

Effect of cashew (*Anacardium occidentale*) biochar on soil chemical properties and agronomy of soybean (*Glycine max L. merril*)

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ABSTRACT: The experiments were conducted at the Teaching and Research Farm, Faculty of Agriculture, Nasarawa State University, Keffi, Shabu-Lafia during the 2018 and 2019 cropping seasons to evaluate the effects of different levels of biochar on soil properties, growth and yield of soybean. 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 were incorporated into the ridges of soybean at planting. The results showed that soil organic matter, organic carbon, total nitrogen, potassium, available phosphorus, calcium, sodium and base saturation decreased with soil layers. Soil pH (4.67 and 4.69), magnesium (1.52 and 1.62 cmol/kg), exchangeable acidity (0.67 and 0.75 cmol/kg) and cation exchange capacity (5.18 and 5.23 cmol/kg) increased with soil depth. Biochar at the rate of 12 tons/ha showed consistently the highest values of soil properties over other rates. The results also showed that biochar at the rate of 8 tons/ha recorded significantly ($p < 0.05$) the tallest soybean plant height at 8 weeks (40.4 and 42.7 cm) and 10 (43.0 and 49.2 cm) after planting in 2018 and 2019 cropping seasons respectively while the highest number of branches (4.5 and 4.5) was recorded 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 seed yield (1304.0 and 1316.7 kg) per hectare in both cropping seasons. From the results of this study, it can be concluded that biochar at the rates of 12 and 8 tons/ha positively influenced soil and soybean plant parameters evaluated. Therefore, biochar at the rate of 8 tons/ha is considered as the optimum rate for sustainable soybean production in the study area.

Keywords: Biochar, evaluate, soybean seed yield, soil properties.

INTRODUCTION

The decline in soil fertility arises from continuous cultivation where levels of soil replenishment by whatever means are too low and cannot mitigate the process of soil nutrient mining whereby the soil fertility is not restored by new inputs (Shisanya *et al.*, 2009). Nigeria soils are characterized with coarse texture, low activity clay and harsh climatic conditions which often result in leaching, erosion and low organic status (Oladipo *et al.*, 2012).

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 (Schmidt and Wilson, 2014). It is one of the oldest soil amendments in the history of agriculture (Wilson, 2014b). Biochar improves soil's physical, chemical and biological properties, increases soil organic carbon, organic matter and total nitrogen (Glasser *et al.*, 2002; Lehmann, 2007; Warnock *et al.*, 2007; Zhang *et al.*, 2010; Beck *et al.*, 2011). It releases plant nutrients and raises soil pH value (Schmidt and Wilson, 2012). Khan *et al.* (2018) reported that biochar treated soils showed higher cation exchange capacity, organic carbon, exchangeable potassium and available phosphorus than the corresponding biomass untreated ones.

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 fibre, 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 Saxena, 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; Fairhurst, 2012). The decomposed leaves of soybean improve soil fertility (Fairhurst, 2012). Soybean grown in rotation with cereals crops serves as catch crop in controlling weeds especially *Striga hermonthica* in maize farms (Dugje *et al.*, 2009).

Local production and uses of biochar has been mostly for energy and fuel purposes only but its use as soil amendment material for maintaining and improving soil fertility for sustainable agricultural and crop production has not received much attention from the farmers. Besides there are 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 but biochar has not been used as a soil amendment for the cultivation of soybean in the study area. Hence, the need for this kind of study to encourage local farmers to use cheap and available biochar for sustainable soil fertility management to increase crop production in the study area. Therefore, this study aimed at evaluating the effect of biochar on soil properties, growth and yields of soybean in the Southern Guinea Savanna of Nigeria.

MATERIALS AND METHODS

Description of the experimental site

The experiments were conducted at the Teaching and Research Farm, Faculty of Agriculture, Nasarawa State University, Keffi, Shabu-Lafia during the 2018 and 2019 cropping seasons. The study area is located between latitude 08°29'30" N and longitude 08° 31'0" E, which falls within the Southern Guinea Savannah zone of Nigeria. Rainfall usually starts in April and ends in October. Lafia generally has a mean annual rainfall range between 1100 and 2000 mm (NIMET 2021). The soil of Lafia is derived mainly from the basement complex and old sedimentary rocks (Jayeoba, 2013).

