# EFFECTS OF BIOCHAR DERIVED FROM DIFFERENT FEEDSTOCK ON COWPEA PRODUCTIVITY IN MINNA, SOUTHERN GUINEA SAVANNA OF NIGERIA

**Adekanmbi,[1] A.A., Afolabi,[1] S.G., Umar,[1] A.O., Fagbenro,[2] J.A., Bala,[1] A. and Osunde,[1] O.A.**
[1]Department of Soil Science and Land Management, Federal University of Technology, Minna, Nigeria.
[2]Department of Environmental Management and Crop Production, Bowen University, Iwo, Nigeria
Corresponding Author's E-mail: ade.kanmbi@futminna.edu.ng; alextunji1@yahoo.co.uk
Phone number: +2348053030696; +447435369507

**ABSTRACT**
*Evaluating the crop response to different biochar type could be a necessary step in adapting biochar technology into the current intensification of legume production in the savanna region of Nigeria. A pot experiment was conducted to evaluate the effect of biochar derived from different feedstocks on cowpea growth and nodulation, in Minna, Nigeria. The experiment was a 4 × 5 factorial experiment consisting of four (4) biochar types made from different feedstock at five (5) application rate and fitted into a completely randomized design (CRD) at three (3) replicates. The Four biochar types were; poultry manure, swine dung manure, sawdust and maize cob biochars and the five different application rates were; 0 tons ha$^{-1}$, 30 kg P ha$^{-1}$, 5 tons ha$^{-1}$, 10 tons ha$^{-1}$, and 15 tons ha$^{-1}$. The results showed that, applying biochar made from Poultry manure and Swine dung increased cowpea height and number of leaves compared to biochar made from sawdust and maize cob. Amending soil with biochar at the rate of 10 or 15 tons/ha led to taller plants and more numerous leaves similar to that of 30 kg P ha$^{-1}$, whereas, 0 tons/ha gave shorter plants with fewer leaves over the growing period. Application of biochar derived from poultry manure increased the Shoot, root, nodule, and total biomass, shoot/root ratio, root length, number and percentage of effective nodules compare to the other biochar types. Applying biochar at 15 tons/ha significantly increased all the above and below ground biomass similar to that of 30 kg P ha$^{-1}$. The significant interaction between biochar type and rate showed that application of biochar at rate up to 10 or 15 tons/ha of manure-based biochar could replace the use of 30 kg P ha$^{-1}$. This study has found that, biochar derived from animal manure have potential to improve cowpea growth and productivity at 10 tons/ha. There is need to re-examine this effect in a field study to validate this claim.*

**Key words:** Cowpea, nodulation, biochar, feedstock, Soil Amendment.

## INTRODUCTION

Cowpea (*Vigna unguiculata L Walp*) which comes from the family *fabaceae* and is a native to Africa. It is one of the most important crops grown in the arid and semi- arid regions of the tropics covering Asia, Africa, Southern Europe, and Central America (Xu *et al.,* 2016). In today's world, man's need for protein makes cowpea an irresistible option for food as cowpea provides a cheap source of human dietary protein especially in developing counties (Xu *et al.,* 2016). It also produces a large biomass used in agriculture either as feed for animals or incorporated into soil to enhance soil fertility. Growing cowpea in the rural area is also beneficial among rural farmers due to its ability to fix atmospheric nitrogen into the soil through a process called biological nitrogen fixation (BNF).

Through biological nitrogen fixation nitrogen gas ($N_2$) present in the atmosphere is fixed and turned into readily available nitrogen for the preceding plant's uptake with the aid of soil micro-organism like rhizobia. This process is fostered by a symbiotic relationship between microorganism and the plant root. Nodules are produced on the root which helps fix atmospheric nitrogen into the soil and in turn the plant provides carbohydrates for the microorganisms. These nodules become home for the bacteria. Usually this process happens only after the plant has grown to a certain stage but before it reaches that stage it has to also take up nutrient from soil. Problem of low soil fertility, and extreme soil acidity have being identified among many other to impede symbiotic relationship between legumes and microbes (Afolabi *et al*, 2014), affirming the need for a favorable environmental condition (Adekanmbi *et al*., 2019) to realize the success of BNF.

Soil amendments (inorganic and organic) are known to improve the uptake of nutrients, increase soil fertility, improve soil quality, and consequently increase crop growth and yield. Biochar has been identified globally for its use as an organic soil amendment which helps in the enhancement of soil fertility, crop growth, water retention and movement in the soil and in soil pollution control (Novotny *et al.,* 2015). Some other benefits of biochar are in raising the pH of the soil, attracting more useful microorganisms, improving the cation exchange capacity (CEC) and also acts as nutrient reservoir (Lehmann and Joseph 2009; Obia *et al.,* 2015).

Biochar is a smooth and fine grain charcoal which has very high but stable organic carbon content. It is made through the heating of natural feedstocks in the presence of limited oxygen or by pyrolysis and it is used today worldwide as soil amendment (Egambiedieva *et al.,* 2016). Naturally, it contains all trace elements that were originally contained in the pyrolysed biomass (Lehman and Rondon 2006). Biochar is made from different feedstocks ranging from Animal waste, poultry litters down to wooden materials like shaving, and plant residue (e.g. straws, leaves, nuts, hulls, shells). There is a key difference between biochar made from different feedstock as some still retains some of their nutrients. Animal derived biochar are chemically distinct from other biochar (wood, crop residue) because of the high nutrient content and are similar to the conventional fertilizer (Filberto and Guant, 2013) in effect.

