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Effect of biochar on soil chemical properties and yield attributes of sweet potato (*Ipomoea batatas*) in an ultisol of Umudike, Southeastern Nigeria

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Abstract

A field trial was carried out at the Michael Okpara University of Agriculture, Umudike to evaluate the effect of plant and animal wastes biochar applied at different rates on the yield of sweet potato (*Ipomoea batatas*) and post-cropping soil chemical properties. . The treatments comprised of control (0t/ha), biochar at 2.5t/ha, 5t/ha, 7.5t/ha and 10t/ha and NPK (15:15:15) at 400kg/ha. The experiment was laid out in RCBD and the treatments were replicated 4 times. The soil of the study area was strongly acidic, having a pH (H_2O) of 4.87 and an exchangeable acidity of 1.92 cmolkg^{-1}. The soil was high in organic matter content (2.81%) and exchangeable bases ((Ca, Mg, K and Na) at (4.40, 2.40, 0.13, and 0.11cmolkg^{-1} respectively). Results from the field study showed that biochar at 5t/ha produced the highest saleable sweet potato (7.84 t/ha), 7.5t/ha of biochar produced the least non-saleable sweet potato root weight (0.21 t/ha) and 5t/ha of biochar gave the highest total root weight (8.11 t/ha). Results of soil analysis after harvest showed that all the rates of biochar applied improved some soil chemical properties such as soil pH, soil organic carbon, available phosphorus, exchangeable calcium and magnesium. In conclusion, the application of biochar is capable of ameliorating acidity, enhancing the nutrient status and improving yield in the study area.

Keywords: Biochar, Soil properties, utilsols, Sweer potato

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1.0 Introduction

Ultisols are commonly known as red clay soils. They are typically quite acidic, often having a pH of less than 5. The red and yellow colours result from the accumulation of iron oxide (rust), which is highly insoluble in water (WRB, 2015). Acid, sandy ultisols, which are common in the humid rainforest zone of southeastern Nigeria, are inherently infertile, especially under the intensive cultivation that has been occasioned by the reduction in fallow periods following high population pressure and industrialization (Udoh, 2018). The usual approach of maintaining fertility has simply been the application of recommended doses of inorganic fertilizers. Inorganic fertilizers when applied on acid sandy ultisols, under a high rainfall regime like that of southeastern Nigeria, the nutrients supplied are easily lost through leaching, surface runoff or soil erosion (Udoh, 2018). Indeed, high dependence on inorganic fertilizers in the humid zones of the tropics is becoming less preferable and uneconomical, coupled with the need for frequent applications to sustain fertility. Organic fertilizers on the other hand improve soil CEC, nutrient stock, soil structure, base saturation and bulk density. However, applications of large doses of manures could cause environmental hazards, stream and river pollution and soil acidification (Munoz *et al.,* 2003).

Biochar is a term used to designate a carbon-rich product obtained when biomass (such as wood, crop residue, etc.) is heated in a closed container with little or no available oxygen (Lehmann and Joseph, 2009a). When added to soil, biochar has been reported to increase available nutrients and prevent their leaching, stimulate the activity of agriculturally important soil microorganisms, act as an effective carbon sink for several hundred years, sequester atmospheric CO_2 in soil, suppress emissions of other greenhouse gases, and mitigate offsets from agrochemicals (Thies and Rillig, 2009).

A fertilizer is any material of natural or synthetic origin (other than liming materials) that is applied to soil or to plant tissues to supply one or more plant nutrients essential to the growth of plants (Heinrich, 2000). According to "Summary of State Fertilizer Laws" (EPA, 2013), NPK fertilizers are three-component fertilizers providing nitrogen, phosphorus, and potassium. NPK classification describes the amount of nitrogen, phosphorus, and potassium in a fertilizer. The three main macronutrients which are contained in fertilizers are important in the following ways: Nitrogen (N) is important for leaf growth, phosphorus (P) for the development of roots, flowers, seeds, fruit and potassium (K) is important for strong stem growth, translocation of water in plants, promotion of flowering and fruiting (Dittmar *et al.,* 2009). These macro-nutrients are required in larger quantities and are present in plant tissue in quantities from 0.15% to 6.0% on a dry matter (DM) (0% moisture) basis (Mills and Jones, 1996). *Ipomoea batatas* (Lam), commonly known as sweet potato belongs to the family *Convolvulaceae*. It is an important root vegetable that is large, starchy, and sweet-tasting (Purseglove, 1972; Woolfe, 1992). *Ipomoea batatas* have played an important role as an energy and phytochemical source in human nutrition and animal feeding. The plant has significant medicinal importance and various parts of the plant are used in traditional medicine. (FNB and Anno, 1980), besides simple starches, sweet potatoes are rich in complex carbohydrates, dietary fibre, iron, and vitamin content such as beta-carotene (a pro-vitamin A carotenoid), vitamin B_2, vitamin C, and vitamin E (Antia *et al.,* 2006). The tuber is an excellent source of flavonoids, phenolic compounds such as beta-carotene which converts to vitamin A once consumed.

There are several papers that report positive effects of biochar addition on crop growth and development (Asai *et al.,* 2009; van *et al.,* 2010; Coomer *et al*., 2012; Zhang *et al.,* 2012; Carter *et al.,* 2013; Saxena *et al.,* 2013; Vinh *et al.,* 2014). Some reports have also illustrated negative (Lehmann *et al.,* 2013; Chan *et al.,* 2008) or no response of crops to biochar (Branndstaka *et al.,* 2010; Borsari 2011; Lal *et al.,* 2013). Some reports emphasized that the effect was positive when biochar and mineral fertilizers were used, with mineral fertilizers having a greater positive effect (Alburquerque *et al.,* 2014). However, more studies are required to understand the difference in the performance of plants when biochar rates and NPK (15:15:15) fertilizers are used.

The objective of this study, therefore, was to determine the effect of biochar rates on soil chemical properties, and the yield of Sweet potato.

The specific objectives of this study were to;

Determine the effects of biochar and NPK (15:15:15) on yield attributes of sweet potato.

