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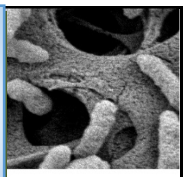

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Efficacy of Biochar and NPK Fertilizer on Soil Properties and Yield of Okra (*Abelmeschus esculentus* L.) in Guinea Savanna Region of Nigeria

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ABSTRACT

The efficacy of biochar and NPK fertilizer on soil properties and yield of okra (*Abelmeschus esculentus* L.) is the central theme in this study. A randomized complete block design (RCBD) was used involving four (4) biochar rates (5, 10, 15 and 20 t/ha) and four (4) NPK (20:10:10) fertilizer rates (0, 100, 150 and 200 kg/ha) arranged factorially in 4 x 4 treatment combinations. Rice husk was used to make biochar since it was readily available and accessible in the study location. soil samples were collected at random locations on the field from two depths (0-15 cm and 15-30 cm) for analysis using standard procedure. Data were collected on plant height, number of leaves, number of branches, stem girth, days to 50% flowering, number of fruits per plant, fruit length, the weight of fruits and total yield. The result shows that biochar application at 20t/ha produced the highest plant height (67.75 cm), number of leaves(31.42), number of branches (16.00), stem girth (2.44 cm), number of fruit/plant (72.00), fruit length (14.33 cm), fruit weight (770.17 g) and total yield (855.74 kg/ha). Similarly, NPK at 200 kg/ha gave higher plant height (61.08 cm), number of leaves(26.75), number of fruit/plant (57.00), fruit weight (560.50 g) and total yield (622.78 kg/ha). The combination of 150 kg/ha and 200 kg/ha NPK fertilizer with 20 kg/ha biochar produced the highest yield (938.89 and 934.45 kg/ha) of okra which was at par. It can therefore be recommended that farmers in the study area can use biochar at 20 t/ha and NPK fertilizer at 150 kg/ha for optimum production of the okra plant.

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is a fruit vegetable crop belonging to the family *Malvaceae*. It is a popular vegetable which originated in the hot climates of Africa [1]. Because of its great nutritional value in diets, the crop is widely farmed in West Africa, particularly Nigeria, as fruits and leafy vegetables in both green and dried form. It is consumed in all sections of the country. Okra is often grown in Nigeria's home gardens and fields during both the wet and dry seasons. Okra's economic significance cannot be underestimated. Carbohydrates, protein, and vitamin C are all abundant in okra. With 86.1 per cent moisture, 9.7 per cent carbohydrates, 12.2 per cent protein, 0.1 per cent fibre, 0.2 per cent fats, and 0.9 per cent ash, the young pods are particularly nutrient-dense [2]. Okra includes essential and non-essential amino acids that are comparable to those found in soybeans. Okra fruit contains about 20% edible oil and protein, according to [3], and its mucilage is used for medical purposes. The mature stem provides crude fibre that is utilized in the paper and rope industries [4]. According to the economic commission for Africa [5] in Ibrahim *et al*. [4], soils in the tropics are substantially affected by a sequence of declines in soil fertility and erosion, resulting in nutrient depletion and reduced soil organism populations. As a result of insufficient input availability, resulting in relatively poor fruit yields, this constitutes a severe production restriction in West Africa, notably Nigeria, and is becoming increasingly crucial to assure sustainable soil productivity [6].

Even when high-yielding cultivars are grown, the intrinsically low soil fertility state, along with insufficient fertilizer application, remains the most important determinant in agricultural production in Nigeria [7]. One possible option is to return organic nutrients to the soil in order to assist maintain soil organic matter, which usually leads to improvements in soil'S physical and chemical qualities [8]. Crop residues, animal waste, home garbage, and industrial waste are all examples of organic matter that can be added to soil [9].

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However, the selection of organic material to apply is critical, since some sources may have negative effects on soils, depending upon the quality of organic material or the presence of contaminants [10].

Biochar is a porous solid with a high carbon content, a wide surface area, and a high cation exchange capacity (CEC) that is made through pyrolysis in an oxygen-deficient environment [11], [12]. The material was an organic alteration that resulted from the pyrolysis of biomass at high temperatures and with very little oxygen [13]. Biochar is a new and potentially useful addition for boosting production on deteriorated, low-fertility acidic soils [14]. Biochar has been identified as a potentially viable alternative to augment soil physical and chemical properties and productivity in a growing number of research studies [15], [14].

