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EFFECT OF DIFFERENT RATES OF BIOCHAR ON NODULATION AND YEILD OF SOYBEAN (*Glycine max.L.*merill)

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ABSTRACT

The experiments were conducted at the Teaching and Research Farm, Faculty of Agriculture, Nasarawa State University, Shabu-Lafia Campus during 2018 and 2019 cropping seasons to evaluate the effect of different rates of biochar on nodulation and yield of soybean in Lafia, Southern Guinea Savanna of Nigeria. The experiments were laid in randomized complete block design (RCBD) with three replications. Biochar at the rates of 0, 4, 8 and 12 tons/ha was incorporated into ridges at planting. Four seeds of soybean were planted per hole at a spacing of 5cm between plants on four manually prepared ridges of 2 m long spaced at approximately 75cm. The seedlings were thinned to two plants after two weeks of planting (WAP). All data collected were subjected to analysis of variance (ANOVA) using GENSTAT statistical package while least significant difference was used to separate treatment means at 5% level of probability. The results obtained showed that biochar at the rate of 8 tons/ha significantly ($p<0.05$) produced the highest number of nodules (20.8 and 16.4), recorded the heaviest weight per 100 seeds (16.9 and 14.9g) and grain yield of soybean (1304.0 and 1316.7 kg/ha) in both cropping seasons. The results further revealed that the highest dose of biochar (12 tons/ha) in this study did not necessarily influence and increase any parameter tested except over the control (0.0 tons/ha) in both cropping seasons. Therefore biochar at the rate of 8 tons/ha is hereby considered to be the optimum rate for sustainable soybean production in the study area.

Keywords: Biochar; nodulation; optimum level; sustainable; soybean yield

INTRODUCTION

Biochar is a heterogeneous and chemically complex material made by heating (thermal degradation) of organic materials (biomass) such as forest residues (woods); green yard waste, animal manure, animal bones, etc in the absence of oxygen through the process known as pyrolysis (Yooyen *et al.*, 2015, Wilson, 2014a, Angin, 2013, Lehmann and Joseph, 2009). Pyrolysis is derived from Greek words- "pyro" means fire while "lysis" means separations (Schemidt and Wilson, 2014). The elemental composition of biochar generally includes carbon, nitrogen, hydrogen, K, Ca, Na, and Mg (Zhang *et al*., 2015). It is one of the oldest soil amendments in the history of agriculture (Wilson, 2014b). Biochar increases soil water holding capacity, improves soil aeration, releases plant nutrients and raises soil pH value (Schmidt and Wilson, 2014). It is widely applied as soil amendments for carbon sequestration, improvement of crop yield and remediation of pollution (Antonangelo *et al*., 2021, Wang *et al.*, 2020, Clurman *et al.*, 2020). Biochar improves the supply of nutrients to plants and enhances plant growth and crop productivity (Tian *et al.*, 2018, Chan and Xu, 2009, Rondon *et al*., 2007).