Determine the effects of biochar and NPK (15:15:15) fertilizer on some soil chemical properties at harvest

2.0 Materials and Methods

A field experiment was carried out at the Eastern farm of Michael Okpara University of Agriculture, Umudike. Umudike is located within the rainforest ecological zone of Nigeria. Soils of this area are acidic. This area has a characteristic bimodal rainfall regime, with peaks in July and September, and an average rainfall of 1916mm per annum. This area lies at Latitude 05°29' North and Longitude 07°33' East with an elevation at 122 meters (400 ft.) above sea level. The mean annual maximum temperatures range from 30^{O}C to 33^{O}C and mean annual minimum temperatures range from 21^{O}C to 29^{O}C while the soil temperature ranges from 23.0 ^{O}C to 24.6^{O}C. Relative humidity varies from 51% to 87% (NRCRI, 2013).

2.1 Soil sampling and soil preparation

Initial soil samples were collected by random sampling from the experimental site at a depth of 0-15cm with a soil auger and bulked together into a composite sample. The composite sample was sent to the laboratory, where it was air-dried, crushed and sieved through a 2mm size sieve for laboratory analysis before experimentation. Also, the soil was analyzed after harvest to determine the effects of treatments on some soil chemical properties on plot basis using the following standard laboratory procedures:

Soil pH was determined in soil and distilled water suspension, in the ratio of 1:2.5. It was stirred for about 30 minutes and the pH value was read with aid of a glass electrode pH meter (Mclean, 1982). Particle size distribution of sampled soils was determined by the Bouyoucos hydrometer method as modified by Gee and Bauder (1986), using sodium hexametaphosphate (Calgon) as a dispersing agent.

Organic carbon was determined by the wet dichromate oxidation method, with H_2SO_4 and $K_2Cr_2O_7$ followed by residual titration with 1N HCl (Walkley and Black, 1934). Organic matter was determined by multiplying % organic carbon by 1.724 (Van Bemmelen Factor) based on the assumption that the Walkley-Black procedure is only able to oxidize 75% of organic carbon present in the soil. Available phosphorus was extracted by the Bray 2 extractant (Bray and Kurtz, 1945). The P in solution was analyzed using the Murphy and Riley method (1965). Total nitrogen was determined by the regular Micro-Kjeldahl distillation method (Black, 1965) where the digested sample was heated by passing steam at a steady rate and the liberated ammonia absorbed turning the pinkish colour to green (AOAC, 1995). Soil exchangeable calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) were extracted with neutral normal ammonium acetate (1N Neutral NH_4OA_C). Exchangeable calcium and magnesium in the extract (leachate) were determined by the ethylene diamine tetra-acetic acid (EDTA) titration method (Suarez, 1996), while sodium and potassium were read using the flame photometry (Kundsen *et al.,* 1982). Exchangeable acidity was determined by extracting 5g of soil with 1N KCl and titrating with 0.5N NaOH using phenolphthalein indicator (Mclean, 1982).

2.2 Treatments

The treatments and their application rates were as follows;
Treatment 1: Control = 0tons/ha.

Treatment 2: Biochar = 2.5tons/ha

Treatment 3: Biochar = 5tons/ha.

Treatment 4: Biochar = 7.5tons/ha.

Treatment 5: Biochar = 10tons/ha

NPK (15:15:15) = 400kg/ha which was a recommended fertilizer for sweet potato was included as a control too.

These treatment rates were replicated four (4) times to give twenty-four (24) observations.

Where,

Tons/ha = Tonnes per hectare

Kg/ha =Kilogram per hectare

NPK= Nitrogen, Phosphorus, and Potassium fertilizer

2.3 Biochar production

Biochar was produced locally using the following feedstocks: sawdust, cocoa pod, palm bunch, rice husk, poultry droppings, goat and cow dung. Animal dung (poultry dropping, goat and cow dung) were sourced from Michael Okpara University of Agriculture, Umudike animal farm, sawdust from Timber Market Ahieke and rice husk from Bende rice mill in Uzoakoli LGA of Abia state. NPK (15:15:15) fertilizer was sourced from the Ministry of Agriculture and Rural Development, Umuahia Abia State. Weights of the feedstocks were taken. These organic residues were combined and subjected to slow pyrolysis using the pyrolysis drum where the materials were top-loaded. The feedstocks were ignited and allowed to burn at an approximate temperature of 450 ^{O}C and afterwards, the produced biochar was allowed to cool before collection into sacks, and the biochar produced was analyzed to determine its chemical properties. Biochar pH was determined in water. The suspension was stirred for about 30mins and the pH value read with aid of a glass electrode pH meter (Mclean, 1982). Organic carbon was determined by the wet dichromate oxidation method, with H_2SO_4 and $K_2Cr_2O_7$, followed by residual titration with 1N HCl (Walkley and Black, 1934). Total nitrogen was determined by the regular Micro- Kjeldahl distillation method (Black, 1965). Available phosphorus was extracted by the Bray 2 extractant (Bray and Kurtz, 1945). The P in solution was analyzed using the Murphy and Riley method (1965). Soil exchangeable calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K) were extracted with neutral normal ammonium acetate (1N Neutral NH_4OA_C). Exchangeable calcium and magnesium in the extract (leachate) were determined by the ethylene diamine tetra-acetic acid (EDTA) titration method (Suarez, 1996), while sodium and potassium were read using the flame photometry (Kundsen *et al.,* 1982).

The farm site was slashed, ploughed, harrowed and marked out. The experiment was laid out in a Randomized Complete Block Design (RCBD), replicated four times with 6 treatments. The plot size was 3m x 3m (9m^2). A planting distance of 30cm x 1m, and inter-row spacing of 1m between experimental plots were used. The variety of sweet potatoes that were planted was Umu spo1. The vine (stem) cuttings of the sweet potato variety Umu Spo1 was obtained from the variety maintenance trials of National Root Crops Research Institute Umudike and was planted at the stem cutting length of 40cm. The stems were placed slanted at about 45^{O}. Soil chemical properties such as pH, organic carbon, total nitrogen, available P, exchangeable cations etc. were determined in the laboratory after harvest using the procedures outlined earlier. The biochar was surface-applied before being incorporated into the soil using a hoe and this was done and allowed for 2 weeks before planting of vines (stem) cuttings. NPK (15:15:15) fertilizer was applied at 4weeks after planting. Weeds were controlled manually using a weeding hoe. This was done without restriction at the slightest emergence of weeds. Pest and diseases were controlled by the use of pesticides and handpicking of the insect pest.

