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GROWTH AND YIELD OF SOYBEAN (*GLYCINE MAX* L. MERRILL) AS INFLUENCED BY BIOCHAR APPLICATION

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Abstract
The experiments were conducted at the teaching and research farm, Faculty of Agriculture, Shabu-Lafia Campus Nasarawa State University, Keffi, during 2018 and 2019 cropping seasons to examine the effects of biochar on growth and yields of Soybean. The experiments were laid in Randomized Complete Block Design. Biochar at the rates of 0, 4, 8 and12 tons/ha was incorporated into the ridges at planting while soybean seeds were planted as uninoculated (without legume inoculant) and inoculated (coated with legume inoculant) respectively. All data collected on soybean parameters were subjected to analysis of variance using GENSTAT statistical package while least significant different was used to separate treatment means at 5%level of probability. The results showed that biochar at the rate of 8 tons/ha produced significantly (P<0.05) the tallest soybean plant in 2018 and 2019 cropping seasons respectively. The results also showed that biochar at the rate of 8 tons/ha recorded the highest number of branches (4.5 cm) in 2018 cropping season only. The results further revealed that biochar at the rate of 8 tons/ha recorded the highest weight per 100 seed (16.9 and 14.9 g) and grain yields (1304.0 and 1316.7 kg/ha) in 2018 and 2019 cropping seasons respectively compared to other rates of biochar applied. However the highest dose of biochar (12 tons/ha) applied did not increase soybean growth and yield parameters tested in this study. Therefore, biochar at the rate of 8 tons/ha is hereby recommended for sustainable soybean production in the study area.
Key words: Biochar, evaluate, growth, seed yield

Introduction

Biochar is a heterogeneous and chemically complex material made by heating or thermal degradation of organic materials/biomass in the absence of oxygen through the process known as pyrolysis (Yooyen *et al.,* 2015, Wilson, 2014a, Lehmann and Joseph, 2009). Pyrolysis is derived from Greek- pyro means fire while lysis means separations (Schemidt and Wilson, 2014). It is one of the oldest soil amendments in the history of agriculture (Wilson, 2014b). Biochar improves soil physical, chemical and biological properties (Lehmann, 2007, Glaser *et al*., 2002, Lehmann *et al.,* 2006, Warnock *et al.,* 2007). It enhances crop productivity and yields (Wang *et al.,* 2020, Antonangelo *et al*., 2021, Clurman *et al.,* 2020). Biochar releases plant nutrients and raises soil pH value (Schmidt and Wilson, 2014). Soybean (*Glycine max* L. Merrill) is a species of legume, widely grown for its edible beans which have numerous uses (Dugje *et al.,* 2009). It is classified as an- oil seed rather than a pulse crop (FAO, 2016).

Soybean contains more than 36% protein, about 30% carbohydrates and 20% oil. It is an excellent source of dietary fiber, Vitamins and Minerals and it is the only available crop that provides an inexpensive and high quality source of protein comparable to meat, poultry and eggs (Manral and Sexana 2003, Atli, 2019). Soybean improves soil fertility by adding nitrogen from the atmosphere which is a major benefit in African farming systems where soils have become exhausted and where fertilizers are hardly available (scarce) and too expensive for farmers (Dugje *et al.,* 2009, Fairhust, 2012). The decomposed leaves of soybean improve soil fertility (Fairhust, 2012). Soybean grown in rotation with cereals crops serves as catch crops in controlling weeds especially *Striga hermonthica* in maize farms (Dugje *et al.,* 2009). There is increasing demand, economic importance and uses of soybean as it is being converted or made into various traditional food products such as soy- cake, soy-milk, soy- soup, etc. and local production and uses of biochar for energy and fuel purposes only has increased over the recent years. However, the use of biochar as soil amendment material for maintaining and improving soil fertility for sustainable agricultural and crop production have not received much attention by the local farmers in the study area. 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 biochar on growth and yield of soybean 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, Shabu-Lafia during 2018 and 2019 cropping seasons. The study area is located between latitude 08^0 29'30" N and Longitude 08^0 31'0" E, which falls within the Southern Guinea Savannah zone of Nigeria. Rainfall usually starts from April and ends in October. Lafia has mean annual rainfall range between 1100 mm and 2000 mm (NIMET 2021). A composite soil samples from 0-15cm and 15-30cm depth were taken randomly at six (6) different locations of the experimental field before ridging. All the soil samples were samples were air dried at room temperature for 7 days, crushed, sieved through a 2-mm sieve and analyzed for some physical and chemical properties in the Agronomy laboratory, of the Faculty of Agriculture, Shabu -Lafia Campus, Nasarawa State University, Keffi. Particle size analysis was determined by Gee and Bauder (1986) method). The textural class was determined from the USDA soil textural triangle. Total Nitrogen was determined by the micro- Kjeldhal method (Bremmer and Mulvaney 1982). Soil pH was determined in 1:25 soil/water extract of the composite samples (Mclean 1982). Soil organic carbon was determined by Nelson and Sommers' (1982) method. This was multiplied by 1.724 to obtain soil organic matter. Available Phosphorus was determined by Bray 2 extract (Olsen and Sommers 1982).

