



SEPARATE AND COMBINED EFFECT OF LEGUME INOCULANT AND BIOCHAR ON YIELD OF SOYBEAN (*Glycine max.* (L.) Merrill)

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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 evaluate the separate and combined effects of legume inoculant and biochar on yields of soybean. The experiments were laid in Randomized Complete Block Design (RCBD). Biochar at the rates of 0, 4, 8 and 12 tons/ha was incorporated into the ridges at planting. Four seeds of soybean were planted as uninoculated (without legume inoculant) and inoculated (coated with legume inoculant). All data collected were subjected to analysis of variance (ANOVA) using GENSTAT Statistical Package while least significant different (LSD) was used to separate treatment means at 5% probability. The results showed that inoculated plots recorded significantly ($P < 0.05$) the heaviest weight per 100 seed (15.4 and 14.9g) and grain yields (1201.7 and 1212.3kg/ha) against the uninoculated plots (14.0 and 12.5g) and (751.0 and 760.0kg/ha) in 2018 and 2019. The results also showed that biochar at the rate of 8 tons/ha recorded the heaviest weight per 100 seed (16.6 and 14.9g) and grain yields (1304.0 and 1316.7kg/ha) against the other rates of biochar in both cropping seasons. The combination of biochar at the rate of 8 tons/ha with inoculants recorded the heaviest weight per 100 seed (18.4 and 16.6g) in 2018 and 2019 and grain yield (1420 kg/ha) in 2018. However the highest dose of biochar (12 tons/ha) applied did not necessarily influenced and increased soybean yield parameters tested.

Key words: Biochar; Combined; Inoculants; Soybean; Sustainable yield

INTRODUCTION

Seed inoculation is the practice of covering (coating) the seed surface with a nitrogen fixing bacteria (Rhizobium or Brady-rhizobium) prior to planting which is characteristically done for legume such as soybeans, cowpea, groundnuts etc. (Grossman, 2019, USDA 2015). Seed inoculation improves biological nitrogen fixation in legumes and ensure proper and compatible rhizobia species in the soil (Folnovic, 2019). Inoculation of legume seeds with appropriate strains of rhizobia helps to increase rhizobia population in the soil especially where legume crops have not been grown before and the native rhizobia population

may not be effective to fix nitrogen (Grossman, 2019, USDA, 2015). Inoculation of soybean seeds with appropriate strains of rhizobia improves soybean growth, nodulation and yields (Abbasi *et al.*, 2008, Kubota *et al.*, 2008). Biochar is a heterogeneous and chemically complex material made by heating (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 increases soil water holding capacity, improves soil aeration, releases plant nutrients and raises soil pH value (Schmidt and Wilson, 2014). Biochar is widely applied as soil amendments for carbon sequestration, improvement of crop yield and remediation of pollution (Antonangelo *et al.*, 2021, Wang *et al.*, 2020, Clurman *et al.*, 2020). Rondon *et al.* (2007) stated that the application of biochar to soil may be more desirable as it improves the supply of nutrients to plants and enhances plant growth. Soybean (*Glycine max* L.) is a species of legume, widely grown for its edible bean which has numerous uses. It is among the major industrial and food crops grown in every continent of the world (Dugje *et al.*, 2009) and 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 the only available crop that provide an inexpensive and high quality source of protein comparable to meat, poultry and eggs (Atli, 2019, Mawiya, 2016). Soybean is described as the world chief source of edible vegetable oil for human diets as it contains all the essential amino acid (Atli, 2019). It is a good source of food such as soy-milk, soy-cheese, dadawa, vegetables oil, soy-cake for human and livestock etc (Dugje *et al.*, 2009). It improves soil fertility by adding nitrogen from the atmosphere through biological nitrogen fixation which is a major benefit in African farming systems where soils have become exhausted by the need to produce

more food for increasing population and where fertilizers are hardly available (scarce) and expensive for farmers (Fairhurst, 2012). Soybean as a legume crop provides itself with nitrogen through biological nitrogen fixation for its growth and for succeeding crop especially cereal crops (Dugje *et al.*, 2009, Mawiya, 2016). The decomposed leaves of soybean improve soil fertility and increase yields of subsequent crop (Fairhurst, 2012, Dugje *et al.*, 2009). It provides excellent fodder for livestock (Fairhurst, 2012). Soybeans grown in rotation with cereal crops, serve as catch crops in controlling weeds especially *striga hermonthica* in maize farms (Dugje *et al.*, 2009). Soybean production has increased globally due to its economic importance, nutritive value and diverse domestic usage (David, 2017) and as such its cultivation in Nigeria is rapidly increasing as farmers are becoming more aware of the importance and potentials of the crop as cash or food crop (Dugje *et al.*, 2009). There is increasing economic importance and uses of soybean as it is being converted and made into various traditional food products such as soy-milk, soy-cake (Wara), soy-soup, soy-oil, etc. There are increasing demands for soybean as it is being converted into various traditional food products such as soy- cake, soy- milk, soy- soup, etc but the use of legume inoculant and biochar to improve poor soil for sustainable production /cultivation and increase the yields of the crop have not receive much attention in the study area. Hence the need for this study to encourage local farmers to increase the production of the