2.4 Record at harvest

At harvest, the following records were taken on plot basis. The effect of treatments at their different rates was evaluated based on the following:

Total root weight: Obtained as the sum of weights of both marketable and unmarketable roots.

Total root number: This was obtained as the sum of the number of marketable and unmarketable sweet potato roots.

Weight of Saleable Roots: This was done by weighing the saleable roots using a 10kg weighing balance. Saleable roots are roots that are more than or equal to 100g (Levette, 1993) or with diameters at the widest point greater than 25mm (Stathers *et al.,* 2003) are called saleable (or marketable) roots. **Weight of Non-Saleable Roots:** This was obtained by weighing the non-saleable roots (unmarketable roots) using a 10kg weighing balance. Non-saleable roots are roots that are less than 100g (Levette, 1993) are called non-saleable (or unmarketable) roots.

Number of Saleable (marketable) Roots: Roots that were more than or equal to 100g (Levette, 1993) or with diameters at the widest point greater than 25mm (Stathers *et al.,* 2003) are called saleable (or marketable) roots and this was done by counting them.

Number of Non-Saleable (unmarketable) Roots: This was done by counting the number of sweet potato roots that were less than 100g (Levette, 1993).

2.5 Statistical analysis

All data collected were subjected to Analysis of Variance (ANOVA) using GenStat Software. Significant means separation was done according to Obi (2002) using Fischer's Least Significant Difference where significance existed.

3.0 Results and discussion

Result of the physical and chemical properties of the soil before treatment application as shown in Table.1 shows that the soil was sandy loam in texture. According to Anikwe and Nwobodo (2002), sandy loam soil is usually highly permeable and allows large quantities of leachate to pass through it. As a result of this high permeability, soils of this texture contain poor plant nutrients and therefore, organic and inorganic fertilizers are needed to improve soil productivity levels. The soil had a pH of 4.87 indicating that it is strongly acidic (Chude *et al.,* 2005). This result is in agreement with a report on similar soils by Mohammed and Ayodele (2011) who also reported the same pH value for soils of the Kaduna Metropolis-Nigeria. In this study, the low pH of the soil could be attributed to the various agricultural activities or high annual rainfall which could have resulted in the leaching of most of the basic cations. For this soil to increase its productivity, liming is needed. The soil nitrogen was 0.09%. This low nitrogen content was a reflection of the organic carbon content in the soil (Onyekwere *et al.,* 2003). The value recorded was lower than the critical level of 0.15% reported by Adeoye and Agboola (1984) for most soils of southern Nigeria. The low level of nitrogen could be a result of losses through crop removal, erosional and leaching losses, and a high rate of mineralization (Agbede, 2009).

Soil exchangeable calcium, potassium, magnesium and sodium were low. The value of the exchangeable K (0.12 cmol/kg) was below 0.20cmol/kg regarded as the critical limit for exchange K in most tropical soils (Onyekwere *et* *al.,* 2001). This result agrees with the findings of Nwite *et al*. (2009); Ezekiel *et al.* (2009) who observed that soils of southeastern Nigeria are low in exchangeable calcium, magnesium, potassium and sodium.

The available phosphorus was 25.6mg/kg, which was much higher than the critical level of 12-15mg/kg for most crops (Enwezor, 1997). The presence of organic matter might have influenced the level of availability of phosphorus since the decomposition of organic matter liberates phosphorus. The soil percentage of organic carbon was 1.63% which is good for the most southern ecosystem. Therefore organic carbon should be added through management practices such as crop residues, manures and other sources. The acidity can be readily managed by careful management of fertilizer and lime applications to increase the soil pH to improve the fertility and productivity of the soil

Table.1 Physical and chemical properties of soil before experimentation

Soil properties	**Values**
Sand (g/kg)	738.00
Silt (g/kg)	94.00
Clay (g/kg)	168.00
Texture	Sandy loam
Soil pH (H_20)	4.87
Total Nitrogen (%)	0.09
Organic carbon (%)	1.63
Organic matter (%)	2.81
Available P (%)	25.50
ExchangeableCa (cmol/kg)	4.40
Exchangeable Mg (cmol/kg)	2.40
Exchangeable K (cmol/kg)	0.13
Exchangeable Na (cmol/kg)	0.11
Total Exchangeable Bases	7.04
Exchangeable Acidity (cmol/kg)	1.92
ECEC (cmol/kg)	8.96
Base saturation (%)	78.57

Table.2 shows the chemical composition of the biochar used for this study. The biochar was alkaline with a pH (H_2O) of 9.05 probably due to the presence of ash produced during the pyrolysis process and this was consistent with the findings of Rabileh *et al.* (2015) and Norazlina *et al.* (2014) whose study with biochar found out same. It was also high in nitrogen (0.44 %), calcium (4.16 %), potassium (1.83%), magnesium (1.67 %), sodium (0.75 %) and organic carbon (13.00 %) with low concentration of phosphorus (0.44%). Production of the biochar under a relative temperature (450^{O} C) may have resulted in high contents of these parameters (Norazlina *et al.,* 2014). These properties proved that biochar has the potential as a good amendment to improve soil fertility and consequently improve crop growth and yield.

Table.2 Chemical composition of biochar used

Parameters	**Values**
pH(H_20)	9.05
Total nitrogen (%)	0.44
Phosphorus (%)	0.44
Organic carbon (%)	13.00
Calcium (%)	4.16
Potassium (%)	1.83
Magnesium (%)	1.67
Sodium (%)	0.75

3.1 Effects of treatments on Yield of sweet potato.

Effects of treatments on the total root weight of sweet potato at harvest (t/ha)

Table 3 Shows the effects of biochar and NPK (15:15:15) fertilizer on the total root weight of sweet potato at harvest. The result showed that biochar and NPK (15:15:15) fertilizer significantly ($p<0.05$) increased the total root weight over the control. , 5t/ha of biochar gave the highest total root weight of sweet potato over NPK (15:15:15) fertilizer and the control. There was no need to apply more than 5t/ha of biochar to obtain a high yield of sweet potato tubers. However, the increase in total root weight by the application of 5t/ha of biochar could be that the plant benefited from Ca and K obtained from the ash in biochar application. This means that 5t/ha of biochar was more superior in effect on the total root weight than other rates used.

