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AMELIORATIVE EFFECT OF BIOCHAR ON GROWTH, NODULATION AND YIELD OF GROUNDNUT (*Arachis hypogaea* L.) GROWN IN ACIDIC SOIL OF DABAGI AREA, SOKOTO STATE, NIGERIA

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ABSTRACT

This research was conducted at screenhouse, Department of Biological Sciences, Usmanu Danfodiyo University, Sokoto to determine the ameliorative effects of biochar on the growth, nodulation and yield of groundnut (*Arachis hypogaea* L.) grown in acidic soil. The research consisted of eight treatments (0, 10, 20, 30, 40, 50, 60 and 70t/ha) of biochar rates. The biochar rates were applied and mixed thoroughly in a rubber bucket containing 5kg of acidic soil 2 weeks prior to sowing. The treatments were replicated three times in a completely randomized design (CRD) and SAMNUT 24 was used as the test crop. Growth parameters (plant height and number of leaves) were taken at 2 weeks interval after sowing. Nodulation count, shoot and root dry weight were also taken at 6 weeks after sowing (WAS). Similarly, yield parameters (number of pods and number seeds) were taken after harvest. The data obtained were subjected to analysis of variance (ANOVA) and significant differences among the means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of significance. The result showed that biochar application significantly ($p<0.05$) increased plant height at 6 and 8 WAS, number of leaves at 4, 6 and 8 WAS, root dry weight at 6 WAS. The application of 20 and 40 t/ha of biochar were found to produced taller plant. 60 and 70 t/ha were found to increased number of leaves, shoot dry weight and pod yield per plant.

Keywords: Biochar; acidic; groundnut; growth parameters; yield parameters

INTRODUCTION

Soil acidity is a major problem for agricultural productivity worldwide (Van Straaten, 2007; Brady and Weil, 2002). Soil acidity reduced 30-40% of the world arable land crop production (Brown *et al.*, 2008). The term soil acidity is largely associated with the presence of hydrogen and aluminum ions in exchangeable forms (Brady and Weil, 2002). Soil acidity is a major constraint to crop production on tropical soils due to toxic levels of aluminium (Al) and the concomitant phosphorus (P) deficiency that hinder plant growth (Kisinyo *et al.*, 2005). Higher concentrations of these ions in soil solution, the higher the acidity. The soil acidity results generally to low soil fertility and consequently poor crop growth and low yield (Fageria and Baligar, 2008). These negative effects on crop production in acidic soil may be due to the combined factors such as the toxicities of Al, Mn and H ions coupled with the deficiencies or the unavailability of P, Ca, Mg and Mo (Yost, 2000). In most cases nutrients availability is related to soil pH in which soils with low pH (<5.5), have low calcium, magnesium and phosphorus availability, and invariably reduce plant growth and productivity (Cerozi and Fitzsimmons, 2016).

Biochar amendments can decrease aluminum toxicity in soils leading to increase root penetration that allows the uptake of nutrients from soil solution (Lehmann and Joseph, 2009). Deal *et al*. (2012) tested several kiln-fired and gasified biochars on a strongly acidic soil and found that the gasified biochar with its higher ash content had a beneficial liming effect that improved growth and nutrients availability. The positive effect of biochar on crop production may be due to pH and CEC increases and changes in the physical properties of the soils, rather than the nutrients associated with the biochar per se (Chan *et al*., 2007). Other studies reported that biochar application to acidic soils increases the pH, plant growth and yield of maize and peanut plants (Yamato *et al*., 2006; Martinsen *et al*., 2015; Chan *et al*., 2008). It was also observed that application of biochars to acidic soil increases its sorption capacity for nutrients (Sohi *et al*. 2010) and reduces the exchangeable acidity.

To increase groundnut yields and reduce crop production risks associated with soil acidity, there is need to focus on soil amendment practice using biochar that could improve nutrients bioavailability and increase the pH of the soil. The use of biochar does not only improve soil production but also stabilized yield over time, improves microbial status and hence their activities in the soils (Krishnakumar *et al*., 2014). However, information on biochar rate that could raise the pH in the study area is inadequate and hence the need to find out biochar rate that could ameliorate the effect of soil acidity as well as performance of groundnut in the study area. Hence, this study aimed to find the ameliorative effect of biochar on growth nodulation and yield of groundnut in acidic soil.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at the screenhouse, Department of Biological Sciences, Usmanu Danfodiyo University, Sokoto. Sokoto state is located in the extreme north western Nigeria, near the confluence of the Sokoto River and Rima River. Sokoto state is situated between latitude 13º 8′ 30″ N and 13º 7′ 0″ N and Longitude 5º 11′ 30″ E and 5º 14′ 30″ E having altitude of 350 m above the sea level (GIS, 2016). Sokoto has a minimum temperature range between 19 to 27º C and maximum temperature range between 30 to 40º C. Hot, semi-arid with long dry season characterized by cool dry air during harmattan around November to February and hot dry air during hot season from March to May, with short rainy season ranging from June to October. Relative humidity ranges from 19 to 29% in the dry season and wind direction is generally from the north-westerly in the dry season and south-westerly in the wet season and wind speed range between 1.7 and 4.0m/s (NMAS, Sokoto, 2014).