Total exchangeable bases (K^{+}, Ca^{2+}, Mg^{2+} and Na^{+}) were determined after leaching the soils with ammonium acetate. Then, Ca^{2+} and Mg^{2+} were determined from extract by using atomic absorption spectrometry (AAS) (Buck Scientific Model 210), while and K^{+} and Na^{+} were analyzed by flame photometer from the same extract (Thomas 1982). Cation exchange capacity (CEC) of the soil was estimated by summation of the exchangeable bases. Biochar was made locally using cashew woods which were arranged and covered with earth and fire was set through four small openings to allow in little air. The fire was quenched after about 4-5 hours with water. The experiments were laid in Randomized Complete Block Design (RCBD) with three replications. Four ridges of 2 m long spaced at about 75 cm were made manually using local hoes. Biochar was crushed into pieces and incorporated into ridges at planting at the rates of 0, 4, 8 and 12 tons/ha was while four seeds of soybean (TGX 1951-3 F) were planted per hole at 5cm spacing. The seedlings were thinned to two at two weeks of planting. All data obtained on plant parameters were subjected to analysis of variance using GENSTAT statistical package while least significant difference (LSD) was used to separate the treatment means at 5% levels of probability.

Results and Discussion

The soil pH (4.67 and 4.69) and organic matter content (3.04 and 2.97) of the experimental site at both surface and subsurface soil layers were moderate while the percentage total nitrogen (0.25 and 0.21), organic carbon (1.77 and 1.73) and available phosphorous (ppm) (2.53 and 2.43) were very low at both surface and subsurface soil layers. The percentage base saturation was high (86.00 and 85.00) at both surface and surface soil layers. The sand particle (85.80) was very high at the surface and subsurface soil layers hence the soil textural class of the experimental site was sandy loam (Table 1). 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 type of the nutrient. The results also showed that soil properties decreased down the soil depth (from surface to subsurface soil layer) except the available phosphorus, magnesium, exchangeable acidity and cation exchange capacity which increased with soil depth. The decreased values in some soil properties down the soil depth (from surface to subsurface soil layers) of the experimental site could be attributed to sandy nature of the soil, poor land/soil management practices, continuous/over cultivation, mono-cropping, bush burning, high temperature, erosion and leaching as a result of sloppy topography of the experimental site. This is in line with the findings of Adam *et al.* (2019), Hayatu *et al.* (2019), Popoola and Mgbonu, (2018), Yakub and Mallo, (2018), Dikko *et al.* (2010) who reported that soil pH, cation exchange capacity, organic carbon, organic matter, total nitrogen and available phosphorus decreased with soil depth from surface to subsurface soil layers. Olubanjo and Inaidoh (2017) also reported that slope position and soil depth significantly influenced soil chemical properties such as pH, N, Ca, Mg, K, H and ECEC. Adam *et al.* (2018) and Dikko *et al.* (2010) attributed this to sparse vegetation, bush burning, removal of crop residues, and nutrient uptake by plant and volatilization of some nutrient due to high temperature at surface soil.