Increased soil pH, nutrient availability, moisture absorption, and carbon sequestration are all benefits of incorporating biochar into the soil [17], (17). It's important to clarify that biochar isn't a compost material; rather, it's a soil microbial activity catalyst that improves soil fertility and water holding capacity, allowing crops to grow and yield more [18], [19]. Due to current interest in employing biochar in establishing sustainable forms of soil management and challenges related to climate change, some experts have nicknamed it "agrichar," or agricultural charcoal [20].

Biochar research is gaining traction, not only because of its potential for carbon sequestration [21], but also because of its numerous co-benefits as a soil amendment, including increased crop yield [22], potential as a technology for immobilizing pollutants [23], and improved soil fertility and nutrient retention. Even though previous researchers have thoroughly investigated the potential of biochar as soil amendments for agricultural production and soil quality improvement [24], research on the precise rate of biochar application on degraded ultisol and other soil types for specific arable crops is scarce and moving slowly. Furthermore, biochar's influence is reliant on soil type [25], and biochar's effects on soil aggregation are dependent on soil and biochar types.

Biochar's impact on soil health and crop productivity has been studied in a variety of soil types and management techniques, with varying results. Plant growth responses ranged from -29 per cent to 324 per cent when biochar was applied at rates ranging from 0.5 to 135 t ha^{-1} [26]. Agricultural systems, crop type, meteorological circumstances, and fertilization status all influenced plant and soil responses to biochar application [28], (28). Biochar, according to [29], can alter soil n cycling and numerous transformation mechanisms, including reduced inorganic n leaching by improving nutrient retention due to cation and anion exchange reactions, and inorganic n immobilization due to biochar's labile c fractions. By enhancing nh_4^+ and no_3^{-2} adsorption, biochar could help prevent nitrification and denitrification losses.

There are few and inconclusive studies on the impact of biochar on Nigerian soils. According to a recent survey of biochar literature in Nigeria, practically all biochar studies were potted/greenhouse experiments [30]. Also, [24] investigated the impact of biochar on soil properties and organic carbon sink in degraded soil in the southern guinea savanna zone of Nigeria, while [31] looked at the impact of biochar and crop yield on tomato growth and yield in Jos, north-central Nigeria. Long-term studies on biochar in field trials are urgently needed, according to [32], to better understand biochar effects and investigate its behavior in different soil types under varying climatic settings, thereby providing framework information about their potential in improving soil quality and increasing crop productivity, as well as the risks that come with it. This study was carried out to fill the gap to investigate the efficacy of biochar on soil characteristics and okra yield in the guinea savanna region of Nigeria.

MATERIALS AND METHODS

Study Area

The experiment was conducted in the Federal College Of Forestry, a demonstration farm located in Jos, Plateau state, Nigeria. It is a region in the middle belt of Nigeria and it falls between latitude 9.9º and longitude 8.8º each with an attitude of 1,200 m above sea level. The vegetation of the area is a typical guinea savannah with an average annual rainfall of 1400 mm. The rain usually starts in April and terminates between September and October with temperatures ranging from 20-30ºC [33].

Experimental Design

A randomized complete block design (RCBD) was used involving four (4) biochar rates (5, 10, 15 and 20 t/ha) and four (4) NPK (20:10:10) fertilizer rates (0, 100, 150 and 200 kg/ha) arranged factorially in 4 x 4 treatment combinations. The materials used for this research work include certified okra seeds obtained from certified dealers of agricultural products at the famous Farin Gada market in Jos, NPK (20:10:10) fertilizer, biochar (rice husk) sourced from the rice milling industry in Jos. Measuring tape, line or rope, meter rule, cutlass, auger bit, shovel, rake, wheelbarrow, bucket or watering can and hoe from the department of crop production technology, federal college of forestry, Jos.

Soil Analysis

Soil samples were collected at random locations on the field from two depths (0-15 cm and 15-30 cm) using an auger bit, hand trowel, and polythene bag to preserve the samples, which were then dried at room temperature and carried to the Agricultural Service and Training Centre (ASTC) for examination using standard procedure. A pH meter and an EC meter were used to measure the soil pH and electrical conductivity in the 1:2.5 soil:water ratios [34]. Soil texture (bouyoucos hydrometer method), organic carbon [35], available nitrogen content and available phosphorus content measured by the bray ii method, total organic carbon, and total nitrogen were all determined using an elementary analyzer.