Effects of treatments on the total number of roots of sweet potato after harvest

Table 4 shows the effect of biochar and NPK (15:15:15) fertilizer on the total number of root tubers of sweet potato. The result showed a significant ($p < 0.05$) difference when treatments were applied, over control. Although NPK (15:15:15) fertilizer applied at 400kg/ha was not significantly different from biochar applied at 2.5t/ha but this is different from the control plot. Also, biochar applied at 5t/ha was not significantly different from biochar applied at 7.5t/ha. Biochar at the rate of 5t/ha gave the highest value of the total number of roots t/ha (160) over other treatments. This result is in line with the findings of Yuni *et al.* (2018) from their work on the effect of biochar on cassava growth and fertilization efficiency, they reported that the total number of roots was significantly influenced by biochar application. This implies that there would be no need to apply beyond 5t/ha of biochar in the study area.

Effects of treatments on saleable sweet potato root weight at harvest (t/ha)

The effects of biochar and NPK (15:15:15) fertilizer on saleable root weight of the harvested sweet potato roots per hectare as shown in Table.3 showed a significant difference in the weight of saleable (marketable) sweet potato root weight over the control. Biochar at the rate of 5t/ha gave the highest saleable root weight (7.84) followed by 7.5t/ha (6.31) and 2.5t/ha (6.09) while 10t/ha of biochar gave the least weight of saleable root (4.76). A probable reason for this could be that at this higher rate there was a slower release of nutrients (DeLuca *et al.,* 2015). What this implies is that there would be no need to apply more than 5t/ha as far as saleable root weight is concerned. Akhtar *et al*. (2014) found that the addition of biochar increased the soil moisture contents, which consequently improved the physiology, yield and quality of tomatoes. In addition, Nair (2015) found that there was an increase in crop yield due to biochar application. The increase in saleable root weight of sweet potato by biochar could be attributed to better water holding capacity, high cation exchange capacity and increased nutrient retention.

Effects of treatments on non-saleable root weight of sweet potato at harvest (t/ha)

The result in Table 3 showed no significant difference ($p>0.05$) among treatments applied. Biochar at the rate of 2.5t/ha gave the highest weight of non-saleable sweet potato roots (0.42), and 7.5 t/ha gave the least weight of non-saleable sweet potato root. The non-saleable root weight was in this order: 2.5t/ha of biochar > control > 10t/ha of biochar > NPK > 5t/ha of biochar and > 7.5t/ha of biochar with values (0.42, 0.35, 0.28, 0.27, and 0.21 t/ha respectively). The result showed that non-saleable root weight when NPK (15:15:15) fertilizer was applied was not different from what was gotten when 5t/ha of biochar was applied. What this implies is that it is better to use 7.5t/ha of biochar in the study area as it is not economical for non-saleable sweet potato roots to be in abundance.

Effects of treatments on the number of saleable roots of sweet potato

From the table, it shows that the number of roots in t/ha was responsive to treatment application. The result showed a significant difference ($p<0.05$) in the number of saleable tubers (t/ha) when treatments were applied, over the control. Biochar applied at 7.5t/ha gave the highest number of saleable roots (132). Although 2.5t/ha, 5t/ha and 7.5 t/ha of biochar were not significantly different from one another but were significantly different from the control plot where there was no amendment. This result is in line with the findings of Xiang *et al.* (2017) who reported in their work on the effect of biochar application in root traits: a meta-analysis that biochar application significantly increased the number of roots of soybean.

Effects of treatments on the number of non-saleable roots of sweet potato after harvest

Table.4 below shows the effects of biochar and NPK (15:15:15) fertilizer on the number of non-saleable roots of harvested sweet potatoes. The result showed a significant difference ($p<0.05$) over NPK (15:15:15) fertilizer and the control. Although, 2.5t/ha and 5t/ha were not significantly different from each other. The result showed that biochar at the rate of 10t/ha gave the least value of the number of non-saleable roots (16.10).

Effects of treatments on percentage number of saleable roots of Sweet potato

Table.4 shows the effect of biochar and NPK (15:15:15) fertilizer on the percentage of the number of saleable roots of sweet potato. The result showed a significant difference ($p<0.05$) when biochar was applied at 7.5 t/ha over NPK (15:15:15) fertilizer and control. The rate of 7.5t/ha of biochar gave the highest percentage number of saleable roots of sweet potato (87.2%). It was however not significantly different from the percentage number of saleable roots at 5t/ha of biochar which recorded 86.50%. The increase in percentage number of saleable roots contradicts a recent meta-analysis reported by Biederman and Harpole (2013) that found that biochar application had no significant effect on root biomass. This means that biochar application improved root morphological development by alleviating nutrient deficiency.

Table 3 Effects of treatments on the yield of sweet potato at harvest

Treatment	Saleable Root Weight (t/ha)	Non Saleable Root Weight (t/ha)	Total Root Weight (t/ha)
Control	2.74	0.35	3.09
400kg/ha NPK	5.73	0.27	6.00
2.5t/ha biochar	6.09	0.42	6.51
5.0t/ha biochar	7.84	0.27	8.11
7.5t/ha biochar	6.31	0.21	6.52
10t/ha biochar	4.76	0.32	5.09
MEAN	5.58	0.31	5.89
$LSD_{(0.05)}$	2.18	NS	2.23
Coefficient of variation (%)	24.60	23.10	23.80

NS= Not Significant

Table. 4 Effects of treatments on some yield parameters of sweet potato (t/ha)

Treatment	Saleable root Number(t/ha)	Non saleable Root Number (t/ha)	Total root Root Number (t/ha)	%Saleable root Root Number (t/ha)	% Non-Saleable Root Number (t/ha)
Control	67.70	19.20	86.90 0	78.70	22.50
400kg/ha NPK	110	22.20	132	84.10	16.80
2.5t/ha biochar	126	34.30	132	79.40	21.50
5.0t/ha biochar	126	34.30	160	86.50	14.40
7.5t/ha biochar	132	22.20	154	87.20	13.70
10t/ha biochar	102	16.10	118	77.10	23.80
MEAN	110	24.70	130	82.20	18.80
$LSD_{(0.05)}$	7.93	2.56	8.80	1.42	1.44
Coefficient of variation (%)	16.20	18.50	17.2	18.20	18.00