Soybean (*Glycine max (L) merrill*) is a species of legume, widely grown for its edible beans which has numerous uses. It is among the major industrial and food crops grown in every continent (Dugje *et al*., 2009) and classified as an oil-seed rather than a pulse crop (FAO, 2016). It improves soil fertility by adding nitrogen from the atmosphere through biological nitrogen fixation which is a major benefit in African farming systems where soils have become exhausted and where fertilizers are hardly available (scarce) and expensive for farmers (Fairhust, 2012, Dugje *et al.*, 2009). Soybean as a legume crop provides itself with nitrogen through biological nitrogen fixation for its growth and for succeeding crop especially cereal crops (Dugje *et al*., 2009). The decomposed leaves of soybean improve soil fertility and increase yields of subsequent crop. It provides excellent fodder for livestock (Fairhust, 2012). Soybeans grown in rotation with cereals crops, serve as catch crops in controlling weeds especially striga hermonthica in maize farms (Dugje *et al.*, 2009). Soybean production has increased globally due to its economic importance, nutritive value and diverse domestic usage (David, 2017) and as such its cultivation in Nigeria is rapidly increasing as farmers are becoming more aware of the importance and potentials of the crop as cash or food crop (Dugje *et al*., 2009). Soybean contains more than 36% protein, about 30% carbohydrates and 20% oil. It is an excellent source of dietary fiber, vitamins and minerals. Soybean is the only available crop that provides an inexpensive and high quality source of protein comparable to meat, poultry and eggs (Atli, 2019, Dugje *et al.*, 2009). It is described as the world chief source of edible vegetable oil for human diets as it contains all the essential amino acid (Atli, 2019, Manral and Saxena, 2003). Soybean is a good source of food such as soy-milk, soy-cheese, dadawa, vegetables oil, and soybean cake for human and livestock etc (Dugje *et al.*, 2009). There are high demands for soybean as it is being converted into various traditional food products such as soy-milk, soy-cake, soy-soup, soy-oil, etc. but the use of biochar for maintaining and improving poor soil for sustainable increase of soybean production have not receive much attention to meet the increasing demands for the crop. However, the local production and uses of biochar have gain ground for energy and fuel purposes only. Hence the need for this kind of study to encourage local farmers to use cheap and available low input technology for sustainable soil fertility management and for increasing crop production in the study area. Therefore, this study aimed at evaluating the effect of different rates of biochar on nodulation (nodules formation) and yield of soybean in order to determine its optimum level

for sustainable production of the crop in Lafia, Southern Guinea Savanna of Nigeria.

MATERIALS AND METHODS

The experiments were conducted at the Teaching and Research Farm, Faculty of Agriculture, Nasarawa State University Keffi, Nigeria, Shabu-Lafia Campus during the 2018 and 2019 cropping seasons. The seeds of soybean (variety TGX1951-3F) were obtained from National Cereals Research Institute (NCRI) Badeggi –Bida Niger State. The study area is located between latitude 08.33^0N and Longitude 08.33^0E which falls within the Southern Guinea Savannah zone of Nigeria (NiMet, 2021). The experiments were laid out in a randomized complete block design (RCBD) with three replications. Biochar at the rates of 0, 4, 8 and 12 tons/ha was incorporated into ridges at planting. Four (4) seeds of soybean were planted per hole at a spacing of 5cm between plants on four manually prepared ridges of 2m long spaced at approximately 75cm between ridges. The seedlings were thinned to two plants after two weeks of planting (WAP). All data obtained from this study were subjected to analysis of variance (ANOVA) using GENSTAT Statistical Package while least significant difference (LSD) was used to separate treatment means at 5% level of probability.

RESULTS AND DISCUSSION

Physico-chemical properties of soil of the experimental site before the experiments (Table 1) indicated that soil pH $_{(H2O)}$ (5.63 and 5.61) and organic matter content (3.04 and 2.97%) of the experimental site at both surface and subsurface soil levels were moderate while the percentage total nitrogen (0.25 and 0.21%), organic carbon (1.77 and 1.73%) and available phosphorous (2.53 and 2.43 ppm) were very low at both surface and subsurface soil levels. The percentage base saturation was high (86.00 and 85.00%) at both surface and surface soil levels. The sand particle (85.80%) was very high at the surface and subsurface soil levels hence the soil textural class was sandy loam. This is in line with the report of Chude *et al*. (2012) who rated and classified soil nutrient status of Southern Guinea Savanna of Nigeria as very low, low, moderate and high depending on the nutrient. The low soil property of the experimental site before the experiments was an indication of the expected response of soybean to the application of biochar as reflected in all the parameters tested.