Soil sampling and analysis

A composite soil samples from 0-15 cm and 15-30 cm depth were taken randomly at six (6) different locations of the experimental field before ridging and another soil

samples were taken (0-15 cm and 15-30 cm depth) from each treatment after harvest. All the soil 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, 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. The value of organic carbon 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 the extract by using atomic absorption spectrometry (AAS) (Buck Scientific Model 210), while 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 preparations

Biochar was made locally using cashew woods which were arranged and covered with earth and the fire was set through four small openings to allow in little air. The fire was quenched after about 4-5 hours with water. The soybean genotype planted was (TGX 1951-3 F).

Experimental design and treatment

The experiments were laid out in Randomized Complete Block Design (RCBD) with three replications. Four (4) ridges of 2 m long spaced at about 75 cm were made manually using local hoes. The gross plot size was 3 m X 2 m (6 m²) while the net plot size was 2 m X 1.5m (3 m²). Biochar was crushed into pieces and incorporated into ridges at planting at the rates of 0.0, 1.2, 2.4 and 3.6 g/plot (0, 4, 8 and 12 tons/ha) while four seeds of the soybean (TGX 1951-3 F) were planted per hole at 5 cm spacing. The seedlings were thinned to two after two weeks of planting.

Statistical analysis

All data obtained on plant height, number of branches, 100 seed weight and seed yield were subjected to analysis of variance (ANOVA) using GENSTAT statistical package while least significant difference (LSD) was used to separate the treatment means at 5% levels of probability.

Table 1. Physico-chemical properties of soil of the experimental site before experiment, 2018

Parameter	Soil depth (mean values)	
	0-15 cm	15-30 cm
Soil parameter		
p _H (H ₂ O)	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) (cmol/kg)	0.67	0.75
Total exchangeable bases (%)	4.51	4.48
Cation Exchange Capacity (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

RESULTS AND DISCUSSION

Physico-chemical properties pre biochar treatment of soil

The soil properties of the experimental site (Table 1) showed that the soil pH (4.67 and 4.69) and organic matter content (3.04 and 2.97%) 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 ppm) were very low at surface and subsurface soil layers respectively. 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 soil was sandy loam. This is in line with the report of Chude *et al.* (2012) who rated and classified the soil nutrient status of the Southern Guinea Savanna of Nigeria as very low, low, moderate and high depending on the type of nutrients.

The results also showed that soil properties decreased from the surface to the subsurface soil layer (Table 1). This is in line with the findings of Adam *et al.* (2019), Hayatu *et al.* (2019), Popoola and Mgbonu (2018), Yakub and Mallo (2018), and 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. The results further showed that the available phosphorus, magnesium, exchangeable acidity and cation exchange capacity increased with soil depth. This however contradicts the findings of Adam *et al.* (2019), Hayatu *et al.* (2019), Popoola and Mgbonu, (2018), Yakub and Mallo, (2018), and 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).

The decreased values in some soil properties down the soil depth 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. Adam *et al.* (2019) and Dikko *et al.* (2010) attributed this to sparse vegetation, bush burning, removal of crop residues, nutrient uptake by plants and volatilization of some nutrient due to high temperature at the surface soil.

Physico-chemical properties of the soil

The soil properties of the experimental site after the

Table 2. Effect of different rate of biochar on soil properties 2019.