Due to the rapid population growth of Nigerians' and the need to increase agricultural productivity, food security and sustainability, increased agricultural practices has resulted in repeated harvest which slowly leads to rapid nutrient depletion, soil erosion, limited organic matter; soil degradation, limited agricultural land and low cation exchange capacity (CEC) (Bot and Benites, 2005). Inorganic fertilizer has been the major soil amendment used since the dawn of industrial age. However, Inorganic fertilizer has its limitations on microorganisms when applied in ignorance, sometimes resulting in leaching and encourages depletion of good and natural soils in the long run (Odesola and Owoseni 2010). It may exert adverse effect to the environment by contributing to the greenhouse gas emission (Saxena *et al.,* 2013). Organic manure is also used as amendment of soil to increase soil productivity, plant productivity and help in water retention and enhancement of microbial activity. However, the benefits of applying Organic manure is often short-lived due to faster decomposition owing to the prevailing tropical conditions.

Biochar is relatively cheap because it is processed from feedstocks and waste products that are locally sourced. This amendment used for improving soil properties and the subsequent crop growth, provides potential for carbon storage strategy in the soil and sequester carbon which in turn reduces global warming (Hunt *et al.,* 2010). Biochar characteristics vary due to variation in feedstocks and there is limited understanding of which biochar type and rate is most effective on cowpea growth and nodulation characteristics. Evidence exist that biochar application could significantly enhance legume growth, nodulation, symbiotic performance with beneficial soil microorganisms and enzyme activities (Egamberdieva *et al*., 2019). This is possible because biochar usually promotes favourable condition for microbial proliferation (Egamberdieva *et al.,* 2016). There may be a synergistic effect of applying biochar to soil as it may enhance the activity of the native rhizobia population and consequently enhance cowpea nodulation and nitrogen fixation. The aim of this study is to examine the effects of biochar derived from different feedstock (swine dung, poultry manure, sawdust, maize cob) on cowpea productivity in Minna, southern Guinea savanna of Nigeria.

## METHODOLOGY

**Study site :** The soil used for the experiment was collected from the Teaching and Research Farm, School of Agriculture and Agricultural Technology, Federal University of Technology, Gidan-Kwano Minna (latitude 9°31' 2.736" N, longitude 6°2622. 548" E, altitude 189.60 m above sea level).The pot experiment was carried out at the school' horticultural garden (latitude 9° 31' 48.762" N, longitude 6°27' 0.594" E, altitude 262.40 m above sea level). Minna is located in the southern guinea savanna of Nigeria. It has a mean annual rainfall of 1248mm and a sub humid climate. It is also characterized by a dry season of about 5 months occurring from November to March and also has its mean maximum temperature of 33.5°C from March to June (Ojanuga, 2006). Some of the physical characteristics of Minna area are the presence of gently undulating high plains which is developed on the basement of complex rocks made up of granites, migmatites, gneisses and schists , inselbergs of " older granite" and also low hills of schists which rises conspicuously above the plains beneath the plains bedrock and is deeply weathered. This constitutes the major part of the parent material (saprolites) (Ojanuga 2006).

**Collection and preparation of soil sample :**The soil sample was collected from a depth of 0 - 15cm within an area of lm by 2m. A shovel was used in the collection of the soil after which the soil was mixed thoroughly, air dried and passed through a 2mm sieve to remove stones and gravels from the soil. Samples for pre - planting analysis were taken from the collected bulk soil. The collected soil was transferred to the horticultural garden. The quantity of soil per pot used was 2.5 kg of soil

**Treatment and experimental design :** The experiment was a 4 x 5 factorial experiment which consisted of four biochar types and 5 rates fitted into a completely randomized design (CRD) with three replicates. The four biochar types used were swine dung biochar, poultry manure biochar, sawdust biochar, maize cob biochar. The biochar rates used were 0 tons $ha^{-1}$, 30 kg P $ha^{-1}$, 5 tons $ha^{-1}$,10 tons $ha^{-1}$, 15 tons $ha^{-1}$.

**Procurement of seeds and biochar :** The variety of cowpea seed used for the experiment was IT99K-573-1-1 and this was sourced from the International Institute of Tropical Agriculture (IITA) Ibadan, while the biochar used were sourced from Bowen University Iwo, Nigeria. These biochar were characterized at Federal University of Technology Minna, Niger State following the same method used in soil analysis. The chemical properties of biochar derived from different feedstocks are shown on Appendix 1

**Laboratory analysis of the soil :** The physical and chemical properties of the sieved soil were analysed in accordance to the standard method described by IITA (1982). Particle size of soil was determined using the hydrometer method. Soil pH was measured in 1:2.5 soil/water and 0.01M $CaCl_2$ suspension with a pH meter. Organic carbon was determined by the Walkey- Black wet oxidation method. The available phosphorous was determined colometrically after Bray-Pl extraction. The exchangeable bases were extracted with a neutral 1N $NH_4OAC$ solution. $Na^+$ and $K^+$ in the leachate were determined by flame photometry while $Ca^{2+}$ and $Mg^{2+}$ were determined by Na-EDTA titration. The exchangeable acidity was extracted by 1.0 N KCl. Effective cation exchange capacity was obtained by the summation of exchangeable cations and the exchangeable acidity. Total nitrogen was determined by micro Kjeldahl method.

**Agronomic practice :** The site where the pots were arranged was cleared manually using hoes to remove grasses and stumps. Jute bags were laid on the ground and polypots were placed on them. The air-dried soil was weighed and mix thoroughly with different biochar types and at different rates i.e. 5, 10, 15 tons $ha^{-l}$ and three replicates was transferred into well plugged polypots. Water was added at 40% water holding capacity (WHC) and left to equilibrate for three days. Control pots i.e. 0 tons per hectare was also treated as pots with biochar while in pots for single super phosphate i.e. 30kg P $ha^{-l}$, the mineral fertilizer was dissolved with water and applied at the same time and rate applied to others. Sowing was carried out immediately after equilibration. Planting stick was used to make a hole in each pot at a depth of 2.5cm and 3 seeds were planted per poly pot. After one week of emergence, thinning was done plants were thinned to one plant per pot.