crop to meet the increasing demands. Therefore this study aimed at evaluating the separate and combined effects of legume inoculant and biochar on 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, Shabu-Lafia Campus of Nasarawa State University, Keffi, during 2018 and 2019 cropping seasons. The study area is located between latitude 08.33°N and Longitude 08.33°E which falls within the southern Guinea savannah zone of Nigeria (NIMET, 2021). Soil samples were collected from 0-15 and 15-30 cm depth of the experimental site for physical and chemical analysis before the experiment. The experiments were laid in Randomized Complete Block Design (RCBD). Biochar at the rates of 0, 4, 8 and 12 tons/ha was incorporated into the ridges before planting. The soybean seeds were planted as uninoculated (without legume inoculant) and inoculated (coated with legume inoculant) respectively on four manually made ridges of 2 m long spaced at about 75 cm. Four seeds were planted per hole at a spacing of 5 cm between plants. The seedlings were thinned to two plants after two weeks of planting (WAP). All data collected were subjected to analysis of variance (ANOVA) using GENSTAT statistical package while least significant different (LSD) was used to separate treatment means at 5 %level of probability.

Results and Discussion

Some physical and chemical properties of soil of the experimental site before the experiments (table 1) indicated that soil pH (H₂O) (5.63 and 5.61) and organic matter content (3.04 and 2.97%) of the experimental site at both surface and subsurface soil levels were moderate while the percentage total nitrogen (0.25 and 0.21%), organic carbon (1.77 and 1.73%) and available phosphorous (2.53 and 2.43 ppm) were very low at both surface and subsurface soil levels. The percentage base saturation was high (86.00 and 85.00%) at both surface and surface soil levels. The sand particle (85.80%) was very high at the surface and subsurface soil levels hence the soil textural class was sandy loam. 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 nutrient. The low soil property of the experimental site before the experiments was an indication of the expected response of soybean to the application of inoculants and biochar as reflected in all the parameters tested.

Table 1: Physical and Chemical Properties of Soil of the Experimental Site before the Experiment, 2018

Soil Parameter	Soil Depth	
	0-15 cm	15-30 cm
pH (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) (%)	0.67	0.75
Total exchangeable bases (%)	4.51	4.48
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 effect of legume inoculants and biochar on 100 seed weight (table 2) indicated that the inoculated plots recorded significantly ($p<0.05$) heavier weight per 100 seed of soybean (15.4 and 14.9g) than the uninoculated plots (14.0 and 12.5g) in 2018 and 2019 cropping seasons respectively. The result also showed that biochar at the rate of 8 tons/ha recorded significantly ($p<0.05$) the heaviest weight per 100 seed of soybean (16.6 and 14.9g) followed by biochar at the rate of 4 tons per

hectare (15.4 and 14.2.0 g) while biochar the rate of 0.0 ton/ha (control) recorded the lowest weight (12.6g) per 100 seed of soybean in both 2018 and 2019 cropping seasons. The positive response of soybean to the application of legume inoculant and biochar in this study may be attributed to high competitive ability and performance of the introduced rhizobia inoculants against the indigenous rhizobia in the soil and effectiveness of biochar which positively improved soil fertility and influenced

plant nutrient availability to the crop. The result is in line with the work of Mathenge *et al.* (2019) who reported that inoculated plots produced significantly ($P<0.05$) higher grain yield/ha of soybean compared to the uninoculated ones. Abbasi *et al.* (2008) and Kubota *et al.* (2008) also reported that

inoculation of soybean seeds with appropriate strains of rhizobia improves soybean growth, nodulation and yields.. Similarly, Mete *et al.* (2015) reported that grain yield of soybean increased on average by 67 % as a result of the application of biochar compared to the control.

