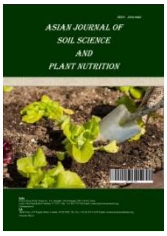

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Effect of Activated Biochar on the Fertility an Acid Soil in Southern Nigeria

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Author's contribution

The sole author designed, analyzed, interpreted and prepared the manuscript.

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ABSTRACT

Soil acidity is a potentially serious land degradation issue. When soil becomes too acidic it can decrease the availability of essential nutrients. Investigation on the effect of activated biochar on soil properties of coastal plain sands of Port Harcourt was conducted at the high tunnel hoop house located at the Teaching and Research farm, Rivers State University Port Harcourt. Separate biochars were produced using following materials: Wood Shavings (WS), Corn Cob (CC), Wood (WD), Palm Kernel Shell (PK), and Animal Bone (AB), And a Control (CO). The 6 treatments made up of the various biochars were replicated three times and fitted into a Randomized Complete Block Design. Soil samples were taken before and after treatment application and for determination of physical and chemical properties. Result shows that the pH values significantly increased from 6.63 – 7.73, when compared to the original soil with a pH of 4.97($P = 0.05$). The organic matter content was significantly higher ($P>0.05$) across all the biochar amended soils. Palm kernel biochar (PK) had 31.4% increase in organic matter when compared to the initial organic matter of 1.19%. There was also substantial increase in the soil total nitrogen (100%) for palm kernel biochar. Available phosphorus was also increased by almost 100% for soil treated with the respective biochars; ranging from 0.33 – 0.43 $cmolkg^{-1}$ when compared to the original value of 0.18 $cmolkg^{-1}$. Remarkably, the values for most of the exchangeable bases increased significantly ($P= 0.05$) after treatment application, ranging from 5.68-18.10, 6.01 – 24.1 and 3.93-6.13$cmolkg^{-1}$ for K^+, Na^+ and Mg^{2+} respectively, as compare to the initial values of 4.36, 2.2 and 1.0$cmolkg^{-1}$.

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Keywords: Acid soils; biochars and fertility status.

1. INTRODUCTION

Studies have shown that biochar application improved the physical, chemical and biological of soil properties and therefore crop yield [1-3]. Beyond its effect as fertilizer, it has also been shown to be more stable than any other soil amendment and increases nutrient availability [4-7]. There are reports that biochar can ameliorate soil nutrient use efficiency and nutrient holding capacity and decreases soil acidity [8-10,2].

Soils become acidic when basic elements such as calcium, magnesium, sodium and potassium held by soil colloids are replaced by hydrogen ions. Soils formed under conditions of high annual rainfall are more acidic than are soils formed under more arid conditions. Acidic soils create production problems by limiting the availability of some essential plant nutrients. Acidity decreases the availability of plant nutrients, such as phosphorus and molybdenum, and increases the availability of some elements to toxic levels, particularly aluminium and manganese. It increases the impact of toxic elements, decrease plant production and water use, affect essential soil biological functions like nitrogen fixation and make soil more vulnerable to soil structure decline and erosion [11,12]. Soil acidification is a natural process, but it can be increased by some agricultural practices. Acidification occurs in agricultural soils as a result of the removal of plant and animal products, leaching of excess nitrate, addition of some nitrogen based fertilizers and build-up in mostly plant-based organic matter.
Due to differences in chemical composition of parent materials, soils will become acidic after different lengths of time. Thus, soils that developed from granite material are likely to be more acidic than soils developed from calcareous shale or limestone [13,14].

The coastal plain sandy soils of Rivers State in Southern Nigeria, being formed from acid parent materials [15] and are also highly leached. A soil pH in the range of 6.0 to 7.0 is also desirable from the standpoint of optimum nutrient availability [16].

Experiments consistently indicate that biochar improves soil quality as against no bochar. It is suspected that biochar will remediate soil acidity. In view of the above, this study seeks to assess the efficacy of the use of biochars from different plant and animal materials to ameliorate soil acidity and thereby improve the fertility status of the soil.

2. MATERIALS AND METHODS

The study was conducted in the High Tunnel Hoop House located at the Teaching and Research Farm Rivers State University, Port Harcourt. The study location lies in the humid tropical zone of the southern Nigeria. It lies between latitude 4.5°N and longitude 7.0°E on an elevation of 18m above sea level. The mean annual rainfall in Port Harcourt ranges from about 3,000mm to 4,500mm, annual temperature ranges from 22°C to 29°C while relative humidity varies between 75% and 95% [17]. Port Harcourt soils are of coastal plan sands which range from loamy sand to sandy loam in the surface soil horizon, with pH values of between 4.0 and 5.8 in water [15].