Source of Biochar

The biochar used for this research was sourced from Labana Rice Mill, Birnin-Kebbi, Kebbi State. The biochar was produced in Labana using rice husk at an average temperature of 25-30^{o}C for 45 minutes to 1 hour. The chemical properties of biochar were determined which includes: pH, organic carbon, available P, N, and exchangeable bases (Mg K, Na and Ca) and CEC.

Experimental Design and Layout

Acidic soil was collected at a depth of 0-15 cm from research site of Center for Agricultural and Pastoral Research (CAPAR), Dabagi, Usmanu Danfodiyo University, Sokoto. The experiment was laid out in a Completely Randomized Design (CRD) and replicated three times. The biochar was applied two weeks before sowing in buckets containing 5kg of acidic top soil (thoroughly mixed) at the rates of 0, 10, 20, 30, 40, 50, 60 and 70 t/ha which correspond to 0, 25, 50, 75, 100, 125, 150, 175 g per 5kg respectively. Hence, a total of 24 plastic buckets were used for this experiment. SAMNUT 24 was used as test crop.

Data Collection

The following agronomic data were collected:

Number of leaves per plant

Number of leaves per plant was determined by counting the number of leaves manually on the plant at 2, 4, 6 and 8 weeks after sowing (WAS).

Plant height per plant (cm)

Plant height was measured from the base to the apex of the plant using meter rule at 2, 4, 6 and 8 WAS.

Number of nodules per plant

One of the two plants in the bucket was used for destructive sampling at 6 WAS. This plant was gently uprooted manually and the number of nodules was counted manually.

Shoot and root dry weights per plant (kg/ha)

Root and shoot dry weights were obtained at 6 WAS by oven drying the fresh shoot and root biomass at 60 ^{0}C for 24 hrs and was extrapolated to per hectare basis.

Number of pods per plant

At harvest the number of pods per plants were counted.

Number of seeds per plant

Seeds per plants were recovered and counted from the pods obtained above after shelling.

Data Analysis

The agronomic data collected were subjected to analysis of variance (ANOVA) techniques. The significant means were separated using Duncan's Multiple Range Test (DMRT) at 5% level of significance.

RESULTS AND DISCUSSION

Chemical Properties of Soil and Biochar Used for the Study

The pre-sowing analyses of the soil and biochar used for this experiment were presented in Table 1. The pH of the soil was 5.02, available phosphorus was 1.14mg/kg, percentage organic carbon was 1.42%, percentage nitrogen was 0.025% and cation exchange capacity was 1.92 cmol/kg and were rated as strongly acidic, very low, low, low and low respectively (Landon, 1984; Enwezor *et al*., 1989 and Esu, 1991). The exchangeable bases of the soil viz.; Ca was 0.55 cmol/kg (0-2 cmol/kg), Mg was 0.50 cmol/kg (0.3-1.0ccmol/kg), K was 0.10 cmol/kg (0-0.15 cmol/kg) and Na was 0.17 cmol/kg (0.1-0.3 cmol/kg) and were rated as low, medium, low and medium respectively (Enwezor *et al*., 1989).

The pH of the biochar was 8.14, available phosphorus was 1.53mg/kg, percentage organic carbon was 7.78%, percentage nitrogen was 0.280% and cation exchange capacity was 10.16 cmol/kg and were rated as moderately alkaline, low, medium, medium and medium respectively (Landon, 1984; Enwezor *et al*., 1989 and Esu, 1991). Similarly, the exchangeable bases of the biochar viz.; Ca was 0.50 cmol/kg, (0-2 cmol/kg), Mg was 0.85 cmol/kg (0.3-1.0 cmol/kg), K was 5.83 cmol/kg (>0.3 cmol/kg) and Na was 2.18 cmol/kg (>0.3 cmol/kg) and were rated as low, medium, high and high respectively. (Enwezor *et al*., 1989).