Table 2: Effect of Legume Inoculants and Biochar on 100 Seed Weight (g) of Soybean during the 2018 and 2019 Cropping Seasons

TREATMENT	2018	2019
Inoculants		
Uninoculated	14.0b	12.5b
Inoculated	15.4a	14.9a
LSD(0.05)	0.09	0.17
Biochar (Bio) (tons/ha)		
0	12.6d	12.6d
4	15.4b	14.2b
8	16.6a	14.9a
12	14.0c	13.1c
LSD(0.05)	0.13	0.25
Interaction (I $\times$ B)	*	*

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

*= Significant at 5% level of significance

The result of the combined effect of legume inoculant and biochar on 100 seed weight (g) of soybean (table 3) showed that the combination of biochar at the rate of 8 tons/ha with legume inoculant recorded significantly ($P<0.05$) the heaviest weight (18.4 and 16.6g) per 100 seed of soybean compared to other levels of combination in the 2018 and 2019 cropping seasons respectively. The result also showed that biochar at the rate of 12 tons/ha without inoculants recorded significantly ($p<0.05$) the

heaviest weight of 100 seed (15.0g) in 2018 cropping season while biochar at the rate of 8 tons/ha with inoculants recorded the heaviest weight (16.6g) per 100 seed in 2019 cropping season. The result further revealed that biochar at the rate of 4 and 8 tons/ha without inoculants showed similar weight (13.2g) per 100 seed of soybean in 2019 cropping season. This revealed the advantage and benefit of integrating inoculant with biochar in soybean production. The positive response of soybean to the

combined application of inoculant and biochar in this study may be that the introduced rhizobia inoculant competed and performed better than the indigenous rhizobia in the soil of the study area. It also showed that biochar contains plant nutrients and make them available in the soil for plant uptake. It could also be that biochar improve soil properties and raise soil pH which contributed to the positive response of soybean to the combined application. The result confirmed the finding of Agboola and Moses (2015) who reported that the combined application of biochar and cow dung significantly increased soybean yield

parameters. Ukem *et al.* (2019) also reported that the combination of inoculant with P, K, micronutrient and manure had the best response as reflected in mean grain and fodder yields of soybean per hectare compared to other treatment combinations. Similarly, Mete *et al.* (2015) recorded 54% increase in seed yield of soybean as a result of the combined application of biochar and NPK compared to the control. Ali *et al.* ((2021) also reported that integrating biochar with compost considerably enhanced soybean yield probably as a result of positive effect of biochar-compost interaction on the soil and the crop.

Table 3: Combined Effects of Legume Inoculants and Biochar on 100 Seed Weight (g) of Soybean at Lafia during the 2018 and 2019 Cropping Seasons

Biochar (tons/ha)	2018		2019	
	Uninoculated	Inoculated	Uninoculated	Inoculated
0	11.6d	13.7c	11.9b	13.8c
4	14.5c	16.3b	13.2a	15.2b
8	14.8b	18.4a	13.2a	16.6a
12	15.0a	13.1d	12.2b	14.0c
LSD (0.05)	0.18	0.18	0.35	0.35

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

The result of the effects of legume inoculants and biochar on seed yield of soybean per hectare (table 4) showed that inoculated plots recorded significantly ($P<0.05$) higher grain yield (1201.7 and 1212.3kg/ha) compared to the uninoculated ones (751.0 and 760.0 kg/ha) in 2018 and 2019 cropping seasons. The result also indicated that application of biochar at the rate of 8 tons/ha recorded significantly ($P<0.05$) the highest grain yield (1304.0 and 1316.7kg/ha) followed by biochar at the rate of

4 tons/ha (1180.0 and 1187.3kg/ha) while biochar at the rate of 0.0 ton/ha (control) recorded the lowest grain yield (739.0 and 745.0 kg/ha) in both cropping seasons. The positive response of soybean to the application of legume inoculant and biochar in this study may be attributed to high competitive ability and performance of the introduced rhizobia inoculants against the indigenous rhizobia in the soil and effectiveness of biochar which positively improved soil fertility and influenced

plant nutrient availability to the crop. This result is in line with the work of Mathenge *et al.* (2019) who reported that inoculated plots produced significantly ($P < 0.05$) higher grain yield/ ha of soybean compared to the uninoculated plots. Abbasi *et al.* (2008) and Kubota *et al.* (2008) also reported that

inoculation of soybean seeds with appropriate strains of rhizobia improves soybean growth, nodulation and yields. Similarly, Mete *et al.* (2015) reported that grain yield of soybean increased on average by 67 % as a result of the application of biochar compared to the control.