Top soil was obtained from uncultivated fallow soil in Port Harcourt Nigeria. The biochar materials used were wood shaving (WS), corn cob (CC) hard wood (WD), palm kernel shell (PK) and cattle bone (CB). Hard wood (HW) and wood shaving (WS) were collected from a Timber Mill in Port Harcourt City of Rivers State Nigeria. Palm kernel shells were collected from Vika Farm in Uyo, Akwa Ibom State Nigeria. Cattle bone (CB) and corn cob (CC), were collected from the Rivers State University Teaching and Research farm abattoir and maize units, respectively.

The Plant and Animal materials (ie Corn cobs, palm kernels shell, wood shaving, wood and animal bone) was subjected to heating through a process known as pyrolysis using a cut drum (local drum) method. The char was removed by sprinkling water to put off the fire and left to cool for (3) three days. After which the char was bagged and kept for use. The various biochars were activated [18] by mixing each biochar with dried poultry manure and fishpond effluent in the ration 1:1:4. The mixtures were left covered to cure for a period of 21 days [19]. Following this, 3kg of each activated biochar was mixed with 30kg (ratio of 1:10) topsoil and bagged in an 8liters planting bag and left for 7 days to further stabilize before use.

Soil samples were collected from both the various treatments before and after treatment application. The samples were air dried, sieved with a 2mm sieve and subjected to routine analysis for fertility status as described by [20]; total nitrogen by the modified macro kjeldahl distillation method, [21], available phosphorus by bray-1 extraction method, exchangeable bases by the ammonium acetate extraction method [22]. Soil pH was measured in water suspension 1:2:5 ratio using the calomel electrode method, Organic carbon was measured by the Walkey and Black Method [23], and it was converted to organic matter by multiplying the percentage of organic carbon by 1.724.

3. RESULTS AND DISCUSSION

3.1 Some Properties of the Soil and Materials Used

Some physical and chemical properties of the top soil in natural condition used in the experiment are shown on Table 1. The soil is a sandy loam soil with 85.85% of sand, 10.4% silt and 13.8% clay. It is acidic with pH value of 4.97, low in percentage organic matter (2.14%) and percentage total nitrogen (0.04%) with a C/N ratio of 29.0 which is within the range for average rate of decomposition and mineralization. The exchangeable cations were in the order 3.34, 1.00, 0.64 and 2.20 cmolkg^{-1} for Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}, respectively.

The chemical properties of the different biochar produced are also as shown on Table 2. There were significant differences among all the biochar produced, with respect to pH. The values ranged between 6.37 to 9.93, with the hard wood and corn cob biochars having the highest values of 9.60 and 9.93 respectively. This was followed by pH value of 7.80 and 7.96 for cattle bone and wood shavings. The biochar produced from PK had the lowest value of 6.37. The high pH values probably may be due to the presence of ash produced during the pyrolysis process, and this is consistent with the findings of [1,24].

There was a significant difference in organic matter of the various biochar produced (P=0.05). Cattle bone biochar had the highest value of 4.70% organic matter content followed by WS biochar with a value of 4.33%. HW biochar had the lowest value of 0.67% organic matter content. The total nitrogen contents were observed to be quite low ranging between 0.011 to 0.027%, with the higher values cattle bone and corn cob biochars. This resulted in very wide C/N ratios for most of the biochars produces; with the exception of hard wood and corn cob. This suggests that the hard wood and corn cob would have faster mineralization rates. The pH value of the poultry manure and fish pond effluent used for the activation was 8.24 and 7.20 respectively (Table 3).

3.2 Effect of Biochars on Soil Properties

There are no differences in particle size distribution with biochar application; the soil textures remained sandy loam (Table 4). This is expected as organic materials will not change mineral particles of the soil.

Soil pH was significantly affected by the biochars produced, when compared with unamended soil. Results showed that the cattle bone biochar treated soil had the highest pH value of 7.73 and followed by the corn cob biochar treated soil with a value of 6.70 (Table 5). A research reported a similar finding on the acidity neutralizing potential of biochar [6].

Soil acidity is reported to have detrimental effects on the availability of essential plant nutrient such as magnesium, calcium and phosphorus as well as toxicity of micro-elements such as Al, Fe and Mn [25]. Microbial activity is also noted to drop in acidic conditions which can lower nitrogen (the key plant nutrient) concentrations, reducing nitrogen fixation and nitrogen mineralization: two processes vital to creating plant-available forms of nitrogen.

Secondly, Gas flaring [26] and other petroleum exploration activities are very common environmental challenge in the Southern Nigeria. These have been reported to reduce soil pH and cause acidity [27,28,29].