Table 1: Chemical properties of soil and biochar used for the study

Properties	Soil	Biochar
pH	5.02	8.14
P (mg/kg)	1.14	1.53
OC (%)	1.42	7.78
N (%)	0.025	0.280
Exchangeable bases (cmol/kg)		
Ca	0.55	0.50
Mg	0.50	0.85
K	0.10	5.83
Na	0.17	0.18
CEC	1.92	10.16

O.C = Organic carbon, N = Nitrogen, P = Phosphorous, Ca = Calcium, Mg = Magnesium, Na = Sodium, CEC = Cation exchange capacity

Effect of Biochar on Plant Height

Biochar application at the rates assayed had no significant difference on plant height of groundnut at 2 and 4 weeks after sowing (WAS), but significant difference ($P \leq 0.05$) was found at 6 and 8 WAS (Table 2). At 6 WAS, biochar rates of 10, 20 and 30 t/ha produced significantly taller plants than the other biochar rates, but statistically produced the same with control and 40 t/ha of biochar rates. Meanwhile at 8 WAS, 40 t/ha of biochar rate significantly produced taller plant followed by 20 and 30 t/ha of biochar rates which is statistically produced the same with 0, 10 and 70 t/ha of biochar rates. Similar result was also observed by Alkali *et al.* (2018) who reported that biochar application had significant effect on plant height of groundnut at 6 and 8 WAS due to it positive effect in supplying essential nutrients.

The non significant difference in plant height among biochar rates at 2 and 4 (WAS) could be due to the slow nature of biochar in releasing nutrients at the beginning of the experiment. The non-significant difference observed in plant height at 2 and 4 WAS is in agreement with Yusif *et al.* (2016) who reported that there was no significant difference in plant height among biochar rates of groundnut.

Table 2: Effects of Biochar on plant height per plant

	Plant height (cm)			
Biochar rates (t/ha)	2 WAS	4 WAS	6 WAS	8 WAS
0	16.73	35.37	40.70^{ab}	45.50^{abc}
10	17.87	37.83	44.80^{a}	49.17^{ab}
20	17.17	36.37	45.03^{a}	50.60^{a}
30	16.57	34.17	44.57^{a}	50.20^{a}
40	17.83	34.97	41.17^{ab}	50.63^{a}
50	14.73	34.47	38.93^{b}	42.63^{c}
60	14.33	36.43	39.50^{b}	44.07^{bc}
70	16.07	36.20	39.67^{b}	46.47^{abc}
SE ±	0.40	0.57	0..67	0.82
Significance	ns	ns	*	*

Means within the same column with the same letters are not significantly different according to Duncan Multiple Range Test at ($p < 0.05$), WAS = weeks after sowing, SE = Standard error, ns = Not significant, * = Significant at ($P < 0.05$)

Effect of Biochar on Number of Leaves per Plant

Biochar application had no significant ($P<0.05$) difference on the number of leaves of groundnut at 2 WAS, but significant ($P <0.05$) difference was observed at 4, 6 and 8 WAS (Table 3). At 4 WAS, 70 t/ha rate of biochar gave the highest number of leaves (69 / plant) when compared with control (43/plant) but statistically comparable with 40, 50 and 60 t/ha of biochar rates. Meanwhile, at 6 WAS, 70 t/ha rate of biochar gave the highest number of leaves (78.00 / plant) followed by 60, 50, 40 and 10 t/ha while 20 t/ha and control gave the lowest number of leaves (51.33/ plant and 52.00/ plant, respectively). At 8 WAS, 60 t/ha rate of biochar gave the highest number of leaves (78 / plant) which is statistically comparable with 50 and 70 t/ha. The number of leaves per plant increased with increasing biochar rates. Increase in the number of leaves under the influence of biochar application observed in this research, could be attributed to biochar potential in supplying the essential nutrients that facilitate plant growth by improving the physical, chemical and biological soil properties. This is in agreement with Carter *et al.,* (2013) who stated that biochar addition was found to increase the number of leaves of lettuce plant when compared with control.

Table 3: Effect of biochar on the number of leaves per plant

	Number of leaves / plants			
Biochar rates (t/ha)	2 WAS	4 WAS	6 WAS	8 WAS
0	20.67	43.33^{c}	52.00^{d}	57.33^{b}
10	22.00	54.00^{bc}	62.00^{bcd}	65.67^{b}
20	21.67	44.00^{c}	51.33^{d}	60.67^{b}
30	22.00	44.00^{c}	58.67^{cd}	65.33^{b}
40	24.67	56.76^{abc}	64.00^{bcd}	63.33^{b}
50	21.00	62.00^{ab}	68.00^{abc}	76.67^{a}
60	22.00	60.00^{ab}	73.33^{ab}	77.67^{a}
70	24.00	69.33^{a}	78.00^{a}	77.00^{a}
SE ±	0.51	2.31	2.23	1.82
Significance	ns	*	*	*

Means within the same column with the same letters are not significantly different according to Duncan Multiple Range Test at (*P> 0.05*), WAS = weeks after sowing, SE = Standard error, ns = Not significant, * = Significant at P < 0.05