Table1: Physico-chemical Properties of Soil of the Experimental Site before the Experiment 2018

	Soil Depth	
Soil Parameter	**0-15 cm**	**15-30 cm**
P^H (H_2O)	5.63	5.61
Organic Carbon (%)	1.77	1.73
Organic Matter (%)	3.04	2.97
Total Nitrogen (%)	0.25	0.21
Available phosphorus (ppm)	2.53	2.43
Exchangeable bases (cmol/kg)		
Potassium(k) (cmol/kg)	0.18	0.17
Calcium(ca) (cmol/kg)	2.71	2.59
Magnesium(mg) (cmol/kg)	1.52	1.62
Sodium (Na) (%)	0.15	0.13
Exchangeable acidity (EA) (%)	0.67	0.75
Total exchangeable bases (%)	4.51	4.48
Base saturation (%)	86.00	85.00
Particle size distribution:		
Sand (%)	85.80	85.80
Silt (%)	4.40	4.40
Clay (%)	9.30	9.80
Textural class	Sandy loam	Sandy loam

The result of the effect of different rates of biochar on number of nodules per soybean plant (Table 2) showed that biochar at the rate of 8 tons/ha produced significantly ($p<0.05$) the highest number of nodules per plant (20.8 and 16.4) while biochar at the rate of 0.0 tons/ha (control) recorded the lowest number of nodules (12.7 and 11.2) in the 2018 and 2019 cropping seasons respectively. The result also showed that biochar at the rate of 8 tons/ha produced the next higher number of nodules (18.1) in 2018 and biochar at the rate of 4 tons/ha recorded the next higher number of nodules per soybean plant (15.3) in 2019. The high nodule number of soybean obtained as a result of the application of biochar to soil may be attributed to its nutrient contents that positively influenced the soil while the low number of nodules recorded as a result of the application of the highest dose of biochar (12 tons/ha) in this study might have made the soil too alkaline which negatively affected the nutrient content of and availability in the soil for the positive response and performance of the crop. The result is in line with finding of Mete *et al.* (2015) who reported that nodulation increased with the increased application of biochar. Bayan (2013) reported that biochar at 2% in pot experiment significantly enhanced and increased soybean nodule formation by 35% over the control and 5% of biochar application.

Table 2: Effect of Different rates of Biochar on number of nodules per soybean plant in the 2018 and 2019 Cropping Seasons

Biochar (tons/ ha	2018	2019
0	12.7d	11.2d
4	17.5c	15.3b
8	20.8a	16.4a
12	18.1b	13.0c
LSD (0.05)	0.08	0.33

Values followed with the same letter (s) within a column are not significant at 5% level of probability.

The result of the effect of different rates of biochar on the weight of nodules of soybean (Table 3) indicated that biochar at the rates of 4 and 8 tons/ha recorded similar weight of fresh nodules of soybean (3.5 and 3.6g) while biochar at the rate of 0.0 tons/ha (control) recorded the lowest weight of nodules (2.2 and 2.0g) in both 2018 and 2019 cropping seasons respectively. However the low weight of nodules recorded as a result of the application of the highest dose of biochar (12 tons/ha) compared to the other rates except the control in this study may be that the highest dose made the soil too alkaline which negatively affected the nutrients of and availability in the soil for positive response and performance of the crop. The result is in line with finding of Mete *et al.* (2015) who reported that nodulation increased significantly ($p<0.05$) with the increased application of biochar. Bayan (2013) reported that biochar at 2% in pot experiment significantly enhanced and increased soybean nodule formation by 35% over the control and 5% of biochar application.

Table 3: Effect of Different rates of Biochar on weight of nodules per soybean plant in the 2018 and 2019 Cropping Seasons

Biochar (tons/ha	*2018*	*2019*
0	2.2c	2.0c
4	3.5a	3.5a
8	3.6a	3.6a
12	2.6b	2.8b
LSD (0.05)	0.11	0.10

Values followed with the same letter (s) within a column are not significant at 5% level of probability.