**Measurement of growth and nodulation characteristics:** Plant heights (cm) were measured using a tape rule at 4, 6 and 8 weeks after sowing (WAS) from all the pots during the growth period. Leaves were counted alongside the plant heights at 4, 6 and 8 (WAS) and the values were recorded for each biochar type and rate. After 8 weeks of planting, plants were harvested using a sharp scissor to cut the shoot from the plant base. The roots (contained in an intact ball of earth) were immediately washed in a 2mm sieve using water to remove soil and also to prevent detached nodules from entering into the water. Nodules were separated from the roots for counting. Shoot weight in grams (g) was immediately measured after harvesting and was also taken after drying in an oven regulated at 75°C to a constant weight for 48 hours. The weight was measured using an electronic weighing balance. The root length (cm) was obtain by measuring the root length using metre rule for each individual biochar type and rate. Root weight (g) was measured by recording an oven-dried weight after drying in an oven regulated at 75°C to a constant weight for 48 hours using an electronic weighing balance. Nodule number was obtained, and Nodules were oven-dried at 75°C to a constant weight after 48 hours to obtain the nodule dry weight as in shoot and root measurements. Prior to drying, the percentage effectivity of the nodules was checked after counting by selecting 5 nodules at random and was cut using a sharp razor blade. Those with pink to reddish-brown colour were recorded as effective while those with green or dark colour were ineffective. The percentage effective number of nodules were recorded.

**Statistical analysis :** All data collected were subjected to Analysis of Variance (ANOVA) using Minitab 17.0 version. Where mean differences are observed, Fishers pairwise comparism was used to separate the means at 5% level of significance.

## RESULTS AND DISCUSSION

The physical and chemical properties of the soil used for the experiment was shown on Table 1. The soil was loamy sand. The soil pH was slightly acidic. The organic carbon (2.72 g $kg^{-l}$) and total nitrogen (0.003 g $kg^{-l}$) were low. The calcium (3.34 cmol $kg^{-l}$) and potassium (0.33 cmol $kg^{-l}$) contents were low. The available phosphorus (12 mg $kg^{-l}$) and magnesium (2.33 cmol $kg^{-l}$) contents were moderately available.

The main effects of biochar type and rate on plant height and number of leaves of cowpea at 4, 6 and 8 WAS were shown on Table 2. The application of the different biochar types showed significant effect ($P< 0.05$) on the plant height of cowpea at 4, 6 and 8 WAS. Poultry manure biochar and swine dung biochar produced taller plants compared to sawdust biochar and maize cob biochar at 4, 6 and 8 WAS (Table 2). There was no significant difference ($P>0.05$) between the biochar rates on cowpea plant height at 4 WAS. Application of 10 and 15 tons $ha^{-l}$ produced statistically taller plants at 6 and 8 WAS compared to the control.

The application of the different biochar types had significant effect ($P< 0.05$) on the number of leaves of cowpea. Poultry manure biochar produced the highest number of leaves which was significantly different ($P<0.05$) from sawdust and maize cob biochar at 6 and 8 WAS (Table 2). Application of 10 and 15 tons $ha^{-l}$ produced higher number of leaves which is significantly different from 0 and 5 ton $ha^{-l}$ at 4 and 6 WAS but similar to 30kg P $ha^{-l}$ at 4 WAS (Table 2).

The interaction effect of both biochar types and rates on the height of cowpea at 6 and 8 WAS were shown on Table 3 and the interaction effect of both biochar types and rates on the number of leaves of cowpea at 4, 6 and 8 WAS were shown on Table 4.

The interaction effect of biochar types and rates on the number of leaves at 4 WAS revealed that 10 tons $ha^{-1}$ of poultry manure biochar produced the highest number of leaves compared to other treatments, similar results was observed at 6 WAS. The result was similar to poultry manure biochar at 15 tons $ha^{-1}$. Poultry manure biochar applied 15 tons $ha^{-1}$ produced the highest number of leaves than other biochar types and rates.

There was significant effect ($P < 0.05$) of biochar types on the shoot weight of cowpea with biochar made from poultry manure having the highest shoot weight, root weight and total biomass. Swine dung biochar was significantly difference from other sources of biochar applied (Table 5). The animal derived biochars (Poultry manure and Swine) were significantly higher than the plant-derived (maize cobs and sawdust) biochars in terms of shoot/root ratio, root length and number of nodules of cowpea. Application of 15 tons $ha^{-1}$ had significant difference ($p< 0.05$) than other rates of biochar and 30 kg P $ha^{-1}$(Table 5).

The interaction effect between biochar types and rates on the shoot weight of cowpea revealed that the effect of poultry manure biochar at 10 and 15 tons $ha^{-1}$ produced the highest shoot weight while the lowest shoot weight was observed at application of maize cobs biochar at 0 tons $ha^{-1}$ (Table 6).

The interaction effect between biochar types and rates on the root weight of cowpea revealed that the effect of poultry manure biochar applied at 10 and 15 tons ha-$^{1}$ produced the highest root weight which was significantly difference from other treatments. A similar result was observed on root length (Table 7).

The interaction effect between biochar types and rates on the number of nodules of cowpea revealed that the effect of poultry biochar applied at 5 tons $ha^{-1}$ and swine dung at 15 tons $ha^{-1}$ produced the highest nodule number which was significantly different from other treatments (Table 8). The interaction effect between biochar types and rates on the weight of nodules was shown in Table 8. Application of poultry manure at 15 tons $ha^{-1}$ produced the heavier nodule weight which was similar to 10 tons $ha^{-1}$ while the lightest was observed when sawdust and maize cobs were applied at 0, 5 and 10 tons $ha^{-1}$ (Table 8).

