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Growth response of soybean (*Glycine max* L.) varieties in biochar-amended typical alfisol in Lafia, Nasarawa State, Nigeria

B.P. Mshelmbula[1*], H.A. Hussaini[1], H.A. Kana[1], S.T. Akinyosoye[2]

[1]Department of Plant Science and Biotechnology, Federal University of Lafia, PMB 146, Lafia, Nigeria
[2]Institute of Agricultural Research and Training, Obafemi Awolowo University, PMB 5029, More Plantation, Ibadan, Nigeria

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Abstract. *In Lafia, Nasarawa State, a study was conducted to assess the growth response of Soybean (Glycine max) genotypes cultivated with Rice Husk Biochar. Two genotypes, T.G.S 1448 and T.G.S 1449, provided by the State's Nasarawa Agricultural Development Program (NADP), were used. The experiment was conducted using three replicates in a Complete Randomized Block Design (CRBD). Four levels of rice husk Biochar were used in the treatments: 0, 60, 120, and 180 g/pot. The TGS1448 genotype, when subjected to the 180g biochar treatment (B180g), had the highest number of leaves (70.33), significantly more than the control which had the fewest leaves (56.00), and the other treatments. The variety TGS1449 exposed to biochar treatment B180g had the maximum plant height (59.33cm), which was substantially higher than the control (50.60 cm) and the other treatments. The same pattern was seen in the TGS1448 variety when it was subjected to the biochar treatment B180g. After 9 weeks, plants with 180g biochar-amended soil produced 11 seeds per plant, whereas control plants did not produce pods or seeds. The study concluded that the addition of biochar to the soil significantly enhanced plant growth in the growth-restricted alfisol.*

Keywords: soybean, biochar, variety, soil, growth, Lafia

Introduction

Due to its nutritional and economic value, as well as its variety of domestic uses, the production of soybean (*Glycine max* L.) in Nigeria has increased. Soybean, being the most nutritious and easily digested bean, is one of the richest and cheapest sources of protein, attributed to its high income-elasticity. Soybean production in Nigeria is predicted to reach 467 thousand metric tons in 2021. Between 2010 and 2021, the country's soybean crop production rose, with the greatest significant increase in 2011, when production increased by about 25% over the previous year. In recent years, production has remained consistent. In Nigeria, demand for soybean has surged due to the rapid growth of the poultry and food processing industries during the last decade (Sasu, 2022).

The crop may be successfully cultivated in many Nigerian states with little agricultural input, and production has increased as a result of its nutritional and economic importance, as well as its numerous household uses. It also serves as a key source of vegetable oil in the global market. On a dry matter basis, the seeds contain roughly 20% oil, which is 85% unsaturated and cholesterol-free.

When alternated with maize, the soybean's capacity to act as a cover crop also provides a low-cost alternative to synthetic fertilizers for improving soil fertility and productivity (Yooyen et al., 2015). Soybean (*Glycine max* L.) is the most important source of oil and protein in the world. It has the highest protein level of any food crop and, among food legumes, is only second to groundnut in terms of oil content (Singh et al., 2008). Soybean has traditionally been widely farmed in Nigeria's middle belt or Savannah Zone (Glaser et al., 2001). It has been identified as a benchmark nitrogen-fixing legume, capable of symbiotically fixing up to 180 kg/ha, with 80 percent of the crop harvested as beans (Singh et al., 1998).

*e-mail: barkapeter5@gmail.com

It is anticipated that cultivation and output will expand as more farmers become aware of the crop's potential. Soil amendment measures are typically created in order to improve production. This is especially true in places with poor soil conditions (Gaunt and Cowie 2009; Ikhajiagbe, 2010; Ikhajiagbe et al., 2017). To boost microorganism activity, a variety of items such as sawdust, plant waste, peat, manure, and fertilizers are added. When added to soil, this amendment improves physical qualities such as water retention, permeability, water infiltration, drainage, aeration, and structure (Davis and Wilson, 2005; Gaunt and Lehmann, 2008; Ikhajiagbe, 2010). Biochar is the amending material in this study.

