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EFFECTS OF LEGUME INOCULANT AND BIOCHAR ON NODULATION OF SOYBEAN (Glycinemax. L. merrill) AT LAFIA, SOUTHERN GUINEA SAVANNA OF NIGERIA.

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Abstract
The experiments were conducted on the Teaching and Research Farm, Faculty of Agriculture Shabu -Lafia Campus, Nasarawa State University keffi Nigeria during 2018 and 2019 cropping seasons to find the effects of legume inoculant and biochar on nodulation of Soybean. The experiments were split plot design in Randomize Complete Block Design (RCBD). The treatments consisted of legume inoculant in the main plot while biochar (at the rate of 0, 4, 8 and 12 tons/ha) was assigned to subplots and the treatments were in triplicates. All data collected were subjected to analysis of variance (ANOVA) and means separated by least significant difference using GENSTAT statistical packages. The results indicated that legume inoculant and biochar significantly (P<0.05) influenced nodules number and weight(g) per Soybean plant in both 2018 and 2019 cropping seasons. Results further showed that inoculated plots produced significantly (P<0.05) higher number of nodules per Soybean plant and weighed heavier than the uninoculated plots in both cropping years respectively. Results further revealed that the interaction effect of legume inoculant and biochar significantly (P<0.05) influenced both number and weight (g) of nodules per Soybean plant in both cropping years. The results also showed that biochar at 8 tons/ha consistently recorded highest number and weight(g) of nodules per Soybean plant on inoculated and uninoculated plots in both cropping seasons while biochar at 12 tons/ha do not necessarily increase nodules per Soybean plant.

Key words: Nodulation, Soybean, Inoculant, Biochar, Southern Guinea Savanna

Introduction

Low soil fertility status of most cultivated tropical soils has been identified as major cause of low crop yields in tropical Africa (Shiferaw *et al*, 2004; Byerlee, 2007). Most soil conditions across the World can provide plants with the majority of nutrition they require but due to intensive agricultural methods and the desire to grow bigger and more rapid growing crops, nutrients are depleted from the soil (https://www.crodacropcare.com).

Seed inoculation is the practice of covering (coating) the seed surface with nitrogen fixing bacteria (Rhizobium or Brady rhizobium) prior to planting. This farm practice is characteristically done for legumes such as Soybean Bean, Groundnut etc. Seed inoculation makes legume more capable to absorb nutrients from soil and improves biological nitrogen fixation in legumes (Folnovic, 2019). Inoculating legume seeds with commercial Rhizobia inoculants is to ensure proper and compatible Rhizobia species in the soil (USDA, 2015). The soil bacteria of the genus Rhizobium are capable of living naturally in the soil without legumes and when forage legumes are grown in these soils, the Rhizobia infect the roots of the plants and form nodules (Anon, 2019). Rhizobia bacteria form root nodules on the root of host plant thereby providing the plant with transformed nitrogen in exchange for a portion of the carbohydrates made by the plant (Grossman, 2019). Most soils do not or contain few bacteria hence the need to inoculate legume seeds with appropriate strains of bacteria prior to planting the seeds (www.Groworganic.com).

Biochar is a black charcoal like substance derived from or made by heating biomass under the exclusion of air (pyrolysis) (Schmidt and Wilson 2014; Wilson 2014a; Wang *et al*., 2016). It is one of the oldest soil amendments in the history of agriculture (Wilson, 2014b). Biochar acts as a long-term soil carbon store and improves soil fertility and crop production {Wang *et al*., 2016). Biochar increase and improve soil water holding capacity, aeration, release plant nutrients, raise soil p^H value and fix degradable plant carbon into long term charcoal while carbon dioxide is slowly but surely removed from the atmosphere (Schmidt and Wilson, 2014).

Legumes such as Soybean, Bean, Groundnut e t c are broadleaved plants that belong to Fabaceae family that associate themselves with nitrogen fixing bacteria (Rhizobia) commonly found in soil capable of fixing atmospheric nitrogen for their use via a symbiotic relationship with bacteria within their root nodules through a complex biochemical process Biological Nitrogen Fixation (BNF) (USDA, 2015, Wikipedia-the free encyclopedia).Ability of legumes to fix gaseous nitrogen makes them an ideal agricultural organism as their requirement for nitrogen fertilizer is reduced (Wikipedia-the free encyclopedia). Legumes add nitrogen to soil and replace nitrogen used by other crops (VOA, 2006). Adding legumes to a crop rotation reduces the need for external nitrogen input (PhysOrg.com, 2010).

Soybean (U.S.), Soyabean (U.K.) (Glycine Max.L. Merrill) is species of legume which belongs to pea family, widely grown for its edible bean and other numerous uses. It is classified by Food and Agricultural Organization (FAO) as an oil seed rather than a pulse crop. Nigeria is the largest producer of soybean in Sub Sahara Africa (SSA) with about 500,000 metric tons produced annually (https://www.IITA.org/crops new/soybean -3,https: www.forafera.com).