4.5 Effects of Treatments on Some Soil Chemical Properties after Harvest

Soil pH (water)

Table 5 shows the effect of treatments on soil pH after harvest. The result showed that treatments increased soil pH over control except biochar applied at 10t/ha. The result showed that biochar applied at 2.5t/ha gave the highest soil pH value over NPK (15:15:15) fertilizer and control plots (where there was no amendment). The increase in soil pH owing to the application of biochar was generally attributed to the ash, as ash residues were generally dominated by carbonates of alkali and considerable amounts of silica (Lehmann *et al.,* 2009). In agreement with this, Arocena and Opio (2003) reported the capacity of ashes to neutralize acidic soil. Sukartono *et al.* (2011) also reported that the increase in soil pH following biochar application may be related to the alkali nature of biochars.

Soil organic carbon

The effects of biochar and NPK (15:15:15) fertilizer on soil organic carbon showed that biochar applied at 7.5t/ha significantly ($p<0.05$) increased soil organic carbon over NPK (15:15:15) fertilizer and control. The result showed that 7.5t/ha and 5t/ha of biochar increased the soil organic carbon over the control. This could be as a result of the organic carbon content of the biochar used (13.00%). Although organic carbon at 7.5t/ha of biochar was not significantly different from that at 5t/ha. It could be that at these rates (7.5t/ha and 5t/ha) biochar enhanced the development of optimum soil conditions that helped release nutrients from the soil (Onwuka *et al.,* 2010). Nigussie *et al.* (2012) conducted a pot experiment to examine the consequence of biochar amendment in different soils, results of his study confirmed that organic carbon increased in soil significantly with the application of biochar. Also, the high organic carbon in soils treated with biochar had been reported by Lehmann (2007); Solomon *et al*. (2007) and Liang *et al*. (2006) also revealed the high organic carbon in the black soil which is the fertile soil of the Amazon due to biochar application.

Soil Total Nitrogen (%)

The soil total nitrogen content due to the application of biochar and NPK (15:15:15) fertilizer is shown in Table 5. The result showed that treatments applied were not significantly different ($p>0.05$) over control The result showed that biochar applied at 7.5t/h gave the highest nitrogen content (0.14%), which was lower than the 0.15% critical level reported by Adeoye and Agboola (1984). It could be attributed to the fact that most of the nitrogen in the biochar was lost through burning, lost through leaching in nitrate form, denitrified and or volatilize (Rochette *et al* 2009; Snyder *et al.,* 2007). Or the high surface area of biochar enabled it to adsorb cations and anions in enormous amounts and so the control value of N was high. Also, the reason for the high amount of nitrogen in unamended soil over treatment amended soils could be as a result of the residual effect of mungbean harvested from the field before the experiment was carried out in the study area.

Soil Available Phosphorus

The effects of biochar and NPK (15:15:15) fertilizer on soil available phosphorus showed that 5t/ha of biochar gave the P -value which was significantly higher than all other treatments (39.40 mg/kg). The effect of biochar on available p may have been influenced by the biochar (Wang *et al.,* 2013) as biochar application to soil has been shown to increase available p due to reduction of P adsorption on Fe- oxides (Cui, 2011). This result is in line with the findings of Van Zwieten *et al.* (2010) who reported a significant increase in available phosphorus after the application of biochar. The result shows a significant ($p<0.05$) increase in available phosphorus. Cao and Harris (2010) reported that biochar amendment can modify P availability in soil. Nelson and Sommers (1996) also reported that the application of biochar increased the availability of P.

Table 5. Effects of biochar and NPK (15:15:15) on soil pH, organic carbon total nitrogen and available phosphorus

Treatments	pH (water)	Organic carbon (%)	Nitrogen (%)	Available phosphorus (mg/kg)
Control	5.10	1.92	0.13	34.10
400kg/ha NPK (15:15:15)	6.60	1.72	0.05	30.20
2.5t/ha biochar	6.69	1.23	0.05	27.10
5.0t/ha biochar	5.91	2.09	0.08	30.40
7.5t/ha biochar	6.05	2.11	0.14	29.60
10t/ha biochar	53	1.61	0.07	20.00
MEAN	5.86	1.78	0.09	30.10
LSD $_{(0.05)}$	0.22	0.25	0.03	3.15
Coefficient of variation (%)	2.60	9.60	20.0	7.00

Effects of treatments on Exchangeable cations (Ca, Mg, K and Na) after harvest

The effects of biochar and NPK (15:15:15) fertilizer on soil exchangeable cations (Ca, Mg, K and Na) after harvest is shown in Table 6. The result showed that biochar applied at the rate of 2.5t/ha gave the highest values for soil Ca, Mg, K and Na. The soil exchangeable cations were significantly (P<0.05) higher than the control when 2.5t/ha of biochar was applied. This could be a result of the adverse effect of biochar recorded by many authors that higher rates of biochar decreases to the level of unamended control (Asai *et al*., 2009) the increase in soil pH facilitated by biochar enhanced the rapid release of the mineral nutrients (Ca, Mg, K, and Na) (Niemeyer *et al.,* 2005). Also, Rajkovich *et al*. (2012); Yuan *et al*. (2011) reported that biochar is rich in available nutrients, especially cationic elements such as Ca, Mg, K, and Na. Studies have also shown that biochar increases the availability of Ca, Mg and K because biochar adsorbs and slowly releases the nutrients (DeLuca *et al.,* 2015).

Table. 6 Effects of treatments on soil exchangeable cations (cmol/kg) after harvest

	(cmol/kg)			
Treatments	Mg	Ca	K	Na
Control	2.30	3.60	0.16	0.16
400kg/ha NPK	4.20	9.50	0.42	0.27
2.5t/ha biochar	5.20	12.00	0.48	0.29
5.0t/ha biochar	2.80	5.90	0.19	0.20
7.5t/ha biochar	3.40	8.30	0.30	0.23
10t/ha biochar	1.60	3.00	0.29	0.09
MEAN	3.25	7.05	0.30	0.21
LSD $_{(0.05)}$	0.61	0.96	0.22	0.02
Coefficient of variation (%)	12.6	9.20	47.9	6.50

Effects of treatments on soil exchangeable acidity, effective cation exchange capacity (ECEC) and base saturation after harvest.