Table 4: Effect of Legume Inoculants and Biochar on Seed Yield (kg/ha) of Soybean during the 2018 and 2019 Cropping Seasons

Treatments	2018	2019
Uninoculated	751.0b	760.0b
Inoculated	1201.7a	1212.3a
LSD(0.05)	0.11	0.13
Biochar (tons/ha)		
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
Interaction (I $\times$ B)	*	*

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

*= Significant

The combined effect of legume inoculant and biochar on soybean grain yield (table 5) showed that biochar at the rate of 8 tons/ha with legume inoculants recorded significantly ($P < 0.05$) the heaviest weight of grain of soybean per hectare (1420.0kg/ha) in the 2018 while biochar at the rate of 4 tons/ha recorded the heaviest grain yield of soybean (1433.7kg/ha) in 2019 cropping season. The result also showed that biochar at the rate of 0.0 ton/ha (control) with

and without legume inoculants recorded the lowest grain yield in both cropping seasons. This revealed the advantage and benefit of integrating inoculants with biochar in soybean production. The positive response of soybean to the combined application of inoculant and biochar in this study could be explained that the introduced rhizobia inoculants competed and performed better than the indigenous rhizobia in the soil of the study area. It also showed that

biochar contains plant nutrients which was made available in the soil for plant uptake. It could also be that biochar improve soil properties and raise soil pH which contributed to the positive response of soybean to the combined application. The results confirmed the finding of Agboola and Moses (2015) who reported that the combined application of biochar and cow dung significantly increased soybean yield parameters. Ukem *et al.* (2019) also reported that the combination of inoculant

with P, K, micronutrient and manure had the best response as reflected in mean grain and fodder yields of soybean per hectare compared to other treatment combinations. Similarly, Mete *et al.* (2015) recorded 54% increase in seed yield of soybean as a result of the combined application of biochar and NPK compared to the control. Ali *et al.* ((2021) also reported that integrating biochar with compost considerably enhanced soybean yield probably as a result of positive effect of biochar-compost

Table 5: Combined Effects of Legume Inoculants and Biochar on Weight of Seed (kg/ha) of Soybean during the 2018 and 2019 Cropping Seasons

Biochar (tons/ha)	2018		2019	
	Uninoculated	Inoculated	Uninoculated	Inoculated
0	735.3d	934.0d	740.0d	939.7d
4	854.3c	1271.3b	863.3c	1433.7a
8	1187.0a	1420.0a	1190.7a	1278.7b
12	1066.7b	1123.0c	1078.3b	1133.3c
LSD (0.05)	0.23	0.23	0.35	0.35

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

Conclusion and recommendation

The results of this study showed that the application of legume inoculants and biochar significantly ($P < 0.05$) and positively influenced 100 seeds weight and grain yields of soybean against other treatments in the 2018 and 2019 cropping seasons respectively. The results also showed that biochar at the rate of 8 tons/ha with legume inoculants showed better and significant performance ($P < 0.05$) compared to

other treatment combinations as reflected in all the variables measured. However, the highest dose of biochar applied (12 tons/ha) in this study did not significantly ($P < 0.05$) increased 100 seed weight and grain yield of soybean. Therefore, Seeds inoculation with legume inoculant and its combination with biochar at the rate of 8 tons/ha are recommended for sustainable soybean production and yield increase in the study area.