Table 1: Physico-Chemical Properties of Soil of the Experimental Site before Experiment, 2018

	Soil Depth	
	0-15 cm	**15-30 cm**
Soil Parameter	**Mean**	**Mean**
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
CEC(cmol/kg)	5.18	5.23
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 results of the effects of different rates of biochar on soybean plant height (Table 2) showed that biochar at the rate of 8 tons/ha produced significantly ($p<0.05$) the tallest soybean plant height (40.4cm) and (48.0 cm) followed by biochar at the rate of 4 tons/ha (40.0cm) and (46.6 cm) at 8 and 10 weeks after planting (WAP) respectively in 2018 cropping season. The results of 2019 cropping season showed similar pattern to that of 2018 cropping season. The results also indicated that biochar at the rates of 12 tons/ha recorded the shortest soybean plants at 8 and 10 WAP in both 2018 and 2019 cropping seasons. The positive response of soybean to the application of biochar may be due to the nutrient content of biochar as reported by Rondon *et al.* (2007) that biochar contains plant nutrients such as P, K, Mg, and Ca, Mo and B. The results are in line with the finding of Mete *et al.* (2015) who reported that total biomass production of soybean increased on average by 67% as a result of the application of biochar compared to the control. Rondon *et al.* (2007) also reported that biochar addition to soil significantly increased total biomass production of beans by 39% up to 60 g/kg of biochar but contrarily decreased biomass to the level of the control with 90 g/kg application of biochar. Bayan (2013) reported that biochar at 2% in pot experiment significantly enhanced soybean plant growth, leaf area and increased nodule formation by 35% over the control and 5% of biochar application. Liu *et al*. (2020) reported that 5% loading of biochar significantly recorded the highest soybean plant height, biomass and yield compared to the control and 10% biochar. Nurmalasari *et al.* (2022) reported that 20 tons/ha of rice husk biochar increase plant height by 14.6% and 15 tons/ha increase leaves by 11.35% and number of branches by 36.65. Contrarily however, Agegnehu *et al.* (2016) reported that plant growth will be inhibited by applying only biochar.

Table 2: Effect of Biochar on Plant Height of Soybean during 2018 and 2019 Cropping Seasons

Treatment	2018		2019	
Biochar (tons/ha)	8	10	8	10
0	38.9^{c}	44.1^{c}	39.9^{c}	46.1^{c}
4	40.0^{b}	46.6^{b}	42.1^{b}	48.1^{b}
8	40.4^{a}	48.0^{a}	42.7^{a}	49.2^{a}
12	38.8^{c}	43.8^{d}	40.0^{c}	46.0^{c}
LSD (0.05)	0.14	0.12	0.22	0.12

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

The results of the effects of different rates of biochar on number of branches per soybean plant (Table 3) indicated that biochar at the rate of 8 tons/ha recorded significantly (P<0.05) the highest number of branches (4.5) and (4.5) followed by biochar at the rate of 4 tons/ha (3.4) and (4.4) at 8 and 10 WAP respectively in 2018 cropping season. The results also showed that biochar at the rate of 12 tons/ha recorded the lowest number of branches per soybean plant (2.9) and (3.3) at the same sampling periods in the same cropping season. The results of 2019 cropping season showed that biochar at the rates of 8 and 4 tons/ha recorded similar number of branches per soybean plant at 8 and 10 WAP respectively.

The results further revealed that biochar at the rate of 12 tons/ha and the control recorded similar number of branches per soybean plant at 8 and 10 WAP in both cropping seasons. The positive response of soybean to the application of biochar may be due to the nutrient content of biochar as reported by Rondon *et al.* (2007) that biochar contains plant nutrients such as P, K, Mg, and Ca, Mo and B. The results are in line with finding of Mete *et al.* (2015) who reported that total biomass production of soybean increased on average by 67% as a result of the application of biochar compared to the control. Rondon *et al.* (2007) also reported that biochar addition to soil significantly increased total biomass production of beans by 39% up to 60g/kg of biochar but contrarily decreased biomass to the level of the control with 90g/kg application of biochar. They concluded that the crop performance was largely an effect of elevated P, K, Mg, and Ca, Mo and B availability and higher pH as a result of biochar addition. Bayan (2013) reported that biochar at 2% in pot experiment significantly enhanced soybean plant growth, leaf area and increased nodule formation by 35% over the control and 5% of biochar application. Liu *et al*. (2020) reported that 5% loading of biochar significantly recorded the highest soybean plant height, biomass and yield compared to the control and 10% biochar. Nurmalasari *et al.* (2022) reported that 20 tons/ha of rice husk biochar increase plant height by 14.6% and 15 tons/ha increase leaves by 11.35% and number of branches by 36.65%. Contrarily however, Agegnehu *et al.* (2016) reported that plant growth will be inhibited by applying only biochar.

