gao et al. (2018) also found that biochar application increased phosphorus concentration of agricultural soil. While biochar at rate 1344 kg/ha had significantly highest P contents, there was no significant difference among other rates. But no significant difference was observed in the available P content of Egbeda soil series at various treatments level. A slight increase in available P was observed in treatment 900 kg/ha, although not significant.

Generally, the increase observed in soil pH and available P from different rates of treatments was similar to the findings of Atere and Olayinka (2013).

Table 4 shows the effect of biochar addition on organic carbon (OC) sequestration in Ultisol after 6 and 12 weeks of addition. OC sequestration significantly reduced from

21.66 to 13.50% at 6 and 12th week, respectively. Since carbon sequestration is long term storage of carbon in soil, the reduction of organic carbon from 6 to 12th week may be due to decomposition with time (Purakayastha et al., 2015).

## Conclusion

The sandy loam soil (Iwo series) responded better to biochar addition when compared with the loamy sand (Egbeda series). Biochar addition at rate 450 and 1344 kg/ha appeared to be more beneficial and adequately improving the soil pH, organic carbon and available phosphorous. 900 kg/ha addition of biochar significantly decreased dispersible clay under the conditions of this study. It was concluded that short term biochar amendment did not improve soil quality of loamy sand.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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