Biochar has been reported to generally improve the biomass of leguminous crops at all stages of growth (Lehmann and Joseph, 2009). Results from this study have shown that, poultry manure followed by swine dung biochar produced taller cowpea plants and numerous leaves, but maize cob biochar and sawdust biochar consistently produced shorter plants and fewer leaves. This may be due to the difference in the chemical composition of the individual feedstock (Filberto and Guant 2013). Filberto and Guant (2013) also reported that animal derived biochar produced higher amount of calcium, potassium, nitrogen and phosphorous which sometimes may be similar to conventional fertilizer. Biochar feedstock derived from animal manure greatly influences the height and number of leaves of cowpea and this may be due to increase availability of nutrients for plant uptake. Application of 30 kg P $ha^{-1}$ also produced tall cowpea plants with reasonable number of leaves but not as much as 10 and 15 tons biochar $ha^{-1}$ which indicates that cowpea is a phosphorous loving crop and application of biochar at 10 or 15 tons could replace the inorganic P requirement of cowpea. Biochar have previously been praised for its ability to increase nutrient more than inorganic fertilizer (Lehmann and Joseph 2009, Adekiya *et al.*, 2020). The chemical nature of the feedstocks of biochar made from poultry manure increases the soil pH because of its alkaline nature, hence it provides a favourable environment for cation exchange. Although maize cob biochar was also alkaline in nature, the chemical nature of the feedstock may be responsible for its poor output even when it was applied at 10 and 15 tons $ha^{-1}$ (Lehmann and Joseph, 2009).

The highest positive effects were observed at the application of poultry manure biochar on the shoot weight, root weight, root length, shoot-root ratio, total biomass, number of nodules, nodule weight and effectivity. There was a partitioning effect that favours the above rather than below ground biomass when Swine dung biochar and poultry manure biochar were added to the soil and this was better represented by the shoot-root ratio. This effect is logical in terms of crop growth since good biomass accumulation is required to achieve better yield. Animal derived biochars also produced the longest roots and the highest number of nodules of cowpea. This may be due to the individual nature of feedstocks and higher nutrient content of biochar made from Poultry manure and Swine dung(Animal derived biochars) as biochar made from Animal wastes contains high minerals like calcium, phosphorous and total nitrogen, this could enhance the growth of roots and better ability to forage for more nutrients and moisture and also produce nodules for BNF (Filberto and Guant, 2013). Agboola and Moses, (2015), noted that, although addition of biochar significantly affects the root length, shoot weight, root weight, nodule number, weight and effectivity in legumes, biochar types significantly affect ability of biochar to enhance legumes growth.

The application 30 kg P $ha^{-1}$ which serves as fertilizer control in this study produced the longest roots and highest percentage effective nodules. This indicates that phosphorous is very important in the development and infestation of cowpea root by native rhizobia. But a similar effect was observed with the application of 15 tons biochar ha$^{-1}$. This may mean that biochar applied at l5 tons ha$^{-1}$ can substitute for the application of 30 kg P SSP ha-1 which was the major fertilizer requirement of cowpea in the area. An application of 10 and 15 tons biochar ha$^{-1}$ had similar effects on shoot-root ratio, nodule weight, number and root weight which also showed higher positive effect. These effects may be due to the formation of more effective nodules as pH improves. This implies that legume growth may benefit from biochar addition to enhance the biochemistry of the soil environments which may influence the root length, shoot weight, root weight, nodule number, weight and effectivity. It is also evidenced that the ability of biochar to enhance legumes growth is significantly by the biochar rates as biochar applied below 10 tons ha$^{-1}$ did not support growth appriopriately. Poultry manure biochar applied at both 10 tons and 15 tons ha$^{-1}$ produced the highest effects on shoot weight, total biomass and root weight in this study while it was noted that poultry manure biochar applied at 15 tons ha$^{-1}$ produced the highest effect on nodule weight. This may be due to the increasing availability of nutrient by biochar. Poultry manure biochar applied at 10 and 15 tons ha$^{-1}$ produced similar root length with those of 30 kg P ha$^{-1}$. This indicates that, though cowpea is a phosphorous loving crop, an application of poultry manure biochar at 10 and 15 tons ha$^{-1}$ can directly substitute for the application of 30 kg P ha$^{-1}$. Our result then implied that that, biochar made from animal derived feedstocks, when applied in the appropriate quantity can increase the availability of nutrient present for plant uptake.

## CONCLUSION AND RECOMMENDATION

In conclusion, poultry manure biochar produced the most outstanding effects on the overall growth and nodulation characteristics of cowpea while biochar applied at 10 tons and 15 tons ha$^{-1}$ had the most positive influence on the overall growth of cowpea. This result was at par with the effect of Swine biochar and they are comparable to application of inorganic P fertilizer at 30 kg P ha$^{-1}$. There is however an urgent need to conduct further studies to access the effect of animal derived biochar applied at 10 tons ha$^{-1}$ on the production of cowpea under field conditions to validate this view.

## REFERENCES

Adekanmbi, A. A., Afolabi, S. G., Adeboye, M. K. A., & Bala, A. (2019). Influence of Soybean Genotype and Rhizobial Inoculation on Soybean Nodulation ,Yield and Yield Component in Minna , Southern Guinea Savanna of Nigeria. *Journal of Science, Technology and Education*, *7*(4), 17–22.