Biochar Preparation

Rice husk was used to make biochar since it was readily available and accessible in the study location. The rice husk was carefully wrapped into bags and sent to the laboratory. Rice husk was converted to charcoal at a rate of 45–55 per cent. For the soil application, the biochar was put through a 2mm filter. The bulk density was calculated by dividing the weight of the dry sample filled in a 10 ml tube by the weight of the dry sample.

Data Collection and Analysis

Data was recorded on germination percentage, plant height, number of leaves, stem girth, days to reach 50% flowering, number of fruits per plant, fruit length, the weight of fruits and total yield. Data collected were subjected to analysis of variance (ANOVA) at 5% level of significance using xlstat 19 statistical

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package. Mean separation was used using Duncan's Multiple Range Test (DMRT) where significance was declared.

RESULTS AND DISCUSSION

Physical and chemical properties of soil and biochar

The results of physical and chemical properties of the soil sample for the experimental site and biochar are presented in table 1. The result indicated that the soil was predominantly sandy loam in texture, slightly acidic with a pH value of 5.8. The total N (0.8gkg^{-1}), available P (5.5gkg^{-1}), available K (3.8g^{-1}), CEC (3.7cmolkg^{-1}, total N (1.8gkg^{-1}), available P (15gkg^{-1}), available K (4.6gkg^{-1}), CEC (7.3cmolkg^{-1}) and organic C (6.6gkg^{-1}). These results according to Esu [36] rating was low indicating that the soil in the area had low fertility status. While the pH value of 6.6 for biochar is very slightly acidic C (65.5gkg^{-1}) and ash content of 22.5%. These results according to [37] contain medium nutrients indicating higher values of properties compared to that of the soil.

According to [38], Biochar is a source of several nutrients: its complex reaction with soil releases nutrients, making them available for plant uptake over time. As suggested by [39] the application of biochar is very important for the improvement of degraded soil. Application of biochar improves soil physical properties such as bulk density, water holding capacity, permeability, chemical properties such as nutrients availability, cation exchange capacity and retention, and biological properties such as microbial population, microbial biomass and microbial activities, thus ultimately increasing crop yield [40]. According to Sara and Shah [41] the net influence of biochar on the physical characteristics of the soil depends on the interaction of the biochar by way of the physicochemical properties of the soil as well as other determinant factors such as the climatic conditions and appliance of biochar management.

Table 1. Physical and chemical properties of soil and biochar.

Properties	Soil	Biochar
pH	5.8	6.6
N (g/kg)	0.8	1.8
P (g/kg)	5.5	15
K (g/kg)	3.8	4.6
CEC (cmol/kg)	3.7	7.3
Ash Content (%)	Nil	22.5
Organic Carbon(g/kg)	6.5	65.5
Clay (%)	6.2	Nil
Silt (%)	10.1	Nil
Sand (%)	83.7	Nil
Textural Class	Sandy Loam	Nil
Specific Surface Area	Nil	0.65

Efficacy of biochar and NPK fertilizer on growth of okra

The growth characters of okra were significantly ($p < 0.001$) affected by biochar as shown in table 2. Statistically taller (plant height) and thicker (stem girth) plants are measured at 15 and 20 t/ha of biochar application respectively. A greater number of branches and number of leaves were obtained on biochar at 20 t/ha while the least number of branches and leaves were obtained at the application of 5 t/ha of biochar.NPK (20:10:10) fertilizer application was found to significantly influence plant height, number of branches and number of leaves but had no influence on stem girth of okra plant. The application of NPK fertilizer at the rate of 200 kg/ha produced the tallest plant (61.08cm), more branches (13.92) and leaves (26.75) while the control treatment (0 kg/ha) gave the least plant height (55.33cm), a number of branches (11.83 and number of leaves (22.58).

No significant interaction effect was recorded for the application of biochar and NPK fertilizer on the growth characters of okra plant. The increased agronomic indicators seen with the addition of biochar in this study are completely at odds with [42] findings. They discovered a detrimental influence on oat plant growth and yield when they applied biochar to the soil, though it was a greenhouse experiment and field study was needed to confirm or refute their findings. Both biochar and compost either by stand-alone or in combination have ability to improve the growth performance of the plant [43].