Effects of Biochar on Number of Nodules, Shoot and Root Dry Weight

There was no significant (P>0.05) differences recorded in the biochar rates of application on the number of nodules at 6 WAS, although treatment with 0 t/ha and 50 t/ha produced the highest number of nodules (Table 4) when compared with other treatments. From the result, it could be seen that the number of nodules decreases with increasing rate of biochar. This is in agreement with the result of Agboola and Moses (2015) who reported that the number of nodules decreases with increasing rates of biochar. Table 4 also showed the effect of biochar on shoot and root dry weight. Biochar application had no significant (P>0.05) differences on the shoot dry weight of groundnut per plant, though 70t/ha and 50t/ha rates of biochar produced the highest values in shoot dry weight. Increased in shoot dry weight among biochar observed in this research was similar with that of Warnock (2004) and Chan *et al.,* (2008) who reported that biochar application increased shoot dry weight even at the lowest rate. There was also significant (P<0.05) difference in root dry weight per plant (Table 4) as a result of the application of biochar. However, control and 10 t/ha produced the highest root dry weight respectively. Root dry weight decreased with increasing in biochar rates. Decrease in the root dry weight with increasing biochar rates observed in this research may be attributed to the translocation of nutrients (N, P, K, etc) to the above biomass than underground biomaas coupled with the slow attribute of biochar in releasing essential nutrients which may in long term shows the differences among the application rates (Singha *et al*., 2019). Similar result was reported by Singha *et al*. (2019) that increasing the biochar rates decreased the root dry weight of Winter wheat (*Triticum aestivum* cv. Isengrain) in Bangladesh. Also, Bayan (2013) reported that increase in the biochar rates, decreased the root dry weight of soybean.

Table 4: Effects of biochar on number nodules, shoot and root dry weights at 6 WAS

Rates of biochar(t/ha)	Number of nodules	Shoot Dry Weight (kg/ha)	Root Dry Weight (kg/ha)
0	30.00	1572	188[a]
10	26.33	1680	132[ab]
20	21.67	1520	68[b]
30	15.67	1730	80[b]
40	22.67	1628	92[b]
50	30.00	1800	108[b]
60	16.33	1332	108[b]
70	29.33	1936	92[b]
SE ±	2.10	266.8	20.5
Significant	ns	ns	*

WAS = weeks after sowing, Means within the same column with the same letters are not significantly different according to Duncan Multiple Range Test at (*$p<0.05$*), WAS = weeks after sowing, SE = Standard error, ns = Not significant, * = Significant at *$p<0.05$*

Effects of Biochar on Pod Yield and Number of Seed per Plant

Table 5 showed that biochar amendment had no significant ($P \leq 0.05$) difference on the number of pods of groundnut among the biochar rates. However, 70t/ha rate of biochar gives the highest number of pods (13 / plant) when compared with other biochar rates. Also, Biochar application did not significantly increase number of seeds of groundnut per plant at 5% level of significant (Table 5). The non significance in both pod yields and number of seed observed in this research could be attributed to the fact that the duration of the research was short to influence the pod yields and number of seeds (Major *et al*., 2010). The non significant in the pods yield and number seeds per plant in this research was in accordance with Agboola and Moses (2015) who reported that there were no significant differences in the pod yield and number of seeds of pea in response to biochar application. This finding is also in agreement with the findings of Major *et al*. (2010) who reported that application of biochar on maize grain yield had no significant effect in the first year; however, in subsequent years, maize yield increased with increasing biochar rate, and the positive effect of biochar was most prominent in the third year after application.

Table 5: Effects of biochar on pod yield and number of seeds per plant

Biochar rates (t/ha)	Pod yield (t/ha)	Total Seed count (t/ha)
0	3732	3868
10	4268	4956
20	3600	3732
30	4932	3732
40	3600	3600
50	4800	5332
60	5068	4268
70	5152	4800
SE ±	290	347
Significance	ns	Ns

WAS = weeks after sowing, SE = Standard error, Means within the same column with the same letters are not significantly different according to Duncan Multiple Range Test at (*$p<0.05$*), ns = Not significant, * = Significant at *$p<0.05$*

CONCLUSION

This study indicated that biochar has the potential to significantly increase growth of groundnut in acidic soil. It is therefore concluded that application of biochar in acidic soil increased plant height, number of leaves, shoot dry weight and number of nodules.

It is recommended that long term studies should be conducted in field so as to determine the optimum level of application required for optimum production of groundnut in acidic soil. It is also recommended that further studies should also be conducted to determine the combine effects of biochar and fertilizer on the growth and yield of groundnut in acidic soil in order to achieve meaningful production of the crop.

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