Soil parameter	Soil Depth (cm)							
	0---15cm				15---30cm			
	B ₁	B ₂	B ₃	B ₄	B ₁	B ₂	B ₃	B ₄
pH(H ₂ O)	5.57	4.61	4.90	5.66	5.61	4.12	4.91	5.38
Organic Carbon (%)	1.70	1.71	1.75	1.74	1.69	1.71	1.75	1.74
Organic Matter (%)	2.92	2.94	3.02	2.99	2.91	2.94	3.02	2.99
Total Nitrogen (%)	0.63	0.07	0.14	0.42	0.56	0.07	0.14	0.28
Available (P) (ppm)	2.45	1.90	0.18	2.54	2.48	1.83	1.83	2.10
Potassium (K)(cmol/kg)	0.16	0.11	0.11	0.21	0.17	0.10	0.10	0.18
Calcium (Ca)(cmol/kg)	2.43	2.08	2.09	2.58	2.50	1.89	1.89	2.26
Magnesium (Mg)(cmol/kg)	1.39	1.13	1.17	0.11	1.45	1.17	1.17	1.87
Sodium (Na)(%)	0.12	0.08	0.08	0.20	0.14	0.07	0.07	0.09
Exchangeable acidity (EA) (cmol/kg)	1.00	1.17	1.17	0.83	0.83	1.17	1.17	1.00
Total exchangeable bases (TEB) (%)	4.10	3.40	3.45	5.10	4.53	3.23	3.74	4.40
Cation exchange capacity (CEC) (cmol/kg)	5.10	4.57	4.62	5.93	5.36	4.40	4.91	5.40
Base saturation (%)	84.40	74.40	74.70	86.00	84.50	73.40	89.30	81.50
Sand (%)	90	88	86	88	90	88	86	88
Silt (%)	3.40	440	5.40	4.40	3.40	4.40	5.40	4.40
Clay (%)	6.60	8.60	8.60	8.60	6.60	8.60	8.60	8.60
Textural class	Sandy loam				Sandy loam			

B₁, B₂, B₃, B₄= 0, 4, 8 and 12 tons of Biochar/hectare.

experiments (Table 2) showed that biochar at the rates of 12 tons/ha had the highest soil pH (5.66 and 5.38), the highest total nitrogen percentage (0.42 and 0.28%), highest phosphorus (2.54 and 2.10 ppm), the highest values of potassium (0.21 and 0.18 cmol/kg), highest values of calcium (2.58 and 2.26 cmol/kg), the highest values of magnesium (0.11 and 1.87 cmol/kg), the highest values of sodium (0.20 and 0.09%), the highest total exchangeable base (5.10 and 4.40%) and the highest values of cation exchange capacity (CEC) (5.93 and 5.40 cmol/kg) at the surface and subsurface soil layers respectively. The results also showed that biochar at the rate of 8 tons/ha recorded the highest percentage organic matter (3.02) and percentage base saturation (89.30) while biochar at the rate of 0.0 tons/ha (control) recorded the lowest soil properties at both surface and subsurface soil layers.

The increased in soil pH as a results of increased biochar rates may be attributed to the alkaline nature of the biochar which might have buffered and reduced soil acidity as reported by Blanco-canqui, (2017), Jha *et al.* (2016) and Shi *et al.* (2018). Jien and Wang (2013) also attributed the change in the soil reaction from strongly acidic to slightly acidic with increasing application rates of biochar to the high liming potential of biochar. Ilori *et al.* (2020) reported that biochar amended soil had higher soil pH values than the other treatments without biochar and attributed the increase in soil pH to the alkaline nature of the biochar. Ilori *et al.* (2020) concluded that biochar may be used as liming material. Knox *et al.* (2015) also reported that soil

pH increased from 5.9 to 7.3 as a result of the addition of biochar to soil. Nigussie *et al.* (2012) reported that the highest mean values of pH were recorded in soils treated with 10 t/ha biochar while the lowest values were recorded at the control (0.0 t/ha). Similarly, Uzoma *et al.* (2011) reported a significant positive linear relationship between cow manure biochar rate and soil pH and that with biochar at 20 t/ha, soil pH increased from 6.4- 8.0 on a sandy soil. Ndor *et al.* (2019) reported that the application of rice husk biochar significantly increased soil pH and all other soil chemical properties but decreased exchangeable acidity. Onwuka and Onwuka (2019) also reported that the application of 5 and 6 tons/ha of biochar significantly increased soil pH and raised exchangeable calcium but reduced exchangeable acidity.

The improvement in some soil properties of the treated plots against untreated ones could be explained that biochar contains plant nutrients and high ash content which were primarily responsible for the improvement and modification of soil chemical properties in the study area according to Ndor *et al.* (2019) who reported that increased biochar rates increased soil pH probably due to high ash concentration and that the general improvement in N, P and K and may also be due to the increased solubility of plant nutrients in the soil as a result of lowering the soil acidity. Biochar increases bio-available P and increases the availability of major cations, total N and P that are responsible for soil fertility (Lehmann *et al.*, 2003; Liang *et al.*, 2006; Peng *et al.*, 2011; Yusuf *et al.*, 2016). Biederman and Harpole (2013) also reported an increase in soil

Table 3. Effect of biochar on soybean plant height during 2018 and 2019 cropping seasons.