Table 3: Effect of Biochar on Number of Branches of Soybean during 2018 and 2019 Cropping Seasons

Treatment	2018		2019	
Biochar (tons/ ha)	8	10	8	10
0	3.0^{c}	3.8^{c}	3.1^{b}	3.7^{b}
4	3.4^{b}	4.4^{b}	3.7^{a}	4.3^{a}
8	4.5^{a}	4.5^{a}	3.6^{a}	4.4^{a}
12	2.9^{c}	3.3^{d}	3.0^{b}	3.3^{b}
LSD (0.05)	0.18	0.08	0.29	0.34

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

The results of the effect of different rates of biochar on 100 seed weight 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 g) and (14.9 g) followed by biochar at the rates of 4 tons/ha (15.4 g) and (14.2 g) in 2018 and 2019 cropping seasons respectively. The results also indicated that biochar at the rate of 0.0 ton/ha (control) recorded the lowest weight per 100 seeds of soybean (12.6 g) and (12.6 g) in both 2018 and 2019 cropping seasons. The positive response of soybean to the application of biochar may be due to the nutrient content of biochar as reported by Randon *et al.* (2007) that biochar contains plant nutrients such as P, K, Mg, and Ca, Mo and B. The results are in line with finding of Yooyen *et al.* (2015) reported that biochar at the rate of 30 tons /ha produced the highest seed weight (36.8% heavier) compared to the control. Liu *et al.* (2020) reported that 5% loading of biochar significantly recorded the highest soybean yield compared to the control and 10% biochar. Zhang *et al*. (2015) reported that average soybean yield increased by 10.1% after applying biochar. Arif *et al.* (2017) reported that biochar application increased wheat and maize grain yields by 18% and 24% respectively compared to the control. Uzoma *et al.* (2011) reported that biochar addition enhanced maize yield compared to the control. Similarly, Njoku *et al.* (2015) reported that maize grain yield were significantly ($P<0.05$) higher in plots amended with biochar than the control. On the contrarily however, Agegnehu *et al.* (2016) reported that crop yields will be reduced by applying only biochar.

Table 4: Effect of Biochar on 100 Seeds Weight (G) Of Soybean during 2018 And 2019 Cropping Seasons

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

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

The results of the effect of different rates of biochar on seed yields of soybean per hectare (Table 5) showed that biochar at the rate of 8 tons/ha recorded significantly ($p<0.05$) the highest seed yield per hectare (1304.0 kg/ha) and (1316.7 kg/ha) followed by biochar at the rate of 4 tons/ha (1180.0kg/ha) and (11867.3 kg/ha) in 2018 and 2019 cropping seasons respectively. The results also indicated that biochar at the rate of 0.0 ton/ha (control) recorded the lowest seed yield per hectare (739.0 kg/ha) and (745.0 kg/ha) in both cropping seasons. The results further showed a low response of soybean to the highest rate of biochar (12 tons/ha) as reflected in all parameters tested in both cropping seasons respectively. The positive response of soybean to the application of biochar may be due to the nutrient content of biochar as reported by Rondon *et al.* (2007) that the crop performance was largely an effect of elevated P, K, Mg, and Ca, Mo and B availability and higher pH as a result of biochar addition. The results are in line with finding of Yooyen *et al.* (2015) reported that biochar at the rate of 30 tons /ha produced the highest seed weight (36.8% heavier) compared to the control. Liu *et al*. (2020) reported that 5% loading of biochar significantly recorded the highest soybean yield compared to the control and 10% biochar. Zhang *et al*. (2015) reported that average soybean yield increased by 10.1% after applying biochar. Arif *et al.* (2017) reported that biochar application increased wheat and maize grain yields by 18% and 24% respectively compared to the control. Uzoma *et al.* (2011) reported that biochar addition enhanced maize yield compared to the control. Rondon *et al.* (2007) also reported that beans yields increased by 46% over the control at 90g/kg and 60g/kg of biochar respectively and concluded that the crop performance was largely an effect of elevated P, K, Mg, and Ca, Mo and B availability and higher pH as a result of biochar addition. Agboola and Moses (2015) reported that the 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. On the contrarily however, Agegnehu *et al.* (2016) reported that crop yields will be reduced by applying only biochar.

Table 5: Effect of Biochar on Seed Yield of Soybean per Hectare (Kg/Ha) During 2018 And 2019 Seasons

Treatment 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 biochar at the rate of 8 tons/ha positively influenced soybean growth and yield parameters evaluated respectively. However, the results showed that the highest dose of biochar (12 tons/ha) in this study did not increase any plant parameters evaluated and hence biochar at the rate of 8 tons/ha is considered as the optimum rate for sustainable soybean production in the study area.

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