Soil Exchangeable acidity

Soil exchangeable acidity as influenced by the application of biochar and NPK (15:15:15) fertilizer is shown in Table 7. The result showed a significant difference (p<0.05) in soil exchangeable acidity. The result showed that biochar at 2.5t/ha gave the least value. The ability of biochar to reduce soil exchangeable acidity could be a result of the addition of biochar which has been shown to eliminate soil constraints that limit the growth of a plant and neutralizes acidic soil because of its basic nature thereby decreasing the soil exchangeable acidity (Hammes and Schmidt, 2009).

Effective Cation Exchange Capacity of the soil (ECEC)

The effective cation exchange capacity of the soil after harvest as influenced by biochar rates and NPK (15:15:15) fertilizer application showed that biochar applied at the rate of 2.5t/ha gave the highest value (18.20cmol/kg) while 10t/ha gave the least value (6.70cmol/kg). This could be a result of biochar which released basic cations into the acidic soil that took part in exchange reactions and replaced the exchangeable acidity in the soil (Warnock *et al.,* 2007; Chan *et al*. 2008; Yuan *et al.,* 2011). Agusalim *et al.,* 2010 and Chan *et al.,* 2008 also revealed the increase in soil effective cation exchange capacity after the application of biochar.

Percentage base saturation

The effects of biochar and NPK (15:15:15) fertilizer on the percentage base saturation status of the soil as shown in Table.7 showed that biochar applied at 2.5 t/ha gave the highest value of per cent base saturation followed by NPK (15:15:15) fertilizer. This is significantly different from 10t/ha of biochar and the control plot. The result showed that all treatments except biochar applied at 10t/ha gave a higher value of base saturation of the soil over the control plot where there was no amendment; biochar at 2.5t/ha gave the highest value of base saturation (%) of the soil over the control. According to (Glaser *et al.,* 2002), biochar can increase base saturation nine-fold over that in control soils and significantly increased available K, Ca, Mg, Total N, and P.

Table 7 Effects of biochar and NPK (15:15:15) fertilizer on soil exchangeable acidity, cation exchange capacity and base saturation after harvest

Treatments	**Soil exchangeable acidity (cmol/kg)**	**ECEC (cmol/Kg)**	**Base saturation (%)**
Control	1.84	8.03	77.10
400kg/ha NPK (15:15:15)	0.38	14.80	97.60
2.5t/ha biochar	0.32	18.20	98.40
5.0t/ha biochar	0.74	9.80	92.50
7.5t/ha biochar	0.50	12.60	96.20
10t/ha biochar	1.92	6.70	71.10
MEAN	0.95	11.70	88.80
LSD $_{(0.05)}$	0.29	1.33	3.12
Coefficient of variation (%)	20.5	7.70	2.40

4.0 Conclusion and Recommendation

4.1 Conclusion

the results, treatments were beneficial for the growth of the sweet potato. In terms of cost, both biochar and NPK are relatively affordable and biochar could be produced at minimal cost, making it accessible to anyone with minimal experience.

One of the main advantages of biochar is that the production technology needed is relatively simple and that industrial processes are not always needed.

Increasing the yield and consumption of orange fleshed sweet potato used in the study area with application of biochar and NPK (15:15:15) which contains more beta carotene than the white or yellow fleshed one, will go a long way in alleviating vitamin A deficiency .

In conclusion, in terms of increasing yield of sweet potato, biochar at 5t/ha is ideal for increasing total yield and saleable (marketable) root tubers of sweet potato. What this implies is that there would be no need applying more than 5t/ha of biochar. Also, 7.5t/ha that gave the least value of non-saleable root tubers is better as it is not economical for non-saleable root to be in abundance. To date, the use of biochar as an amendment brings about numerous benefits to soil properties that help to improve the fertility of the soil such as increase in soil pH, addition of basic cations, improvement of CEC, gradual release of nutrients to growing plants and improved water holding capacity and many more.

4.2 Recommendation

1. In further research, I suggest comparism among sweet potato varieties to see if it conforms to what I got in this study
2. There is a need to identify the differences between the effects of biochar and NPK (15:15:15) fertilizer applied solely, and biochar with NPK (15:15:15) fertilizer in combination to improve growth and yield.
3. In further study, I would like it to be organic matter specific as to ascertain which biochar plant material was more effective and productive in sweet potato production.

References

Adeoye, G.O. and Agboola, A.A (1984). Critical level for soil pH available P ,K, Zn and Mn and maize content of P, Cu and Mn in the sedimentary soils of southwest Nigeria. *Fertilizer research,* 6:65-71

Agusalim, M. Wani, H.U. and Syechfani, M.S (2010). Rice husk biochar for rice based cropping system in acid soil. The characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth in West Kalinantan. Indonesia *J. Agric. Sci*. 2(1): 39-47

Alburquerqu . J.A., Calero, J.M., Barron, V. Torrent, J. Del Compillo, M.C., Gallads A and Villar, R (2014),' Effects of Biochars produced from different feedstocks on soil properties and sunflower', *Journal of plant Nutrition and soil science,* Vol 177(1) 16-25

Anikwe, M.A.N., and Nwobodo K.C.A (2002). Long-term effect of municipal wastes disposal on soil properties and conductivity of sites used for urban agriculture in Abakaliki. Nigeria. *Bioresource Tech. 83.241-250*

Antia, B.S., Akpan E.J., Okon P.A., and Umoren, I.U (2006). Nutritive and anti-nutritive evaluation of sweet potatoes (*Ipomoea batatas*) *Leaves.Pak J Nutr* 5:166－168.

AOAC, (1995). Official Methods of Analysis. 16th ed. Association of Official Analytical Chemists, Washington DC

Asai H, Samson B.K, Stephan H.M, Songyikhagsuthor K, Homma K, and Kiyono Y, (2009). Biochar amendment techniques for upland rice production in Northern Laos In: Soil physical properties, leaf SPAD and grain yield. Field Crops Research.111 (1-2):81-84

Black. C.A. (ed.) (1965*). Methods of Soils Analysis Agronomy No.9.part 2 Amer. Soc. Agronomy, Madison. Wisconsin*.