Adekiya, A O., Agbede, T.M., Olayanju, A, Ejue, W. S., Adekanye, T. A., Adenusi, T.T., & Ayeni J.F., (2020). Effect of Biochar on Soil Properties, Soil Loss, and Cocoyam Yield on a Tropical Sandy Loam Alfisol. *Scientific World Journal* Volume 2020, https://doi.org/10.1155/2020/9391630

Table 1: Some Physical and Chemical Properties of the Soil used for the experiment

| Parameters | Values |
|---|---|
| Sand (g kg$^{-1}$) | 809.4 |
| Silt (g kg$^{-1}$) | 56.4 |
| Clay (g kg$^{-1}$) | 104.2 |
| Textural class | Loamy sand |
| pH in water at 1: 2.5 | 6.2 |
| pH in $CaCl_2$ at 1: 2.5 | 5.83 |
| Organic Carbon (g kg$^{-1}$) | 2.72 |
| Total Nitrogen (g kg$^{-1}$) | 0.003 |
| Available phosphorus(mg kg$^{-1}$) | 12 |
| Exchangeable Bases (cmol kg$^{-1}$) | |
| $Ca^{2+}$ | 3.34 |
| $Mg^{2+}$ | 2.33 |
| $Na^{+}$ | 0.68 |
| $K^{+}$ | 0.33 |
| Exchangeable acidity (cmol kg$^{-1}$) | 0.022 |
| Effective Cation Exchange Capacity cmol kg$^{-1}$ | 6.7 |

Table 2: Effects of Biochar Type and Rate on plant height and number of leaves of cowpea

| | Plant heights (cm plant $^{-1}$) | | | Number of leaves (plant$^{-1}$) | | |
|---|---|---|---|---|---|---|
| Treatments (T, WAS) | 4 | 6 | 8 | 4 | 6 | 8 |
| Biochar Type | | | | | | |
| Swine dung | 23.17$^{ab}$ | 21.96$^{a}$ | 27.19$^{a}$ | 8$^{b}$ | 11$^{a}$ | 13$^{a}$ |
| Poultry manure | 24.48$^{a}$ | 23.38$^{a}$ | 30.26$^{a}$ | 10$^{a}$ | 13$^{a}$ | 14$^{a}$ |
| Sawdust | 20.25$^{c}$ | 18.3$^{b}$ | 18.81$^{b}$ | 7$^{b}$ | 8$^{b}$ | 9$^{b}$ |
| Maize cob | 21.87$^{bc}$ | 18.34$^{b}$ | 19.17$^{b}$ | 7$^{b}$ | 8$^{b}$ | 9$^{b}$ |
| SE± | 0.73 | 0.77 | 1.51 | 0.5 | 1 | 1 |
| level of significance | S | S | S | S | S | S |
| Biochar Rates / ha ( R) | | | | | | |
| 0 tons | 20.84$^{a}$ | 16.23$^{b}$ | 15.48$^{c}$ | 6$^{c}$ | 5$^{c}$ | 6$^{b}$ |
| 30 kg P | 23.3$^{a}$ | 21.68$^{a}$ | 24.98$^{ab}$ | 9$^{a}$ | 11$^{ab}$ | 13$^{a}$ |
| 5 tons | 22.48$^{a}$ | 19.96$^{a}$ | 22.34$^{b}$ | 7$^{b}$ | 9$^{b}$ | 12$^{a}$ |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10 tons | 23.08$^{a}$ | 22.29$^{a}$ | 28.44$^{a}$ | 9$^{a}$ | 13$^{a}$ | 13 |
| 15 tons | 22.86$^{a}$ | 22.32$^{a}$ | 28.04$^{a}$ | 9$^{a}$ | 14$^{a}$ | 14$^{a}$ |
| SE± | 0.82 | 0.86 | 1.69 | 0.5 | 1 | 1 |
| level of significance | NS | S | S | S | S | S |
| T×R | NS | S | S | S | S | S |

Means that do not share a letter are significantly different at P< 0.05 using Fishers pairwise comparison
S= Significance at P<0.05 ; NS= Not Significant at P> 0.05

Table 3 : Interaction between Biochar type and rate on plant height of cowpea at 6 and 8 WAS

| Biochar types | Biochar rates (ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | 0 tons | 30 kg P | 5 tons | 10 tons | 15 tons |
| | | | 6 WAS | | |
| Swine dung biochar | 16.8$^{fgh}$ | 22.93$^{bcde}$ | 21.67$^{cdef}$ | 23.73$^{bcd}$ | 24.67$^{bc}$ |
| Poultry biochar | 15.87$^{gh}$ | 20.53$^{cdefg}$ | 23.23$^{bcd}$ | 29.63$^{a}$ | 27.63$^{ab}$ |
| Sawdust biochar | 17.6$^{fgh}$ | 21.63$^{cdef}$ | 18.13$^{efgh}$ | 16.43$^{gh}$ | 17.7$^{fgh}$ |
| Maize cob biochar | 14.67$^{h}$ | 21.6$^{cdef}$ | 16.8$^{fgh}$ | 19.37$^{defgh}$ | 19.27$^{defgh}$ |
| | | | 8 WAS | | |
| Swine dung biochar | 16.83$^{gh}$ | 29.17$^{bcdef}$ | 24$^{cdefg}$ | 32.27$^{bcd}$ | 33.7$^{bc}$ |
| Poultry biochar | 13.8$^{h}$ | 24.53$^{cdefg}$ | 31.37$^{bcde}$ | 43.53$^{a}$ | 38.07$^{ab}$ |
| Sawdust biochar | 17.53$^{gh}$ | 22.07$^{efgh}$ | 17.27$^{gh}$ | 17.97$^{gh}$ | 19.2$^{gh}$ |
| Maize cob biochar | 13.77$^{h}$ | 24.17$^{cdefg}$ | 16.73$^{gh}$ | 20$^{fgh}$ | 21.2$^{fgh}$ |