Soybean performs well in both Southern and Northern Guinea Savannas of Nigeria where annual rainfall is more than 700mm. It is produced mostly in middle belt of Nigeria with Benue state accounting for about45-70% of the total production in the country (https://www.foramfera.com). Soybean requires well drained, fertile loamy soils with high organic matter. Soybean contains more than 36% protein, about 30% carbohydrates and 20% oil. It improves soil fertility by adding nitrogen from atmosphere which is a major benefit in Africa farming systems where soils have become exhausted by the need to produce more food for increasing population and fertilizers are hardly available (scarce) and expensive for peasant farmers (https://www.IITA.org/crops new/soybean).

Therefore, the aims of this study are to find the effects of legume inoculant and biochar on nodulation of Soybean and to restore and maintain lost soil fertility for sustainable Soybean and other crops production in Lafia in Southern Guinea Savanna of Nigeria.

Materials and methods

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. Lafia falls within Southern Guinea Savanna zone of Nigeria. It has mean annual rainfall range between 1100mm and 2000mm which usually starts in April and ends in October (https://www.onlinenigeria.com).

The experiment was a split plot in Randomize Complete Block Design (RCBD) with legume inoculant in the main plot while biochar was assigned to subplot and replicated three times.

Soybean seed (TGX 1951-3F) from National Cereals Research Institute (NCRI) Badeggi-Bida, were inoculated with Nodumax legume inoculant powder from International Institute for Tropical Agriculture (IITA) Ibadan. The inoculation was done by preparing sugar solution as sticking agent to moist the soybean seeds while legume inoculant powder was sprayed on the seeds and mixed thoroughly. Charcoal purchased from local charcoal seller in Lafia was crushed into pieces and used as biochar. Biochar was incorporated into the ridges before

planting the soybean seeds according to the experimental design at the rates of 0.0, 4.0, 8.0 and 12 tons/ha.

Four seeds of Soybean were planted at 5cm on four ridges of 2m long as uninoculated (without legume inoculant) and inoculated (coated with legume inoculant powder) on locally prepared ridges spaced at about 75cm apart. The soybean seedlings were thinned to two plants at two weeks after planting (WAP). Weeding were done manually at 3,6,9 weeks after planting (WAP). Three (3) randomly selected soybean plants from each treatment were carefully dug, gently washed, nodules collected. Counted and weighed (g) using sensitive weighing scale. Data collected in this study were subjected to analysis of variance (ANOVA) while least significant difference (LSD) was used to separate treatment means at 5% probability($p<0.05$) using GENSTAT statistical package.

Results and Discussion

Table:1 Effects of legume inoculant and biochar on number of nodules per soybean plant at lafia during 2018 and 2019 cropping seasons

Treatments	2018	2019
Uninoculated	14.0^{b}	12.1^{b}
Inoculated	20.5^{a}	15.9^{a}
LSD	0.27	0.23
Biochar(tons/ha)		
0	12.7^{d}	11.2^{d}
4	17.5^{c}	15.3^{b}
8	20.8^{a}	16.4^{a}
12	18.1^{b}	13.0^{c}
LSD	0.39	0.33

Values with the same letter within a column are not significant at 5% probability (P>0.05).

Table 1 above is the result of effects legume inoculant and biochar on number of nodules per Soybean plant at Lafia during 2018 and 2019 cropping seasons. The result indicates that legume inoculant influenced Soybean nodules numberas inoculated plots produced significantly($P<0.05$) higher number of nodules per Soybean plant over uninoculated plots in both 2018 and 2019 cropping seasons. Result also shows that biochar influenced number of nodules per Soybean plant with biochar at 8 tons/ha producing significantly ($P<0.05$) highest number of nodules in both cropping seasons. However, this was followed by biochar at 12 tons/ha and biochar at 4 tons/ha in 2018 and 2019 cropping years respectively while control produced lowest number of nodules per Soybean plant in both cropping years.

Table: 2 Interaction effect of legume inoculant and biochar on number of nodules per soybean plant at lafia during 2018 and 2019 cropping seasons

Biochar(tons/ha)	Treatments	2018	2019	
	uninoculated	inoculated	uninoculated	inoculated
0	10.8^{d}	14.7^{d}	10.2^{d}	12.2^{d}
4	13.4^{c}	21.6^{b}	12.8^{b}	17.8^{b}
8	16.8^{a}	24.8^{a}	13.7^{a}	19.1^{a}
12	15.1^{b}	21.0^{c}	11.6^{c}	14.4^{c}
LSD (0.5)	0.55		0.47	

Values with the same letter within a column are not significant at 5% probability (P>0.05)

Table 2 above is the result of interaction effects of legume inoculant and biochar on number of nodules per Soybean plant at Lafia during 2018 and 2019 cropping seasons. The result indicates that biochar at 8 tons/ha produced significantly (P<0.05) highest number of nodules per Soybean plant on both inoculated and uninoculated plots in both 2018 and 2019 cropping seasons. The result also shows that biochar at 4 tons/ha and biochar at 12 tons/ha produced next significant (P<0.05) higher number of nodules on both inoculated and uninoculated plots respectively in 2018 cropping year. On the other hand, result revealed that biochar at 4 tons/ha produced next significant (P<0.05) higher number of nodules on both inoculated and uninoculated plots in 2019 cropping year. Result further revealed that biochar at 0 ton/ha (control) on both inoculated and uninoculated plots produced least number of nodules per Soybean plant in both 2018 and 2019 cropping seasons.