Borsari, B. (2011). A preliminary study of the effects of biochar from maple *(Acer spp)* on root growth of selected Agronomic crops in International symposium in growing media compositing and subtract analysis 1013, 117-22

Branndstaka T., Helenius J., Hovi, J., Kivela J., Koppelmaki K., Soimojoki A., Soinne, H and Tammeorg P (2010). Biochar filetr use of biochar in agriculture as soil conditioner, university of Helsinki, Heisinki, fineland Report for BSAS commitment 1-19.

Bray, R.H. and L.T Kurtz (1945). Determination of Total Organic and Available Forms of Posphorus in Soils. *Soil Sci. 59:39-45*

Carter, S.S, Sohi BounSuy, T. and Haefele, S (2013). Impact of biochar application on soil properties and plant growth of pot grown lettuce (*Lactuca sativa*) and Cabbage (*Brassica chinensis*). *Agron. 3, 404-418*

Chan, K.Y., Van Zwieten, E.L, Meszaros, I., Downie, A., and Joseph, S. (2008). Using poultry luter biochar as soil amendement.soil research 46 (5), 437-444.

Chude, V.O., Jayebi, J.O., and Oyebanji D.O. (2005). Handbook on soil fertility and use of agricultural line in crop production.1-14.

Coomer, T.D, Oosterhuis D.M, Longer D.E, and Lora D.A. (2012) effect of poultry litter Biochar in early season cotton growth summaries of Arkansas Colton research AAES Research series 610

Cui, H.J. (2011). Enhancing phosphorus availability in Phosphorus fertilized zones by reducing phosphate adsorbed on ferrihydrite using rice straw-derived biochar. *Journal of soils and sediments* 11(7).1135-1141

DeLuca, T.H., Gundale, M.J, Mackenzie, M.D, and Jones D.L. (2015). Biochar effects on soil nutrient transformation. In: Lehmann J, Joseph S, editors. *Biochar for Environmental Management Science and Technology. 2nd ed. Routledge.* 421-454

Dittmar, Heinrich. Drach, Manfred. Vosskamp, Ralf. Trenkel, Martin E. Gutser, Reinhold and Steffens, Gunter (2009). "Fertilizers, 2. Types". Ullmann's Encyclopedia of Industrial Chemistry.

Enwezor, W.O (1997). Soil testing for phosphorus in some Nigeria soils. 2 predicting response of phosphate for soils of southeastern Nigeria. *Soil Sci* .123 : 11 16.

Gee, G.W. and Bauder, S.U (1986). Particle size analysis. In: klute, A. (ed). Methods of soil analysis. Par*t* 1.2nd *ed. Agron. Monogr. G. America Soc. Agron. Madison, wI*. 91-100

Glaser B, Lehmann J, and Zech W. (2002). Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal: a review, Biology and fertility of soils. 35: 219-230

Heinrich W. Scherer (2000). "Fertilizers" in Ullmann's Encyclopedia of Industrial Chemistry. Wiley-VCH, Weinheim.

Kundsen, K Peterson, G.A. and Pralt, P.F (1982). Lithium, sodium and potassium. In page; A.I. (*Ed)*. Method of soil analysis. Part 2. Monograph, No.9. *American Soc. Agron. Madison. WI*. pp 241-262

Lal, W.Y., Lal, C.M., Ke, G.R, Chung, R.S., Chen C.T., Cheng, C.H., Pai, C.W., and Chen, C.C (2013). "The effect of wood chip biochar application on crop yield, carbon sequestratum and greenhouse gas emissions gas with riu or leaf beat; *Journal of the Taivan institute of chemical engineers*, Vol 44(6) 1039-44.

Lehmann J. (2007). Bio-energy in the black. Frontiers in Ecology and the environment. 5(7): 381-387

Lehmann J. Ezimcizik C. Laird C., Sohi S. (2009). Stability of biochar in soil. In Lehmann J., Joseph *(eds) Biochar for environmental management. Science and technology. Earthscan, London*

Lehmann, J., Hollister, C.C., Bisogni J.J (2013). Ammonium, Nitrate and Phosphate Sorption to and solute leaching from biochars prepared corn stover (*Zea mays* L.) and oak wood (*Quercus* spp.),’ ’ *Journal of Environmental Quality*, vol. 42(1)137-144.

Levette, M.P. (1993). The effects of methods of plant cuttings of sweet potato (*Ipomoea batatas* (*L*) *Lam*) on yield. *Tropical Agric. Trinidad Vol. 70. No2. April 1993. Pp.110-115*

Liang B. Lehmann J, Solomon D, Kinyangi J, Grossman J, (2006). Black carbon increases cation exchange capacity in soils. *Soil Science Society of America Journal, 70 (5), pp.1719-1730*

Mills, H. A and Jones, J.B. jr. (1996). Plant Analysis Handbook II: A practical Sampling, Preparation, Analysis, and Interpretation Guide.

Mohammed S.S., and Ayodele J.T (2011). Analysis of soil pH in Guinea corn and maize grown soils of kaduna metropolis- Nigeria *journal of soil and sediments. Pp. 1135-1140.*

Munoz, G.R. Powell, J.M and Kelling, K.A (2003). Nigeria budget and soil N dynamics after multiple appliof non- labelled or nitrogen enriched dairy manure. Soil sci. Soc. Am. J. 67: 817-825

Murphy, J. and Riley, J.P, (1965). Modified single solution methods for determination of phosphate in natural water. Annual chem. Aeta 27:31-36

N.R.C.R.I. (2013). National Root Crop Research Institute, Umudike *Annual Report*. Pp.294

Nelson, D.W. and Sommers L.E (1996). Total carbon. Organic matter. Methods of soil analysis. Part III chemical methhods. *Soil Sc. Soc. Am. B.K. Series*

Niemeyer, T., Niemeyer, M., Mohamed, A Fottner, S and Hardtle, W (2005). Impact of precsribed burning on the nutrient balance of heathlands with particular reference to nitrogen and phosphorus. Applied Veg. Sci.8:183-192

Norazlina, A.B., Fauziah, C.I, and Rosenani, A.B (2014). Characterization of oil palm empty fruit bunch and rice husk biochar and their potential to adsorb arsenic and cadmium *Am. J. Agric. Biol. Sci*. 9(3):450-456.