Biochar is a type of charcoal made by pyrolysis of agricultural products (typically wood, plant residues, manure, and food waste) burned under low nitrogen conditions and used as a cooking fuel (Major, 2011). However, one of the most significant differences between biochar and charcoal is that biochar is made with the intention of being incorporated. It is sown into the soil to trap carbon and improve soil quality. Biochar has been shown to improve soil fertility and quality by reducing soil acidity, increasing moisture holding capacity, and attracting more beneficial fungi and microorganisms when used as a soil amendment. It improves Cation Exchange Capacity (CEC) and enhances nutrient retention in the soil (Lehmann et al., 2006). Another major benefit associated with the use of biochar as a soil amendment is the ability to sequester carbon from the atmosphere and transfer it into the soil (Guant and Lehmann, 2007).

Consequently, in their comparative study of soil properties in the Lafia Region of Nasarawa State, Yusufu and Abenu (2019) recommended the poor nature of most soils, which is a major agrarian community. Onwuka et al. (2020) also showed low fertility status of the investigated soils. Yusufu and Abenu (2019) thus recommended in their comparative study of soil properties in Lafia Region, Nasarawa State, that it was necessary to improve soil nutrients in these areas to promote continuous farming through combined use of crop soil amendments and sustainable cropping systems.

Therefore, the primary aim of this study was to assess the response of various soybean (*Glycine max* L.) varieties grown in biochar-amended soil in Lafia.

Material and methods

Description of the study area

The study was carried out at the Student Farm of the Department of Plant Science and Biotechnology, Federal University of Lafia, Nasarawa State (Guinea Savanna Zone of North Central Nigeria; Latitude 8.51667°E, and Longitude 8.4916°N).

Experimental procedure

Topsoil samples were taken at depths of 0-15cm and 15-30cm from the study area at random. Subsequently, both soil samples were pooled together as no significant differences in their properties were found (Table 1). The experiment utilized 24 pots, each containing 5kg of sun-dried soil. Then there was a pre- and post-soil analysis (Ndor et al., 2016). To make biochar, rice husk material was taken from a rice mill in Lafia. An improvised kiln was made of an empty drum with perforations and a cover. Sawdust was poured halfway into the drum, ignited, and then more sawdust was added. The drum lid was covered to encourage slow burning, and the contents in the drum were consistently agitated to improve burning uniformity. After 3-4 hours, the contents of the drum were emptied out and quenched with water (by spraying water on the hot char) before being dried in the sun for 2 days (Ndor, 2016).

Table 1. Physicochemical characteristics of the soil samples Lafia

SOIL DEPTHS (CM)	SOIL DEPTHS (CM)		P-VALUE
	0-15	15-30	
pH (H_2O)	5.75	6.86	0.42
pH ($CaCl_2$)	4.55	5.43	0.14
O.C. (%)	1.47	1.75	0.53
TOM (%)	2.52	3.01	0.32
N (%)	0.45	0.53	0.84
Avail. P (ppm)	3.82	4.56	0.14
K (Cmol/kg)	0.44	0.52	0.62
Ca (Cmol/kg)	4.18	4.99	0.18
Mg (Cmol/kg)	2.16	2.58	0.74
Na (Cmol/kg)	0.34	0.41	0.47
… (Cmol/kg)	0.14	0.16	0.57
TEB (Cmol/kg)	7.05	8.42	0.19
ECEC (Cmol/kg)	7.19	8.58	0.17
Sand (%)	63.39	75.69	0.07
Silt (%)	3.35	4.24	0.16
Clay (%)	13.09	15.63	0.52

O.C. - Organic carbon; TOM- total organic matter; N - (%) percentage nitrogen; K - exchangeable potassium, Ca - calcium, Avail P-available phosphorus; Na -sodium, E.A. - exchangeable acidity; TEB -total exchangeable bases; ECEC - cation exchange capacity

The rice husk Biochar treatment comprised of four (4) levels: 0, 60, 120, and 180 g/pot. The Nasarawa Agricultural Development Program (NADP) in Nasarawa State provided two types of soybeans (*Glycine max* L.). The varieties used were TGS 1449 and TGS 1448, each with three replicates, in a Complete Randomized Block Design (CRBD). Weed control was conducted manually through hoeing 2 weeks after biochar introduction, again at 2 Weeks After Sowing (WAS), and at 5-6 WAS, as advised by Dugje et al. (2009), and then handpicking to keep the site weed-free for the duration of the trial. Throughout the experiment, no herbicide was utilized.