Table:3 Effects of legume inoculant and biochar on weight(g) of fresh nodules per soybean plant at lafia during 2018 and 2019 cropping seasons

Treatments	2018	2019
Uninoculated	2.5^{b}	2.3^{b}
Inoculated	3.4^{a}	3.6^{a}
LSD	0.07	0.07
Biochar(tons/ha)		
0	2.2^{c}	2.0^{d}
4	3.6^{a}	3.5^{b}
8	3.6^{a}	3.6^{a}
12	2.6^{b}	2.8^{c}
LSD	0.11	0.10

Values with the same letter within a column are not significant at 5% probability (P>0.05).

Table 3 above is the result of effects of legume inoculant and biochar on weight (g) of fresh nodules per Soybean plant at Lafia during 2018 and 2019 cropping seasons. The result shows that legume inoculant influenced the weight (g) of fresh nodules per Soybean plant in both 2018 and 2019 cropping seasons as inoculated plots recorded significantly (P<0.05) higher weight(g) of nodules per Soybean plant against the uninoculated plots in both cropping seasons. The result of the effect of biochar levels/rates on nodules fresh weight (g) per Soybean plant indicates that biochar at 8 tons/ha and biochar at4 tons/ha recorded similar weight(g) of fresh nodules per Soybean plant and not significant among them but significant(P<0.05) over the biochar at 0 ton/ha(control) and biochar at 12 tons/ha in both 2018 and 2029 cropping seasons. Result also shows that biochar at 0 ton/ha (control) recorded lowest weight(g) of fresh nodules in both cropping seasons.

Table:4 Interaction effect of legume inoculant and biochar on weight(g) of fresh nodules per soybean plant at lafia during 2018 and 2019 cropping seasons

Biochar(tons/ha)	Treatments	2018	2019	
	uninoculated	inoculated	uninoculated	inoculated
0	1.5^{c}	2.9^{c}	1.8^{d}	2.2^{c}
4	3.1^{a}	3.9^{b}	2.5^{b}	4.4^{a}
8	3.1^{a}	4.1^{a}	2.7^{a}	4.4^{a}
12	2.4^{b}	2.8^{c}	2.3^{c}	3.2^{b}
LSD (0.5)	0.15		0.14	

Values with the same letter within a column are not significant at 5% probability (P>0.05).

Table 4 above is the result of interaction effect of legume inoculant and biochar on weight (g) of fresh nodules per Soybean plant at Lafia during 2018 and 2019 cropping seasons. The result of the interaction indicates that biochar at 4 and 8 tons/ha recorded similar weight (g) of nodules fresh weight(g) per Soybean plant and not significant among them but significant over the biochar at0 ton/ha(control) and biochar at 12 tons/ha in 2018 cropping year. The result also shows that biochar at 8 tons/ha recorded significantly ($P<0.05$) higher weight(g) of fresh nodules per Soybean plant followed by biochar at 4 tons/ha while biochar at 0 ton/ha (control) recorded least nodules fresh weight (g) on both inoculated and uninoculated plots in 2018 cropping year. In 2019 cropping year the reverse was the case in which biochar at 8 tons/ha recorded significantly ($P<0.05$) highest weight (g) of fresh nodules per Soybean plant followed by biochar at 4 tons/ha on uninoculated plots while on inoculated plots biochar at 4 and 8 tons/ha recorded similar and not significant among them nodules fresh weight(g) but significantly ($P<0.05$) higher than those of biochar at control and at 12 tons/ha.

Results from this study are in line with the report of USDA (2015) that the greater the number of nodules on the root system of a legume the greater the potential for nitrogen fixation. Adeyeye*et al.,* (2017) obtained 35% higher grain yields of Soybean on inoculated plots than uninoculated plots. Heerwaarden*et al*., (2018) estimated grain yields of Soybean with and without inoculation to be 1343 and 1227 kg/ha respectively. Bayan (2013) reported that biochar at 2% in pot experiment significantly enhanced Soybean plant growth leaf area and increase nodule formation by 35% over the control and the 5% application of biochar.

Conclusion

Results from this study indicated that legume inoculant significantly ($P<0.05$) enhanced nodulation of Soybean as reflected in number and weight (g) of nodules per plant in both 2018 and 2019 cropping seasons. The inoculated plots consistently produced significantly higher number of nodules and weighing heavier than uninoculated plots in both cropping seasons. Further results showed that biochar significantly influenced the number and weight (g) of nodules per Soybean plant in both cropping years and biochar at 8 tons/ha consistently produced significantly higher number of nodules and weighing heavier followed by biochar at 4 tons/ha while biochar at 12 tons/ha do not necessary increased the number and weight (g) of nodules in both cropping years. The further revealed that of legume inoculant and biochar also influenced the number and weight (g) of nodules per Soybean plant in both cropping season.

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