Biochar (tons/ha)	2018		2019	
	Weeks after planting		Weeks after planting	
	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.

phosphorus, potassium, total nitrogen and organic carbon with biochar addition compared to the control. Yusif *et al.* (2016) reported significant differences in soil pH, organic carbon, nitrogen, phosphorus and calcium among biochar rates with 20 tons/ha of biochar producing the highest values compared with 10 tons/ha and 0.0 tons/ha (control).

Plant height

The results of the effects of different rates of biochar on soybean plant height showed that biochar at the rate of 8 tons/ha produced significantly ($p < 0.05$) the tallest soybean plant height (40.4 cm) and (48.0 cm) followed by biochar at the rate of 4 tons/ha (40.0 cm) and (46.6 cm) at 8 and 10 weeks after planting (WAP) respectively in 2018 cropping season (Table 3). The results of the 2019 cropping season showed a similar pattern to that of the 2018 cropping season. The results also indicated that biochar at the rate of 12 tons/ha recorded the shortest soybean plant height at 8 and 10 WAP in both the 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 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 the findings 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. 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. Nirmalasari *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. Similarly, Njoku *et al.* (2015) reported that maize grain yield were

significantly ($p < 0.05$) higher in plots amended with biochar than the control. Agegnehu *et al.* (2016) reported that plant growth will be inhibited and crop yields reduced by applying only biochar contrary to the results of this study

Number of branches

The results of the effects of different rates of biochar on number of branches per soybean plant 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 (Table 4). 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 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. 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 90 g/kg application of biochar. 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. 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

Table 4. Effect of biochar on number of branches per soybean plant during 2018 and 2019 cropping seasons.

Biochar (tons/ ha)	2018		2019	
	Weeks after planting		Weeks after planting	
	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% probability.

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%. Similarly, Njoku *et al.* (2015) reported that maize grain yield were significantly ($p < 0.05$) higher in plots amended with biochar than the control. Contrarily, Agegnehu *et al.* (2016) reported that plant growth will be inhibited and crop yields reduced by applying only biochar.

Seed weight

The results of the effect of different rates of biochar on 100 seed weight of soybean (Table 5) 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 2018 and 2019 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) who 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 plant height, biomass and yield compared to the control and 10% biochar. Zhang *et al.* (2010) 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.

Agegnehu *et al.* (2016) reported that plant growth will be inhibited and crop yields reduced by applying only biochar, contrary to the results of this study.

Seed yield

The results of the effect of different rates of biochar on seed yields of soybean per hectare (Table 6) 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 (1180.0 kg/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 low response of soybean to the highest rate of biochar application (12 tons/ha) in this study as reflected in all parameters tested 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 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. Rondon *et al.* (2007) also reported that beans yields increased by 46% over the control at 90 g/kg and 60 g/kg of biochar. The results are also in line with findings of Yooyen *et al.* (2015) who 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 plant height, biomass and yield compared to the control and 10% biochar. Zhang *et al.* (2010) 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. Agboola and Moses (2015) reported that the application of biochar increased yield of soybean significantly. Chan *et al.* (2007)

Table 5. Effect of biochar on 100 seeds weight (g) of soybean during 2018 and 2019 cropping seasons.

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.

Table 6. Effect of biochar on seed yield of soybean per hectare (kg/ha) during 2018 and 2019 seasons.

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

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

also reported that the application of biochar and nitrogen fertilizer increased dry matter production by 266% of biochar without N-fertilizer. Similarly, Njoku *et al.* (2015) reported that maize grain yield were significantly ($p < 0.05$) higher in plots amended with biochar than the control. Agegnehu *et al.* (2016) reported that plant growth will be inhibited and crop yields reduced by applying only biochar, contrarily to the results of this study.

Conclusion and Recommendation

From the results of this study, it can be concluded that biochar at the rates of 12 and 8 tons/ha positively influenced soil and soybean plant parameters evaluated respectively. However, the results showed that the highest dose of biochar (12 tons/ha) did not increase any soybean plant parameters evaluated and hence biochar at the rate of 8 tons/ha is considered the optimum rate for sustainable soybean production in the study area. Although the 12 tons/ha of biochar positively influenced soil physico-chemical characteristics but might have made the soil too alkaline for the crop performance.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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