Laboratory analysis

The soil (alfisol) had a loamy sand surface and was well drained. The study area's pre-cropping soil analyses were completed. Air dried soil samples were sieved via a 2mm sieve. These were tested for pH, total nitrogen, organic carbon, available phosphorus, and exchangeable cations (Ca, K, Na, and Mg), among other physical and chemical parameters. The particle size analysis was carried out according to Bouyoucos' instructions (1951). The Kjeldahl (Bremner and Keeney, 1965), Walkey, and Black techniques (Nelson and Sommers, 1980) were used to determine total nitrogen and organic carbon, respectively. Soil pH was determined by the method described by IITA, Available phosphorus by Bray-1 method, while flame photometry method was used to determine calcium, sodium, magnesium and potassium. Cation exchange capacity (C.E.C) was obtained by the summation of the exchangeable cations (K^+, Na^+, Ca^{2+} and Mg^{2+}) and total exchangeable acidity (Sparks et al., 1996). The methods for analyses of soil N, P and K mentioned above were also used for the biochar analyses.

Plant growth analyses

Plant height was measured from the base to top with the aid of a measuring tape at weekly intervals till maturity. Also measured were internodes length, number of Branches per plant, number of leaves per plant, number of pods per plant, number of days to flower initiation, as well as number of Days to 50% Flowering. Days to physiological maturity were calculated as the total number of days from sowing to the physiological maturity of the seeds. Peduncle length was also measured as well as number of seeds per plant.

Data Analysis

The collected data were subjected to Analysis of Variance (ANOVA). The treatment means was separated using least significant difference (LSD) at 5% probability level. This analysis was achieved using Genstat discovery.

Results and discussion

There were changes in concentrations of Fe and Mn across the soil depths (Table 1). Soils were less ferruginous. Based on the rating by Metson (1961), organic carbon was high (1.47 – 1.75%), while magnesium contents were moderate (2.16 – 2.58 Cmol/kg) across the soil depth. Similarly, nitrite levels were comparable irrespective of location and depth (0.45 – 0.53 ppm) (Table 1). Also, results revealed that there was significant difference in the plant height among the accessions used with increased amount of biochar applied (Table 2). Several reports, including those by and Sarma et al. (2017), Głodowska et al. (2017), Jeffery et al. (2017), Ma et al. (2019), Elsaeed et al. (2021), have indicated that biochar increased seed germination, plant growth, and soybean yield (Table 2), aligning with the findings of Sarma et al. (2017), Głodowska et al. (2017), Jeffery et al. (2017), Ma et al. (2019), Elsaeed et al. (2021). Biochar has the valuable ability to retain water and nutrients. Moreover, the material offers a conductive habitat to soil fertility. However, there was no significant difference in the number of branches among the accessions considered. This was also seen across the treatments. On the other hand, there was significant difference in the number of leaves per plant with increase in the amount of Biochar applied. For example, with the application of 180 g of biochar, an increase in the number of leaves was observed in both TGS1449 and TGS1448 accessions. This study's results align with Agboola and Moses (2015), who observed that in soybeans, the number of leaves per plant increased with higher rates of biochar and cow dung. This is most likely due to higher soil N, P, and K levels and lower exchangeable acidity.

Table 2. Effect of Biochar treatments on some growth parameters of soybean

Treatment	Plant height (cm) at 9WAS		Number of branches at 9WAS		Number of leaves at 9WAS		Stem Girth at 9WAS		Leaf area (cm2)	
	TGS1449	TGS1448	TGS1449	TGS1448	TGS1449	TGS1448	TGS1449	TGS1448	TGS1449	TGS1448
CT	50.60^{a}	50.63^{a}	3.00^{a}	3.00^{a}	59.00^{a}	56.67^{a}	5.13^{a}	5.17^{a}	93.68^{a}	93.39^{ab}
B60g	53.33^{b}	53.57^{ab}	3.33^{a}	3.00^{a}	60.00^{a}	60.33^{b}	5.33^{b}	5.33^{ab}	99.34^{a}	97.53^{ab}
B120g	53.17^{b}	54.30^{ab}	4.00^{a}	3.00^{a}	60.00^{a}	58.00^{a}	5.23^{ab}	5.33^{ab}	74.57^{a}	67.54^{a}
B180g	59.33^{c}	57.10^{b}	3.67^{a}	3.00^{a}	67.33^{b}	70.33^{c}	5.33^{b}	5.40^{b}	90.28^{a}	129.5^{b}
LSD	**2.24**	**3.84**	**2.03**	**1.88**	**6.27**	**3.26**	**0.17**	**0.17**	**62.76**	**50.97**

Means with same superscripts across same row are not significantly different. WAS Weeks after sowing.