REFERENCES

- Abbasi, M. K., Majeed, A., Sadiq, A. and Khan, S. R. (2008). Application of brady-rhizobium japonicum and phosphorus fertilization improved growth, yield and nodulation of Soybean in the sub-humid hilly region of Azad Jammu and Kashmir, Pakistan. *Journal of Plant Production Society*, 8(4): 368-376.
- Agboola, K. and Moses, S.A. (2015). Effect of Biochar and Cow dung on Nodulation, Growth and Yield of Soybean (*Glycine max* Merrill.). *International Journal of Agriculture and Biosciences*, 3(4): 154-160.
- Ali, T., Abdelkhalik, A., Abdel-mageed, S.A. and Semida, W.M. (2021). Co-composted Poultry Litter, Biochar Enhanced Soil Quality and Eggplant Productivity under Different Irrigation Regimes. *Journal of soil science and plant nutrition*, 4 (2): 267-270.
- Antonangelo, J. A., Sun, X., and Zhang, H. (2021). The roles of co-composted biochar (COMBI) in improving soil quality, crop productivity, and toxic metal amelioration. *Journal of Environmental Management*, 277, 111443.
- Atli, A. (2019). Nutrition Fact and Health Effects. Iceland: Headline Press.
- Chude V. O. Olayiwola, S.O., Daudu, C. and Ekeoma, A. (2012). Fertilizer Use and Management Practices for Crops in Nigeria. Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development. Abuja, Nigeria. 4th Edition, 2012.
- Clurman, A. M., Rodríguez-Narvaez, O. M., Jayarathne, A., De Silva, G., Ranasinghe, M. I., Goonetilleke, A. and Bandala, E.R. (2020). Influence of surface hydrophobicity/hydrophilicity of biochar on the removal of emerging contaminants. *Chemical Engineering Journal*, 402, 126277.
- David, W. (2017). Trends in Global Soybean Production. U.S.A Agricultural Economic Insights: 141-144pp.
- Dugje, I. Y., Omoigui, L.O., Ekeleme, F., Bandyopadhyay, R., Lava, P.K. and Kamara, A.Y. (2009). Farmers Guide to Soybean Production in Northern Nigeria. International Institute Tropical Agriculture, Ibadan, Nigeria. 21pp.
- Fairhurst, T. (ed.) (2012). Handbook for Integrated Soil Fertility Management. Africa Soil Health Consortium, CAB International, Nairobi, Kenya. Pp.124.
- FAO (2016). Biannual Report on Global Food Markets. ISSN:1560-8182.
- Folnovic, T. (2019). How can Farmers Benefits from Seed Inoculation? Retrieved from [blog.agrivi. Com/post/how-can- farmers - benefits-from-seed-inoculation](http://blog.agrivi.com/post/how-can-farmers-benefits-from-seed-inoculation).
- Grossman, J. (2019). Legume Inoculation for organic farming systems. Retrieved from <http://www.articles.exetion.org/pages/64401/legume-inoculation-for-organic-farming-systems>.
- Kubota, A., Hoshiba, K. and Bordon, J. (2008). Effect of fertilizer N application and seed coating with rhizobial inoculants on Soybean yield in eastern Paraguay. *Journal of Agricultural Research*, 32: 1627- 1633.
- Lehmann, J. and Joseph, S. (2009). Biochar for environmental management: an introduction. In: Lehmann J, Joseph S (eds.) Biochar for Environmental Management: Science and Technology. Earthscan, London. pp. 1-12.
- Mathenge, C. T., Masse, C. G., Onyango, J. and Vanlauvwe, B. (2019). Variability of Soybean Response to Rhizobia Inoculants Varmicompost and Legume. Specific fertilizer blend in Sirya country of Kenya, soil and tillage research. November, 2019.



194: 104290. ELSEVIER.

Mawiya, W. (2016). Effect of genotype and plant population on growth, nitrogen fixation and yield of soybean [*Glycine max* (L.) Merrill] in the Sudan Savanna Agro-Ecological Zone Of Ghana. M.SC. Dissertation, University of Development studies, Ghana).

Mete, F. Z, Mia, S., Dijkstra, F.A., Abuyusuf, M.D. and Hossain, A.S.M.I. (2015). Synergistic Effects of Biochar and NPK Fertilizer on Soybean Yield in an Alkaline Soil. *Pedospher* 25(2): 718 - 719.

NIMET (2021). Nigeria Meteorological Agency. The State of the Climate in Nigeria, 2021.

Rondon, M. A., Lehmann, J., Ramírez, J., & Hurtado, M. (2007). Biological nitrogen fixation by common beans (*Phaseolus vulgaris* L.) increases with bio-char additions. *Biology and fertility of soils*, 43(6), 699-708.

Schmidt, H. P. and Wilson, K. (2014). The 55 Uses of Biochar, *the Biochar Journal* 2014, Arbaz, Switzerland, ISSN 2297-1114. Retrieved from (www.biochar-journal.org/en/ct/2) www.biochar-journal.org/en/ct/2 "http://www.biochar-journal.org/en/ct/2" [journal.org/en/ct/2](http://www.biochar-journal.org/en/ct/2) Accessed 24th May, 2021.

Ukem, B., Kamail, N., Sangodelle, E., Abikoye, J. and Chinedu, E. (2019). Effect of Fertilizer, Rhizobium Inoculation and Manure Application on Production of Soybean (*Glycine max* L.) in Northern Nigeria Savanna In: Jayeoba, J. O., Idoga, S., Olatunji, O., Jimin, A. A., Adaikwu, A. O., Ibrahim, F. and anikwe, M. A. N. (eds). (2019). Understanding Nigerian Soils for Sustainable Food Nutrition Security and Healthy Environment. Proceedings of the Soil Science Society of Nigeria, held at the Department of Soil Science, College of Agronomy, Federal University of Agriculture, Makurdi Benue State, Nigeria. 15th-19th July, 2019.