Table 2. Efficacy of biochar and NPK fertilizer on growth of okra.

Treatment	plant height (cm)	Stem girth (cm)	Number of branches	Number of leaves
Biochar (t/ha)				
5	44.75^{c}	0.87^{c}	8.58^{c}	16.83^{c}
10	53.42^{b}	1.18^{b}	14.00^{b}	25.17^{b}
15	67.25^{a}	2.46^{a}	14.08^{b}	26.17^{b}
20	67.75^{a}	2.44^{a}	16.00^{a}	31.42^{a}
P - value	0.000***	0.000***	0.000***	0.000***
NPK Fertilizer (kg/ha)				
0	55.33^{c}	1.62	11.83^{b}	22.58^{c}
100	56.83^{bc}	1.65	13.33^{a}	25.50^{ab}
150	59.92^{ab}	1.77	13.50^{a}	24.75^{b}
200	61.08^{a}	1.91	13.92^{a}	26.75^{a}
P – value	0.006**	0.128^{NS}	0.000***	0.000***
Interaction				
Biochar*NPK	0.635^{NS}	0.955^{NS}	0.056^{NS}	0.894^{NS}

Note: means in a column of any set of treatment(s) followed by different letter (s) are significantly different, NS = not significant, **significant at $p < 0.01$, ***significant at $p < 0.001$

Efficacy of biochar and NPK fertilizer on yield of okra

The efficacy of biochar and NPK fertilizer on the yield of okra was found to be significant ($p<0.001$). Days to 50% flowering showed that 20 t/ha biochar application measured the least number of days to reach 50% flowering (42.08) and 5 t/ha had more number of days to attain 50% flowering (54.42). A higher number of fruits /plant (72.00), fruit length (14.33cm), fruit weight (770.17g) and total yield (855.74kg/ha) were measured at the application of 20 t/ha of biochar while the least were recorded at the application of 5 t/ha respectively. days to 50% flowering and fruit length are not affected by NPK fertilizer rates.

The number of fruits/plant, fruit weight and total yield significantly influenced NPK fertilizer rates. The application of 200 kg/ha NPK fertilizer rate produced the highest number of fruits/plant (57.00), fruit weight (560.50g) which was at par with 150 kg/ha NPK application (566.08g) and also (200 kg/ha NPK) the highest total yield of 622.78kg/ha. Increasing the amount of biochar and NPK fertilizer results in an increase in the yield characteristics of okra plant. This result implies that biochar exhibited a tough effect on yield characters of okra as the fruit yield was considerably better in biochar than in the NPK fertilizer treatments. wheat, maize, canola, barley, rice, sorghum, tomato, groundnut, fava bean, turnip, and peanut yields were reported in studies included in the meta-analysis which indicates that biochar application boosted crop yield considerably ($p < 0.001$) when compared to the control [44]. Biochar application can reduce soil acidity and improve yield [45]. As reported [31] significantly higher yield of tomatoes in beds treated with charcoal than without charcoal. Similarly, biochar application increased vegetable yields by 4.7 to 25.5% as compared to farmers‟ practices.

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Table 3. Efficacy of biochar and NPK fertilizer on yield of okra.

Treatment	Days to reach 50% flowering	Number of fruits/plant	Fruit length (cm)	Fruit weight (g)	Total yield (kg//ha)
Biochar (t/ha)					
5	54.42^{a}	35.75^{d}	5.72^{c}	381.33^{d}	423.70^{d}
10	49.92^{b}	48.42^{c}	6.38^{c}	457.75^{c}	508.61^{c}
15	46.17^{c}	59.08^{b}	10.17^{b}	528.25^{b}	586.94^{b}
20	42.08^{d}	72.00^{a}	14.33^{a}	770.17^{a}	855.74^{a}
P - value	0.000^{***}	0.000^{***}	0.000^{***}	0.000^{***}	0.000^{***}
NPK fertilizer (kg/ha)					
0	48.83	50.25^{c}	8.80	487.25^{c}	541.39^{c}
100	48.33	52.17^{bc}	9.20	523.67^{b}	581.85^{b}
150	47.50	55.83^{ab}	9.29	566.08^{a}	628.98^{a}
200	47.92	57.00^{a}	9.29	560.50^{a}	622.78^{a}
P – value	0.597^{ns}	0.003^{**}	0.595^{ns}	0.000^{***}	0.000^{***}
Interaction					
Biochar*NPK	0.715^{ns}	0.413^{ns}	0.427^{ns}	0.000^{***}	0.000^{***}