It is noted that all the biochars increased the soil pH to values required for optimal production of most crops (6.0 to 7.5). This finding is a welcomed information, given previous findings on the soil degradation due to soil acidification in Southern Nigeria.

The organic matter contents were significantly increased by amending the soil with the various biochars produced (Table 5). The percentage organic matter ranged between 2.10 to 2.5% for biochar treated soils when compared with the control with organic matter of 1.91%. The higher organic matter content would provide better living condition for soil microbes and these can partly improve the effect of biochar on soil structure; as also reported by [30,5].

Table 1. Physicochemical properties of the soil in its natural condition used in the execution of the research

pH	% OC	% OM	% Total N	C/N Ratio	Av. P $Mgkg^{-1}$	Ca^{2+}	Mg^{2+} Cmolkg^{-1}	K^{+}	Na^{+}	% Sand	% Silt	% Clay	Textural Class
4.97	1.17	2.02	0.004	292.5	0.18	3.34	1.00	4.36	2.20	85.8	10.4	13.8	Sandy Loam

Table 2. Some properties of the Biochar produced

Samples	pH	% C	% OM	% TN	C/N Ratio
Palm Kernel Shell	6.37	1.17	2.02	0.011	106.4
Hard Wood	9.60	0.39	0.67	0.011	35.5
Wood Shaving	7.96	2.51	4.33	0.011	228.2
Corn Cob	9.93	0.59	1.02	0.021	28.1
Cattle Bone	7.80	2.73	4.70	0.027	101.1

Table 3. Some properties of the activation materials

Samples	pH	% C	% OM	% TN	C/N RATIO
Poultry Manure	8.24	5.27	9.10	0.111	47.5
Fish Pond Effluent	7.20	-	-	-	-

Table 4. Effect of biochar on soil particle size distribution

Treatment	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Textural Class
Animal Bone	84.5	10.7	4.8	Sandy Loam
Corn cob	84.1	11.1	4.1	Sandy Loam
Palm Kernel	84.8	11.7	3.5	Sandy Loam
Hard Wood	83.5	11.4	5.1	Sandy Loam
Wood Shavings	85.5	10.7	3.8	Sandy Loam
Control	84.8	11.1	4.1	Sandy Loam

Table 5. Effect of biochar on soil chemical properties

Biochar	pH	% OC	% OM	% Total N	C/N Ratio	Av. P Mgkg^{-1}	Ca^{2+}	Mg^{2+} Cmolkg^{-1}	K^{+}	Na^{+}
Cattle Bone	7.73	1.38	2.38	0.004	345.0	0.39	4.60	5.40	18.1	24.1
Corn cob	6.70	1.41	2.42	0.004	352.5	0.43	6.40	5.60	8.67	6.01
Palm Kernel	6.67	1.46	2.51	0.008	182.5	0.33	4.93	3.93	10.3	21.8
Hard Wood	6.63	1.22	2.10	0.005	244.0	0.39	3.60	6.13	5.68	2.29
Wood Shavings	6.63	1.39	2.40	0.003	463.3	0.34	4.00	4.53	13.6	11.2
Control	4.97	1.11	1.91	0.004	277..5	0.18	3.34	1.00	4.36	2.20

The available phosphorus as affected by biochars followed the same trend with organic matter contents (Table 5). The available Phosphorus values were generally increased by about 100% when compared with the control, ranging between 0.33 to 0.43 $mgkg^{-1}$, when compared with the control with 0.19 $mgkg^{-1}$ [31-33] have earlier reported similar findings that biochar application increased phosphorus concentration of agricultural soil and also boosts soil fertility and improved soil quality.

The soil exchangeable bases were all better enhanced by the amendment with biochars. Ca^{2+} was better enhanced by corn cob biochar while hard wood better enhanced Mg^{2+}. K^+ on the other hand was better improved by Palm kernel biochar, while Na^+ was better improved by cattle bone biochar (Table 5). These improvements on exchangeable bases will improve the cation exchange capacities of soils amended with biochars, and therefore an improvement on fertility status and quality of the soil so amended.

The C/N ratios were however, very high because of the very high organic matter contents and low nitrogen contents. From the point of view of soil conservation and mineralization, the nitrogen content of such biochar amended soils should be improved by some kind of fertilization.

4. CONCLUSION

Acidic soils create production problems by limiting the availability of some essential plant nutrients. Biochar application have been shown to improve the physical, chemical and biological properties of soils.

Results of this current research has shown that biochars made from either animal or crop residue significantly improved soil pH, organic matter contents, available phosphorus and exchangeable bases of the soil amended with them. The biochar from corn cob better improved the exchangeable bases, while that from palm kernel better improved total nitrogen.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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