In terms of stem girth, there was no significant difference, with the lowest stem girth recorded in the control, which differed significantly from the Variety TGS1448, which was subjected to biochar treatment B180g, which had the largest stem girth. However, minimal variation was observed among the other varieties subjected to different biochar treatments. The girth of the stem is a measure of vegetative development (Squire, 1990). Nonetheless, this finding contradicts Agboola and Moses (2015), who noted an increase in stem girth with higher rates of biochar and cow dung. On the other hand, there was generally an increase in the leaf area with increased amount of biochar especially at the highest amount; this is clearly seen in 180 g across both accessions, which is significantly different from the lower amount of biochar. Consequently, it is known that leaves are the primary sites of photosynthesis in plants, biomass is produced, partitioned among various parts of the plant, and stored for agricultural production (Asare et al., 2011; Mshelmbula et al., 2018). They can be utilized as a crop growth and yield index. It is in control of the amount of solar energy intercepted, the accumulation of photosynthates and dry matter in the plant, and hence, yields. This also concurs with Ndor and Iorkua (2013), Tawadchai et al. (2012), who found that biochar soil amendment improved soil water retention capacity nutrient utilization efficiency, and overall fertility was responsible for the significant increase in soybean growth metrics.

There was an increase in the number of flowers per plant, number of seeds per pod and number of pods per plant as the amount of biochar increased which was significantly different from the lower doses of biochar applied (Table 3). Incorporation of biochar may, therefore, give higher yield with the same amount of fertilizers. Nutrient uptake and availability can also be affected by change in pH as a result of biochar addition (Lehmann and Joseph, 2009). Yooyen et al. (2015) used biochar to boost soybean growth and yield, with a significant increase in plant height as a result of increased biochar application. This could be due to good plant height, which is vital for photosynthesis and ultimately affects productivity (Uzoma et al., 2011). It has been reported that the plant uptake of several of these nutrients has increased after biochar application (Chan et al., 2007). Major et al. (2010) observed that nutrient uptake by plant was increased by biochar amended soil and concluded that increased plant yield was a result of greater availability of Ca and Mg in soil. Chan et al. (2007) confirmed that biochar can act as an absorber reducing N leaching and increasing N use efficiency. Nitrogen use efficiency is of great importance, especially to sustain future plant growth.

Table 3. Effect of Biochar treatments on some reproductive and yield parameters of soybean

Treatment	Number of flowers at 7WAS		Number of Pods 8WAS		Number of seeds/ plants at 9WAS	
	TGS1449	TGS1448	TGS1449	TGS1448	TGS1449	TGS1448
CT	41.67^{a}	48.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
B60g	37.00^{b}	34.67^{b}	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}
B120g	41.33^{a}	34.67^{b}	0.00^{a}	0.00^{a}	0.00^{a}	0.00a
B180	66.67^{c}	67.33^{c}	3.67^{b}	4.00^{b}	8.02^{b}	11.13^{b}
LSD	**4.21**	**6.52**	**0.54**	**0.94**	**3.21**	**4.02**

Means with same superscripts across same row are not significantly different. WAS Weeks after sowing.

Conclusion

Results from this study revealed that biochar can be used for the crop improvement of soybean. There was general increase in growth parameters among the two varieties considered. For example, there was increase in plant height, leaf area and number of leaves per plant in both the varieties treated. This trend was also seen in the yield component of the plant where higher doses of biochar (B60 g and B180 g) recorded higher number of flowers per plant, number of pods per plant and number of seeds per pod which was significantly different from the lower amount of biochar and also the control.

Conflict of interest

The authors have no conflict of interest.

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