Note: means in a column of any set of treatment(s) followed by different letter (s) are significantly different, NS = not significant, ***significant at $p < 0.001$

Interaction between biochar and NPK fertilizer on yield of okra

Fig. 1 shows the result of the interaction between biochar and NPK fertilizer rates on total yield. This is the combination of biochar and NPK fertilizer on the same plot. The combination of 150 kg/ha and 200 kg/ha NPK fertilizer with 20 kg/ha biochar produced the highest yield (938.89 and 934.45 kg/ha) of okra which was at the same level. The last yield was recorded on the treatment combination between the control (0 kg/ha NPK) and 5 kg/ha biochar (398.1 5 kg/ha). According to [45], the combination of the two amendments is more effective in increasing the plants' development than applying each amendment separately.

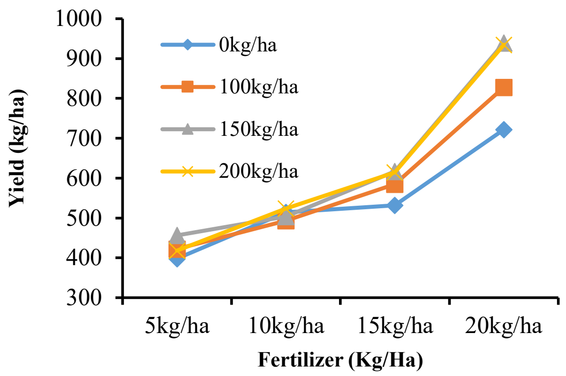

Fig. 1. Interaction between biochar and NPK fertilizer on yield of okra.

CONCLUSION

It can be concluded from this research findings that biochar application improves soil properties and nutrient status and also enhances the growth and yield of the okra plant. The effect of biochar application on growth (plant height, number of leaves, number of branches and stem girth) and yield (days to 50% flowering, number of fruits/plant, fruit weight, fruit length and total yield) of okra was found to be significant. NPK fertilizer did not have any influence on the number of leaves, days to 50% flowering and fruit length of okra plant but significantly influenced the plant height, number of branches, stem girth, number of fruits/plant, fruit weight and total yield. Similarly, the combination of biochar at 20t/ha and NPK fertilizer at 150 kg/ha produced the highest total yield of okra. This shows that it gives the best result in improving the soil properties and growth performance of okra. It can therefore be recommended that farmers in the study area can use biochar at 20 t/ha and NPK fertilizer at 150 kg/ha for optimum production of the okra plant. also, field experiments are needed to measure and quantify the long-term agronomic and environmental benefits of biochar on agricultural soils in the study area.