Nwite J.C, Essien B.A, Eke K.A, Essien J.B and Igwe C.A (2009). Maize production and chemical properties of an ultisol amended with different ash sources in southeastern Nigeria , Niger Agric.J. 40. No 1: 65-72.

Obi, I.U., (2002). Statistical Methods of Dectecting Differences between treatmeent means and research methodology issues in laboratory and field expriments. 2nd Edn. Ap express Publishing company Ltd., Nsuka, Nigeria, 116

Onwuka M.I, Osodeke V.E. and Ano A.O (2010). Assessment of the effect of liming materials on some soil chemical properties in a degraded ultisol of southeastern Nigeria. Nig.J. Soil Sci. Vol.20(2). Pp.54-62

Onyekwere I.N, Ano A.O, Ezenwa M.I.S, Osunde A.O, and Bala A (2003). Assessment of exchangeable acidity status and management of wetland soils of Cross River, Nigeria. A paper presented at the 28th Annual conf. Of soil science society of Nigeria at NRCRI at Umudike, pp 180-191

Onyekwere I.N., Akpan- Idiok, A.V, Amalu, U.C., Asawalam, D.O and Eze, P.C., P.C., (2001). Constraints and opportunity in Agricultural utilization of some wetlands in Akwa Ibom State.

Purseglove, J.W (1972). Tropical crops: Dicotyledons. Vol. 1. Longman,London, pp. 82 – 91

Rabileh, M.A., Shamshuddin, J, Panhwar, Q.A, Rosenani, A.B and Anuar, A.R (2015). Effects of biochar and/ or dolomitic limestone application on the properties of ultisol cropped to maize under glasshouse conditions.

Rajkovich S. Enders A, Hanley K. Hyland C., Zimmerman A.R. and Lehmann J. (2012). Corn growth and nutrition after addition of biochars with varying properties to a temperate soil. Biol. Fertile soils 48:271-284

Rochette P., Angers D.A., Chantigny M.H., Mac Donald J.D, Bissonnette N., and Bertrand N (2009). Ammonia volatilization following surface application of urea to tilled and no-till soils; a laboratory comparison. *Soil Tillage Res*. 103, 310-315

Saxena J. Rana G., and Pandey M. (2013). Impact of addition of biochar along with Bacillus Sp. On growth and yield of French beans scientia Horticulture 162. 351-356

Snyder, C.S., T.W Bruulsema, and T.L. Jensen (2007). Greenhouse gas emmisions from cropping systems and the influence of fertilizer management. A literature review. International plant nutrition institute, Norcross, Georgia, U.S.A. (htpp://www.Ipn.net/ghgreview)

Solomon, D. J., Lehmann, J., Thies, T., Schafer, B., Liang J., Kinyangi, E., Neves, J., Petersen, F., Luizo and Skjemstaad, J (2007). Molecular signature and sources of biochemical recalcitrance of organic C in Amazonian dark earths. Geochemica et cosmochimica Acta, 71:2285-2298

Stathers, T.E., Rees, D., Kabi, S., Mbilingyi, L., Smit, N., Joizya, H., Jeremaiah, S., Nyango, A. and Jeffries, D. (2003). Sweet potato infestation by Cylas sp in East Africa I*: international Journal of pest management. 49: 131-140.*

Suarez, D.L. (1996). Beryllnium, Magnessium, Calcium, Strontium and Barium. Methods of soil Analysis. Part III. Chemical methods. *Soil science of America Book Series* No5

Thies, Janice E and Mathias C. Rillig (2009). Characteristics of biochar Biological properties. In: Lehmann, J and Joseph S. (eds). Biochar for Environmental management. Earthscan publication

Udoh, D.J (2018). Evaluation of Effectiveness and Determination of Optimum rates for Organic and Inorganic Fertilizers in the Production of Market Garden Crops. Nigeria Journal of Soil Science. Vol 28 (1) 68-82

van Zwieten, l., Kimber, S., Morris, S., Chan, K.Y., Downie, A., Rust, J., Joseph, S., and Lowie, A., (2010). Effects of biochar from slow pyrolysis of papermill waste on agronomic performance and soil fertility. Plant & soil 327-246.

Vinh N.C., Hien, N.V., Anhm, T.L., Lehmann, J. and Joseph S. (2014). " Biochar treatment and its effect on rice and vegetable yield in mountainous areas of nounturn Vietnam, International Journal of Agricultural and soil Science. Vol 2, pp5-13

W R B (2015). "World Reference Base for Soil Resources 2014, Update 2015" (PDF). World Soil Resources Reports 106, FAO, Rome.

Walkley. A. and I.A. Black (1934). An Examination of the Digestion Method for Determining Soil Organic Matter and Proposed Modification of the Chromic Acid Titration Method. *Soil sci.37:29-38.*

Wang, T., Camps-Arbestain, M., and Hedley, M (2013). The fate of phosphorus of ash-rich biochars in a soil-plant system. Plant soil, 1-14

Warnock D D, Lehmann J, Kuyper T.W, and Rillig M (2007). Mycorrhizal responses to biochar in soil-concepts and mechanism plant and soil. 300, 9-20

Xiang Y, Deng Q, Duan H, and Guo Y (2017). Effects of biochar application on root traits: a meta-analysis GCB Bioenerg 9:1563-1572

Yuan, J. Xu, R. and Zhang, H (2011). The forms of alkalis in the biochar produced from crop residues at different temperatures. *Bioresource Technology*. 102:3488-3497

Zaharan, A. and Tan, S.L. (2006). Performance of selected sweet potato varieties under different growing seasons on bris sandy soil in Malaysia. *In 14th Triennial Symposium of international Society of Tropical Root Crops, 20-26 November, 2006.Central Ruber Crops Research Institute, Thiruvanathapuram, India, 225-226*

Zhang, A., Bian, R., Pan G., Cui, Li., Hussain, Q., Li, L. and Yu (2012). Effect of biochar amendent on soil quality, crop yield and greenhouse gas emission in a Chinese rice paddy. A field study of 2 conservative rice growing circles. Field crops research, vol. 127.153-160