Means that do not share a letter are significantly different at P< 0.05 using Fishers pairwise comparism

Table 4: Interaction between Biochar type and rate on the number of leaves of cowpea at 4, 6 and 8 WAS

| | Biochar types | | Biochar rates (ha$^{-1}$) | | |
|---|---|---|---|---|---|
| | 0 tons | 30 kg P | 5 tons | 10 tons | 15 tons |
| | | | 4 WAS | | |
| Swine dung biochar | 6$^{ghi}$ | 7$^{fghi}$ | 7$^{fghi}$ | 10$^{bcd}$ | 9$^{bcdef}$ |
| Poultry biochar | 5$^{hi}$ | 8$^{cdefg}$ | 10$^{bcde}$ | 15$^{a}$ | 12$^{b}$ |
| Sawdust biochar | 6$^{ghi}$ | 11$^{bc}$ | 6$^{ghi}$ | 5$^{i}$ | 7$^{fghi}$ |
| Maize cob biochar | 6$^{ghi}$ | 8$^{defgh}$ | 6$^{ghi}$ | 7$^{fghi}$ | 7$^{fghi}$ |
| | | | 6 WAS | | |
| Swine dung biochar | 6$^{def}$ | 12$^{bc}$ | 13$^{b}$ | 13$^{bc}$ | 13$^{b}$ |
| Poultry biochar | 4$^{ef}$ | 9$^{bcdef}$ | 10$^{bcd}$ | 20$^{a}$ | 25$^{a}$ |
| Sawdust biochar | 6$^{def}$ | 12$^{bc}$ | 6$^{def}$ | 7$^{cdef}$ | 8$^{bcdef}$ |
| Maize cob biochar | 3$^{f}$ | 12$^{bc}$ | 6$^{def}$ | 11$^{bcd}$ | 9$^{bcde}$ |
| | | | 8 WAS | | |
| Swine dung biochar | 7$^{ghij}$ | 13$^{cdef}$ | 15$^{bcd}$ | 12$^{cdefg}$ | 16$^{abc}$ |
| Poultry biochar | 5$^{ij}$ | 11$^{cdefgh}$ | 19$^{ab}$ | 15$^{bcd}$ | 21$^{a}$ |
| Sawdust biochar | 6$^{hij}$ | 13$^{cdef}$ | 8$^{efghij}$ | 12$^{cdefg}$ | 9$^{efghij}$ |
| Maize cob biochar | 4$^{j}$ | 13$^{cde}$ | 8$^{efghij}$ | 12$^{cdefg}$ | 10$^{defghi}$ |

Means that do not share a letter are significantly different at P< 0.05 using Fisher pairwise comparison

Table 5 : Effects of Biochar Type and Rate on above and below ground cowpea productivity and Nodule characteristics

| Treatment | Shoot weight (g plant-1) | Root weight (g plant-1) | Total Biomass (g plant-1) | Shoot/Root ratio (plant-1) | Root length (cm plant-1) | Number of Nodules (plant-1) | Nodule weight (g plant-1) | Nodule effectivity (%) |
|---|---|---|---|---|---|---|---|---|
| Biochar Type (T) | | | | | | | | |
| Swine dung | 1.63$^{b}$ | 1.11$^{b}$ | 2.73$^{b}$ | 1.44$^{a}$ | 26.45$^{a}$ | 16$^{a}$ | 0.07$^{b}$ | 66.67$^{b}$ |
| Poultry manure | 2.42$^{a}$ | 1.65$^{a}$ | 4.07$^{a}$ | 1.34$^{a}$ | 26.51$^{a}$ | 18$^{a}$ | 0.14$^{a}$ | 73.33$^{a}$ |
| Sawdust | 0.47$^{c}$ | 0.56$^{c}$ | 1.02$^{c}$ | 0.8$^{b}$ | 26.8$^{a}$ | 6$^{b}$ | 0.02$^{c}$ | 54$^{ab}$ |
| Maize cob | 0.54$^{c}$ | 0.69$^{c}$ | 1.23$^{c}$ | 0.75$^{b}$ | 22.12$^{b}$ | 6$^{b}$ | 0.02$^{c}$ | 40$^{b}$ |
| SE± | 0.18 | 0.1 | 0.23 | 0.15 | 0.99 | 2 | 0.01 | 7.87 |
| level of significance | S | S | S | S | S | S | S | S |
| Biochar Rates / ha ( R) | | | | | | | | |
| 0 tons | 0.17$^{c}$ | 0.31$^{b}$ | 0.48$^{d}$ | 0.71$^{a}$ | 18.27$^{d}$ | 1$^{b}$ | 0.0007$^{b}$ | 13.33$^{c}$ |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 30 kg P | 1.19$^{b}$ | 1.17$^{a}$ | 2.35$^{bc}$ | 1.03$^{a}$ | 31.76$^{a}$ | 15$^{a}$ | 0.07$^{a}$ | 88.33$^{a}$ |
| 5 tons | 1.21$^{b}$ | 1.01$^{a}$ | 2.22$^{c}$ | 1.17$^{a}$ | 21.92$^{c}$ | 12$^{a}$ | 0.07$^{a}$ | 61.67$^{b}$ |
| 10 tons | 1.76$^{ab}$ | 1.24$^{a}$ | 3$^{b}$ | 1.16$^{a}$ | 26.76$^{b}$ | 14$^{a}$ | 0.08$^{a}$ | 56.67b |
| 15 tons | 2$^{a}$ | 1.28$^{a}$ | 3.28$^{a}$ | 1.35$^{a}$ | 28.64$^{ab}$ | 16$^{a}$ | 0.09$^{a}$ | 72.5$^{ab}$ |
| SE± | 0.2 | 0.11 | 0.25 | 0.17 | 1.1 | 2 | 0.01 | 8.8 |
| level of significance | S | S | S | NS | S | S | S | S |
| T×R | S | S | S | NS | S | S | S | NS |