REFERENCES

1. Nosiru M.O., Banjo J.O.S. and. Adedeji T.O. Determinants Of Improved Productivity of Okra (*Abelmoschus esculentus*) by farmers in lowland areas of Ogun State, Nigeria. American-Eurasian J Agri Environ Sci. 2012;12(12):1572-1578,
2. Ibrahim Iro, **I.,** Yaroson, AY., Lawal IH., Idris JA., Goma AA. Growth and yield characteristics of *Abelmoschus esculentus* L. (Okra). Influenced by application of poultry manure and Npk fertilizers on the Jos Plateau. Int J Inno Sci Res Technol. 2018;3(10).
3. Tiamiyu RA Ahmed HG. And Muhammad AS. Effect of Sources of Organic Manure on Growth and Yields of Okra (*Abelmoschus esculentus* L.) In Sokoto, Nigeria. Niger J Basic Appl Sci. 2012, 20(3): 213-216
4. Ojo Gos., Richard Bi. And Iorlamen T. Evaluation of okra cultivars for dry season production in the southern guinea savanna ecology of Nigeria. Int J Agro Agri Res. 2012;2(5):13-18.
5. Economic Commission of Africa, State of the Environment in Africa. Economic Commission of Africa,(2001;P.O.Box 3001, Addis Ababa, Ethiopia, ECA/FSSDD/01/06.
6. Olson, R.A., Rhodes, M.B., Dreier, A.F. Available Phosphorus status of Nebraska soils in relation to series classification, time of sampling and method of measurement. Agronomy J. 1954;46(4):175–180.
7. Ibrahim, U., Hamma, I. L., Yahqub, M. and Namakka, A. Effect of organic and inorganic fertilizers on growth and yield of okra (*Abelmoschus esculentus* (L.) Moench) IN Zaria, Nigeria. Niger J Agric Food Environ. 2014; 10(3):91-95.
8. Girmay G, Singh BR, Mitiku H, Borresen T, Lal R. Carbon stocks in Ethiopian soils in relation to land use and soil management. Land Degrad Develop. 2008;19(4):351–367
9. Ali K, Munsif F., Zubair M., Hussain Z, Shahid M, Din Iu, Khan N. Management of organic and inorganic nitrogen for different maize varieties. Sarhad J Agr. 2011;27(4):525–529
10. Jones Dl, Healey Jr. Organic Amendments For Remediation: Putting Waste To Good Use. Elements. 2010;6(6):369–374.
11. Hussain, M., Farooq, M., Nawaz, A., Al-Sadi, A.M., Solaiman, Z.M., Alghamdi, S.S., Yong, U.A., Siddique, K.H.M. Biochar for crop production: potential benefits and risks. J Soil Sed. 2017;17(3):685–716.
12. Mansoor, S., Kour, N., Manhas, S., Zahid, S., Wani, O.A., Sharma, V., Wijaya, L., Alyemeni, M.N., Alsahli, A.A., El-Serehy, H.A., Paray, B.A., Biochar as a tool for effective management of drought and heavy metal toxicity. Chemosphere. 2020;129458.
13. Billa, S. F., Angwafo, T. E., &Ngome, A. F.. Agro-Environmental characterization of biochar issued from crop wastes in the humid forest zone of Cameroon. Int J Recyc Org Waste Agri. 2019;8(1); 1–13.
14. Bayu D., Tadesse, M. &Amsalu, N., Effect of biochar on soil properties and lead (pb) availability in a military camp in South West Ethiopia. Afr J Environ Sci Technol. 2016;10(3)77–85.
15. Ścisłowska, M. Biochar To Improve The quality and productivity of soils. J Ecol Eng. 2015;16(3):31–35.
16. Crane-Droesch, A. Heterogeneous global crop yield response to biochar: A Meta-Regression Analysis. Environ Res Letters. 2013;8(4; P.44049
17. Spokas, K. A. Impact of biochar field aging on laboratory greenhouse gas production potentials. Gcb Bioenergy. 2013;5(2):165–176.
18. Mekuria, W. And Noble, A., The role of biochar in ameliorating disturbed soils and sequestering soil carbon in tropical agri production systems. Appl Environ Soil Sci. 2013;Volume 2013 |Article ID 354965
19. Ahmad, M., Rajapaksha AU., Lim JE., Zhang M., Bolan N., Mohan D., Vithanage M., Lee SS. And Ok Ys. Biochar as a