United States Department of Agriculture (USDA) (2015). Natural Resource Conservation Service: Legume Seed Inoculation- Plant Material Technical Note No. TX-pm-15-01.

Wang, L., Yang, K., Gao, C., & Zhu, L. (2020). Effect and mechanism of biochar on CO₂ and N₂O emissions under different nitrogen fertilization gradient from an acidic soil. *Science of The Total Environment*, 747, 141265.

Wilson, K. (2014a). How Biochar Works in Soil, *the Biochar Journal* 2(4) 101-108, 2014 Arbaz Switzerland. Retrieved from (www.biochar-journal.org/en/ct/32) [pp25-33](http://www.biochar-journal.org/en/ct/32).

Wilson, K. (2014b). Justus Von Liebig and the birth of modern biochar. *The Biochar journal* 2014, Arbaz, Switzerland. ISSN 2297-1114. Retrieved from (www.biochar-journal.org/ct/5) [Version](http://www.biochar-journal.org/ct/5) of 24, July 2014) Accessed 24th May, 2021.

Yooyen, J., Wijilkosum, S. and Sriburi, T. (2015). Increasing Yield of Soybean by adding Biochar. *International Journal of Environmental Research and Development*, 9 (1): 1066-1074.

chemical and organic fertilizers to supplement nutrient in soils is one of the fertility management technique recommended for sustainable production of crops in Nigeria (Ogundele, *et al.*, 2020). Though chemical fertilizers contain high concentrations of nutrients, easy to handle and quick release of nutrients; but excessive application may lead to increase in soil acidity and ground water pollution (Akintola, *et al.*, 2021). In Nigeria, inorganic fertilizers are costly and scarce, particularly during cropping seasons (Mahmood *et al.*, 2017; Shehu, *et al.*, 2019). Organic amendments are commonly used by local farmers as a source of nutrients for crops cultivated on nutrient deficient soil. Application of organic amendments supplies essential nutrients, improves physical, chemical and biological properties of soils. Organic amendments also has long term supply capacity for plant nutrients, but generally they are bulky, releases nutrient slowly and contains small quantities of plant essential nutrients (Akintola, *et al.*, 2021).

Application of either organic or inorganic fertilizers for fertility management practices and improved crop production, require periodic and site specific evaluation of soil fertility status is critical. Evaluation of soil fertility is perhaps the most basic decision making tool for appropriate nutrient management strategies (FAO, 2020). There are various techniques for soil fertility evaluation, among them soil testing is the most widely used in the world (Bhatt, 2014). Soil testing assess the current fertility status and provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for maximizing crop yields and to maintain the adequate fertility in soils for longer period (Dinesh *et al.*, 2016).

Most of the research conducted around the area

was on macronutrients assessment and soil characterization (Osujieke, *et al.*, 2018; Ezeaku *et al.*, 2022). Only few studies that have been conducted on the availability of micronutrients around the study area. This study was conducted to assess the macro and micronutrients as well as the fertility status and the availability of some micronutrients in soils of College of Agriculture Teaching and Research Farm, Jalingo, savanna zone of north eastern Nigeria.

MATERIALS AND METHODS

Study Area

The study area, Teaching and Research Farm, College of Agriculture Jalingo has an area of 90 hectares, located between longitude 11°18'13"E to 11°18'50"E and latitude 8°52'29"N to 8°53'10"N. Mean annual rainfall of the study ranges between 700 to 1000mm, while temperature ranges between 15.2 – 39°C. The temperature is high throughout the year with a mean monthly temperature of 26.7°C in the south and 27.8°C in the northern part of the state. Relative humidity varies seasonally in the state. It is extremely low (20 – 30 %) between January and March. It starts increasing as from April and reaches its peak (above 70 %) in August and September. The relative humidity then starts to decrease as from October following the cessation of rains. The study area fall within the Northern guinea savannah zone this is characterized by high grassland with many shrubs and few trees. Common grasses in the study area include: *Cassia ssp.*, *Chloris pilosa*, *Tridax precumbens*, *Euphorbia spp.* (Adebayo, 2012).

The soil in the study is deep, sandy loam on the surface and sandy clay loam in the sub-surface. The color of the soil is yellowish brown and poorly drained. The pH is slightly acidic (6.5 –