Means that do not share a letter are significantly different at P< 0.05 using Fishers pairwise comparison
S= Significance at P<0.05 ; NS= Not Significant at P> 0.05

Table 6. Interaction effect between biochar types and rates on the shoot weight and the total biomass

| | Biochar types | | Biochar rates (ha$^{-1}$) | | |
|---|---|---|---|---|---|
| | 0 tons | 30 kg P | 5 tons | 10 tons | 15 tons |
| | | | Shoot weight (g plant$^{-1}$) | | |
| Swine dung biochar | 0.23$^{ef}$ | 1.37$^{cde}$ | 1.92$^{bcd}$ | 2.03$^{bcd}$ | 2.59$^{b}$ |
| Poultry biochar | 0.13$^{f}$ | 1.16$^{def}$ | 2.33$^{bc}$ | 4.06$^{a}$ | 4.43$^{a}$ |
| Sawdust biochar | 0.21$^{ef}$ | 1.34$^{def}$ | 0.35$^{ef}$ | 0.27$^{ef}$ | 0.37$^{ef}$ |
| Maize cob biochar | 0.12$^{f}$ | 1.08$^{ef}$ | 0.22$^{ef}$ | 0.66$^{ef}$ | 0.59$^{ef}$ |
| | | | Total biomass (g plant$^{-1}$) | | |
| Swine dung biochar | 0.73$^{f}$ | 2.34$^{cd}$ | 3.12$^{bc}$ | 3.46$^{bc}$ | 4.01$^{b}$ |
| Poultry biochar | 0.3$^{f}$ | 2.51$^{cd}$ | 4.35$^{b}$ | 6.3$^{a}$ | 6.9$^{a}$ |
| Sawdust biochar | 0.51$^{f}$ | 2.27$^{cde}$ | 0.77$^{f}$ | 0.72$^{f}$ | 0.84$^{ef}$ |
| Maize cob biochar | 0.35$^{f}$ | 2.28$^{cd}$ | 0.63$^{f}$ | 1.52$^{def}$ | 1.35$^{def}$ |

Means with the same letter in a column within the same treatments are not significantly different (p>0.05)

Table 7. Interaction between Biochar type and rate on the Root length and Root weight

| Biochar types | | Biochar rates (ha$^{-1}$) | | | |
|---|---|---|---|---|---|
| | 0 tons | 30 kg P | 5 tons | 10 tons | 15 tons |
| | | | Root length (cm plant$^{-1}$) | | |
| Swine dung biochar | 26.17$^{cde}$ | 28.77$^{abcde}$ | 23.7$^{e}$ | 27.23$^{cde}$ | 26.37$^{cde}$ |
| Poultry biochar | 13.83$^{f}$ | 34.27$^{a}$ | 25.47$^{cde}$ | 28.17$^{abcde}$ | 30.83$^{abc}$ |
| Sawdust biochar | 23.57$^{e}$ | 33.87$^{ab}$ | 24.67$^{cde}$ | 24$^{de}$ | 27.9$^{bcde}$ |
| Maize cob biochar | 9.5$^{f}$ | 30.13$^{abcd}$ | 13.87$^{f}$ | 27.63$^{bcde}$ | 29.47$^{abcde}$ |
| | | | Root weight (g plant$^{-1}$) | | |
| Swine dung biochar | 0.51$^{efg}$ | 0.97$^{cde}$ | 1.2$^{cd}$ | 1.43$^{bc}$ | 1.42$^{bc}$ |
| Poultry biochar | 0.18$^{g}$ | 1.35$^{cd}$ | 2.02$^{ab}$ | 2.24$^{a}$ | 2.47$^{a}$ |
| Sawdust biochar | 0.3$^{fg}$ | 1.14$^{cd}$ | 0.42$^{efg}$ | 0.45$^{efg}$ | 0.47$^{efg}$ |
| Maize cob biochar | 0.23$^{g}$ | 1.2$^{cd}$ | 0.41$^{efg}$ | 0.86$^{cdef}$ | 0.76$^{defg}$ |

Means that do not share a letter are significantly different at P < 0.05 using Fisher pairwise comparison

Table 8 : Interaction between Biochar type and rate on the Number of nodules and Nodule weight of cowpea

| Biochar types | | | Biochar rates ( ton ha$^{-1}$) | | |
|---|---|---|---|---|---|
| | 0 | 30 kg P | 5 | 10 | 15 |
| | | | Number of nodules (No. plant$^{-1}$) | | |
| Swine dung biochar | 0$^{f}$ | 17$^{abc}$ | 15$^{bcd}$ | 22$^{ab}$ | 26$^{a}$ |
| Poultry biochar | 0$^{f}$ | 16$^{abcd}$ | 26$^{a}$ | 23$^{ab}$ | 25$^{ab}$ |
| Sawdust biochar | 4$^{ef}$ | 11$^{cde}$ | 5$^{def}$ | 3$^{ef}$ | 7$^{cdef}$ |
| Maize cob biochar | 0$^{f}$ | 15$^{bcd}$ | 1$^{ef}$ | 7$^{def}$ | 6$^{def}$ |
| | | | Nodule weight (g plant$^{-1}$ ) | | |
| Swine dung biochar | 0$^{f}$ | 0.08$^{de}$ | 0.09$^{d}$ | 0.1$^{cd}$ | 0.1$^{d}$ |
| Poultry biochar | 0$^{f}$ | 0.08$^{de}$ | 0.16$^{bc}$ | 0.18$^{b}$ | 0.25$^{a}$ |
| Sawdust biochar | 0$^{f}$ | 0.08$^{de}$ | 0.02$^{ef}$ | 0$^{f}$ | 0.01$^{f}$ |
| Maize cob biochar | 0$^{f}$ | 0.05$^{def}$ | 0$^{f}$ | 0.02$^{f}$ | 0.01$^{f}$ |