sorbent for contaminant management in soil and water: A Review. Chemosphere. 2014; 99, Pp. 19-33
20. Abewa A, Yitaferu B, Selassie Yg, Amare T. The Role Of Biochar On Acid Soil Reclamation And Yield Of Teff (Eragrostistef) In Northwestern Ethiopia. J Agri Sci. 2014;6(1):1.
21. Sohi, S., Lopez-Capel, E., Krull, E. And Bol, R. Biochar, climate change and soil: A Review to guide future res. Csiro Land Water. Sci Rep. 2009;5(09):17-31.
22. Akca MO. and Namli A. Effect of poultry biochar on soil enzyme activities and tomato, pepper and lettuce plant growth. Eur J Soil Sci. 2015; 4 (3):161-168.
23. Herath, I., Kumarathilaka, P., Navaratne, A., Rajakaruna, N. And Vithanage, M. Immobilization and phytotoxicity reduction of heavy metals in serpentine soil using biochar. J Soil Sed. 2015;15:126-138.
24. Ndor E, Amana Sm, Asadu Cla Effect of biochar on soil properties and organic carbon sink in degraded soil of Southern Guinea Savanna Zone, Nigeria. Int J Plant Soil Sci. 2015; 4(3):252-258.
25. Nelissen V, Ruysschaert G, Manka"Abusi D, D"Hose T, De Beuf K, Al-Barri B, Cornelis W, Boeckx P. Impact of a woody biochar on properties of a sandy loam soil and spring barley during a two-year field experiment. Eur J Agro. 2015; 62:65-78.
26. Glaser, B.; Lehmann, J. And Zech, W. Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal—A Review. Biol Fert Soils. 2002;35, 219–230.
27. Gundale, M.J. And Deluca, T.H. Charcoal effects on soil solution chemistry and growth of K*oeleria macrantha* in the ponderosa pine/douglas-fir ecosystem. Biol Fert Soils. 2007; 43, 303–311.
28. Haefele, S.M.; Konboon, Y.; Wongboon,W.; Amarante, S.; Maarifat, A.A.; Pfeiffer, E.M.; Knoblauch, C. Effects and fate of biochar from rice residues in rice-based systems. Field Crops Res. 2011;121, 430–440.
29. Lone, A.H.; Najar, G.R.; Ganie, M.A.; Sofi, J.A.; Ali, T. Biochar for sustainable soil health: a review of prospects and concerns. Pedosphere. 2015;25, 639–653.
30. Onwuka MI, Adiele PO, Ogbonna KE. Improving the soil available phosphorus and exchangeable calcium of three parent materials of the smallholder farmers using amendments in Abia State, Southeastern Nigeria.Int J Adv Res. 2015;3(8):172-183
31. Yilangai RM, Manu A, Pineau W, Mailumo S, Okeke-Agulu K. The effect of biochar and crop veil on growth and yield of tomato (*Lycopersicum esculentus* Mill) In Jos, North Central Nigeria. Curr Agri Res J. 2014;2(1):37-42.
32. Osaji K. Micheal, Ogbujor D. A. And Oghenerho E. A. Effect of biochar on soil properties and yield of cucumber (*Cucumis sativus* L). Int J Soil Sci Agr. 2017;4(4):131–142.
33. Inusa D. Home of Peace And Tourism, Jos Plateau State. Docume/Local/Term/Tri, Ebnc Web P. 2; 2002.
34. Jackson, M.L. Soil chemical analysis. Asia Publishing House, Bombay. 1967
35. Walkley, A., Black, I.A., An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. Soil Sci. 1934;371); 29–38.
36. Esu, I.E (1991) Rating for soil fertility classes in the Nigerian Savannah. Dutse J Agr Food Secur (DUJAFS). 2019;6(2):93-99.
37. Hill, J. D And Rackham, L.J. Interim report on land forms, soils, climate and vegetation on the Jos Plateau. Land Resources Division, Misc Rep. 1974;153:2
38. Lehmann, J.; Kuzyakov, Y.; Pan, G.; Ok, Y.S. Biochar and the plant-soil interface. Plant Soil. 2015;395: 1–5.
39. Lehmann J., Da Silva Jr., J.P. Rondon, M., Nehls, T., Zech, W. And Glaser, B. Nutrient availability and leaching in an archaeological anthrosol and a ferralsol of the Central Amazon Basin: Fertilizer, Manure And Charcoal Amendments. Plant Soil. 2006;249:343-357
40. Sara, Sz And Shah T. Residual effect of biochar on soil properties and yield of maize (*Zea mays* L.) under different cropping systems. Open J Soil Sci. 2018;8:16-35.
41. Yuan Jh., Xu Rk. And Zhang H. The Forms of alkalis in the biochar produced from crop residues at different temperatures. Bioresour Technol. 2011, 102, 3488-3497.
42. Schultz H, Dunst G, Glaser B. No effect level of co-composted biochar on plant growth and soil properties in greenhouse experiment. Agronomy. 2014;4:34 -51.
43. Hardeep, S., Brian, K., Northup, C. W., Rice, P.V. And Vara, P. Biochar applications influence soil physical and chemical properties, microbial diversity, and crop productivity: A Meta-Analysis. 2022; Review. 4:8
44. Prakriti, B., Rajan, G., Stephen, M. And Larry, P. Biochar effects on soil properties and wheat biomass vary with fertility management. Agronomy. 2019;9:623; Doi:10.3390/Agronomy9100623
45. Liu, D., Ding, Z., Ali, E. F., Kheir, A. M. S., Eissa, M. A., And Ibrahim O. H. M. Biochar and compost enhance soil quality and growth of roselle (*Hibiscus Sabdariffal*.) under saline conditions. Sci Rep. 2021;11:8739. Https:// Doi.Org/10. 1038/S41598-021-88293-6