The result of the effect of different rates of biochar on 100 seed weight (g) of soybean (Table 4) showed that biochar at the rate of 8 tons/ha recorded significantly ($p<0.05$) the heaviest weight per 100 seed of soybean (16.9 and 14.9g) followed by biochar at the rate of 4 tons/ha (15.4 and 14.2g) while biochar at the rate of 0.0 ton/ha (control) recorded the lowest weight per 100 seeds of soybean (12.6 and 12.6g) in the 2018 and 2019 cropping seasons respectively. However the low weight per 100 seed recorded as a result of the application of the highest dose of biochar (12 tons/ha) compared to other rates except the control in this study may be explained that the highest dose made the soil too alkaline which negatively affected the nutrient contents of and availability in the soil for positive response and performance of the crop. The positive response of soybean as reflected in 100 seed weight may be that biochar positively influenced nutrient contents of and availability in the soil. The result is in line with finding of Mete *et al. (2015)* who reported that seed yield of soybean increased significantly ($p<0.05$) on average by 54% as a result of the application of biochar compared to the control. Agboola and Moses (2015) reported that application of biochar increased yield of soybean significantly ($p<0.05$). Similarly, Njoku *et al.* (2015) reported that maize grain yield were significantly ($P<0.05$) higher in plots amended with biochar than the control. Rondon *et al.* (2007) also reported that yield of soybean was significantly ($p<0.05$) increased by 46% over the control as a result of the application of 90 g/kg of biochar to soil.

Table 4: Effect of Biochar on 100 Seeds Weight (g) of soybean during 2018 and 2019 Cropping Seasons

Biochar (tons/ha)	2018	2019
0	12.6d	12 6d
4	15.4b	14.2b
8	16.9a	14.9a
12	14.0c	13.1c
LSD (0.05)	0.13	0.25

Values followed with the same letter (s) within a column are not significant at 5% levels of probability.

The result of the effect of different rates of biochar on the weight of grain of soybean per hectare (Table 5) showed that biochar at the rate of 8 tons/ha recorded significantly ($p<0.05$) the highest grain yield (1304.0 and 1316.7 kg/ha) followed by biochar at the rate of 4 tons/ha (1180.0 and 1187.3 kg/ha) while biochar at the rate of 0.0 ton/ha (control) recorded the lowest grain yield (739.0 and 745.0 kg/ha) in 2018 and 2019 cropping seasons respectively. The high grain yield of soybean per hectare obtained could be that biochar positively influenced nutrient contents of and availability in the soil which positively influence the yield performance of the crop while the low grain yield of soybean per hectare recorded as a result of the highest dose of biochar (12 tons/ha) in this study may be explained that the highest dose made the soil too alkaline which resulted in the low yield of the crop. This result confirmed the report of Mete *et al.* (2015) who reported that seed yield of soybean was significantly ($p<0.05$) increased by 54% as a result of the application of biochar compared to the control. Agboola and Moses (2015) reported that application of biochar increased yield of soybean

significantly. Similarly, Njoku *et al.*(2015) reported that maize grain yield were significantly (P<0.05) higher in plots amended with biochar than the control. Rondon *et al*. (2007) also reported that yield of soybean significantly (p<0.05) increased by 46% over the control as a result of the application of 90 g/kg of biochar to soil.

Table 5: Effect of Biochar on Seed Yield of soybean per Hectare (kg/ha) in the 2018 and 2019 Seasons

Biochar (tons/ha)	2018	2019
0	739.0d	745.0d
4	1180.0b	1187.3b
8	1304.0a	1316.7a
12	1053.7c	1066.0c
LSD (0.05)	0.16	0.19

Values followed with the same letter(s) within a column are not significant at 5% probability

CONCLUSION

From the results of this study it can be concluded that the application of biochar to soil positively and significantly (p<0.05) influenced nodulation (nodule number and weight) and yield of soybean. The results revealed that application of biochar at the rate of 8 tons/ha consistently and significantly (p<0.05) produced the highest number of nodules per soybean plant, recorded the heaviest weight per 100 seed and grain yield of soybean per hectare in the 2018 and 2019 cropping seasons respectively. The results also showed that the high response shown by the crop as a result of the application of biochar at the rate of 8 tons/ha against other rates seemed to be the optimum rate for sustainable soybean production in the study area and is hereby recommended for both small and large scale soybean farmers.

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