Means that do not share a letter are significantly different at P< 0.05 using Fishers pairwise comparison

Appendix 1. Some chemical properties of biochar made from different feedstocks

| Parameters | Feedstocks | | | |
|---|---|---|---|---|
| | Swine dung | Poultry manure | Sawdust | Maize cob |
| pH in water | 7.1 | 9.59 | 7.38 | 8.93 |

| | | | | |
|---|---|---|---|---|
| pH in $CaCl_2$ | 5.82 | 9.25 | 6.62 | 9.04 |
| Available Phosphorous mg $kg^{-1}$ | 2.01 | 1.8 | 0.42 | 0.84 |
| Total Nitrogen g $kg^{-1}$ | 0.97 | 0.98 | 0.07 | 0.94 |
| Exchangeable bases cmol $kg^{-1}$ | | | | |
| $Na^+$ | 1.14 | 9.60 | 1.73 | 1.09 |
| $K^+$ | 19.02 | 37.7 | 16.52 | 28.87 |
| $Ca^{2+}$ | 3.58 | 4.1 | 15.72 | 3.41 |
| $Mg^{2+}$ | 16.04 | 12.63 | 6.81 | 12.71 |


Afolabi, S.G., Adekanmbi, A.A., Adeboye, M.K.A., & Bala, A. (2014) Effect Of Various Input Combinations On The Growth, Nodulation And Yield Of Inoculated Soyabean In Minna, Nigeria. *Int'l Journal Of Agric And Rural Dev.* 17, 2006–2011

Bot, A., & Benites, J.(2005). The importance of soil organic matter: Key to Drought-Resistant Soil Sustained Food and Production; Food and Agriculture Organisation. UN: Rome, Italy. 5-10pp.

Egamberdieva, D., Wirth, S. B. U., Abd_Allah, E.F. & Berg. (2016). Biochar treatment resulted in a combined effect on soybean growth promotion and a shift in plant growth promoting rhizobacteria. *Frontiers Microbiology*. 7: 1-11.

Egamberdieva, D., Li, L., Ma, H., Wirth, S., and Bellingrath-Kimura, S. D. (2019). Soil Amendment with Different Maize Biochars Improves Chickpea Growth Under Different Moisture Levels by Improving Symbiotic Performance With *Mesorhizobium ciceri* and Soil Biochemical Properties to Varying Degrees. *Frontiers in microbiology*, *10*,2423. https://doi.org/10.3389/fmicb.2019.02423

Filiberto, M. D. & Gaunt, L. J. (2013). Practicality of biochar additions to enhance soil and crop Productivity. *Agriculture*. 3: 715-725

Hunt, J., DuPonte, M., Sato D., & Kawabata A. (2010).The Basics of biochar: A natural soil amendment. Soil and crop management, SCM-30, UH–CTAHR. College of Tropical Agriculture University of Hawaii, Manoa. 1-6 pp.

IITA (International Institute of Tropical Agriculture). (1982) Automated and semi-automated methods for soil and plant analysis. IITA, Ibadan. Manual series No. *7*.

Lehmann, C. J. and Rondon, M. (2006). Biochar soil management on & highly weathered soils in the tropics. In: Uphoff, N.T. (Ed.), Biological Approaches to Sustainable Soil Systems. CRC Press, Boca Raton. 517-530pp.

Lehmann, J. and Joseph, S. (2009). Biochar for Environmental management: An introduction. Biochar for Environmental management: In: Lehmann. J. and Joseph. S (eds). Biochar for Environmental management Earthscan, London, UK. 1-416pp.

Novotny, E.H, Maia, C.M.B.F., Carvalho, M.T.M, & Madari, B.E. (2015). Biochar: pyrogenic carbon for agricultural use - A critical review. *Revista Brasileira de Ciência do Solo*, *39*(2), 321-344. https://doi.org/10.1590/01000683rbcs20140818

Obia A, Cornelissen G, Mulder J, & Dörsch P (2015) Effect of Soil pH Increase by Biochar on NO, $N_2O$ and $N_2$ Production during Denitrification in Acid Soils. *PLoS ONE* 10(9):e0138781.https://doi.org/10.1371/journal.pone.0138781.

Odesola, I. F., Owoseni, T. & Adetayo. (2010). Small scale biochar production technologies: a review. *Journal of Emerging Trends in Engineering and Applied Sciences* (JETEAS). 1 (2):151-156.

Ojanuga, A. G. (2006). Agro-ecological zones of Nigeria Manual. Food and agricultural organisation/NSPFS, Federal ministry of Agriculture. 1-24pp.

Saxena, J., Rana, G., & Pandey, M.(2013) Impact of addition of biochar along with *Bacillus spp*.on growth and yield of French bean*s*. *Scientia Horticulturae*. 162:351–356.

Xu, P., Wu, X., Mu~ noz-Amatriaın, M., Wang, B., Wu, X.,Hu Y., Huynh, B. L., Close, T. J., Roberts, P. A., Zhou, W., Lu, Z. & Li, G. (2016). Genomic regions, cellular components and gene regulatory basis underlying pod length variations in cowpea (*Vigna unguiculata L.Walp). Plant Biotechnology journal.* 10:1-9.