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GROWTH AND YIELD OF SOYBEAN (*Glycine Max.* L. Merril) AS INFLUENCED BY COMBINED APPLICATION OF BIOCHAR AND MICRONUTRIENT

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ABSTRACT

The experiments were conducted at the Teaching and Research Farm, Faculty of Agriculture, Shabu–Lafia Campus of Nasarawa State University, Keffi, during the 2018 and 2019 cropping seasons to examine the integrated effects of biochar and micronutrient on the growth and yields 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 was incorporated into the ridges before planting the soybean seeds. Micronutrient at the rate of 0.0, 0.5 and 1 litre/ha was foliar applied two weeks after planting. 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. The results revealed that biochar at the rate of 8 tons/ha, when combined with micronutrient at the rate of 0.5 litre/ha, recorded significantly ($P<0.05$) tallest soybean plant,the highest number of branches and nodules number per plant, heaviest weight of fresh nodules per soybean plant and grain yields (kg/ha) against other treatment combinations. The results also showed that the integration of the highest dose of biochar (12 tons/ha) with the highest dose of micronutrient (1 litre/ha) did not necessarily influence and increased soybean growth and yield parameters tested in this study. Therefore, integration of biochar at the rate of 8 tons/ha with micronutrients at the rate of 0.5 litre/ha is recommended for sustainable soybean production in the study area.

Keywords: Biochar, integrated, growth, soybean, yield

INTRODUCTION

The increasing population, the realization of the concept of balanced nutrition by farmers in Nigeria and the country drive for food security has necessitated the abandonment of the traditional extensive agricultural practices to a more intensive agricultural system that involved the use of high yielding and rapidly growing crop varieties that are nutrient demanding (Mustapha and Loks, 2005). Biochar is a heterogeneous and chemically complex material, made by heating biomass under the exclusion of air (oxygen) through the process known as pyrolysis (Wilson, 2014a). It is one of the oldest soil amendments methods in the history of agriculture (Wilson, 2014b). Biochar improves soil properties, maintains environmental sustainability, increases soil water holding capacity, improves soil aeration, releases plant nutrients and raises soil pH values (Aneseyee and wolde, 2021, 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. Clurman *et al. 2020,* Wang *et al.,* 2020). Biochar improves soil structure, facilitates carbon sequestration and maintains soil fertility (Sun *et al.,* 2021,Yang and Lu 2021, Zheng *et al.,* 2018, Wang, *et al.,* 2017, Kookana *et al., 2011*). Micronutrients are essential elements required by plants in small quantities/amounts. However, their unavailable or inadequacy levels in the soil limit critical plants functions which result in plants abnormalities, reduced growth and consequently low crop yields. They complement the functions of expensive macronutrients that are required by plants in large quantities/amounts.(Kabata-pendias & Pendias, 2011). Brady and Weil ,(2014) stated that micronutrients are required by plants in very small quantities and their concentration in plant tissues is lower than the macronutrients but plays many complex roles in plant nutrition and participate in life - supporting and functioning processes such as enzyme systems in plants. Micronutrients are becoming increasingly important to World agriculture as their removal by crops increases (Brady and Weil, 2014). The increasing attention to micronutrients deficiencies is due to the increase in high - yielding crop varieties which leads to increase uptake of the nutrients from the soil and most chemical fertilizers do not contain the nutrients (Brady and Weil, 2014). Kabata-pendias & Pendias, (2011) and Kumar & Babel, (2011) stated that micronutrients play important role in maintaining soil health and productivity of crops. Micronutrients are important in plant nutrition as macronutrients and have the same agronomic importance as macronutrients and play vital roles in plant growth (Havlin *et al.,* 2014, Nazif *et al.,* 2006). Soybean (*Glycine max*. (L.) Merill) is a species of legume, widely grown for its edible bean which has numerous uses. It is classified by Food and Agricultural Organization (FAO) as an oil-seed rather than a pulse crop. Soybean is a leguminous vegetable crop belonging to the pea family and a native to East Asia which was domesticated in the 11th century BC around Northeast of China. It is believed that it might have been introduced to Africa in the 19th century by Chinese traders along the East coast of Africa. Nigeria is the largest producer of soybean in sub-Saharan Africa (SSA) followed by South Africa. It requires an annual rainfall of more than 700 mm and well- drained and fertile loamy soils with high organic matter and pH range between 6.0 and 7.5. It is produced mostly in the middle belt of Nigeria with Benue State accounting for about 45%-70% of the total production in the country (Dugje *et al.,* 2009). It is an excellent source of dietary fiber Vitamins and Minerals and the only available crop that provides an inexpensive and high- quality source of protein comparable to meat, poultry and eggs. It is a good source of food such as soy-milk, soy-cheese, dadawa (soy-maggi),various vegetables oil, soybean cake for human and livestock etc. It contains more than 36% protein, about 30% carbohydrates and 20% oil (Atli, 2019; Manral and Sexana, 2003). Soybean provides excellent fodder for livestock, improves soil fertility and crop production by adding nitrogen from the atmosphere for its growth and for succeeding crops especially cereal crops 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 (Fairhust, 2012, Dugje *et al.,* 2009). The decomposed leaves of soybean improve soil fertility (Fairhust, 2012). When soybeans are grown in rotation with cereals crops, they serve as catch crops in controlling weeds, especially *striga hermonthica* in maize farms (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- cake, soy- milk, soy- soup, etc. in Lafia by the local populace but combine use of biochar and micronutrient to improve and increase the cultivation of the crop has not received much attention in the study area. Hence the need for this kind of study to encourage local farmers to increase the production of the crop to meet the increasing demands by the inhabitants of the study area. Therefore this study aims at evaluating the combined effects of biochar and micronutrient on the growth and 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, Nasarawa State University, Shabu-Lafia Campus in the Southern Guinea Savannah zone of Nigeria, during the 2018 and 2019 cropping seasons. The experiments were laid out in a randomized complete block design (RCBD) with three replications. Biochar was incorporated into ridges before planting at the rates of 0, 4, 8 and 12 tons/ha. Four (4) seeds of soybean were planted per hole on four manually prepared ridges of 2m long at a spacing of 5cm between plants and at about 75cm between ridges. Seedlings were thinned to two (2) plants at two (2) weeks after planting (WAP) while micronutrient at the rates of 0.0, 0.5 and 1 litres/ha was foliar applied at two weeks after planting (WAP). All data obtained from this study were subjected to analysis of variance (ANOVA) using GENSTAT Statistical Package (discovery edition 1) while the least significant difference (LSD) was used to separate treatment means at 5% level of probability.

RESULTS AND DISCUSSION

The result of the integrated effects of biochar and micronutrient on soybean plant height indicated that biochar at the rate of 8 tons per hectare, when combined with micronutrient at the rate of 0.5 litres per hectare, produced significantly (P<0.05) tallest soybean plant (42.4 and 47.5cm) against other treatment combinations of biochar and micronutrient in 2018 and 2019 cropping seasons respectively (Table 1). This finding is in line with the finding of Ali *et al.* (2021) who reported that integrating biochar with compost considerably enhanced soybean growth parameters probably due to the positive effect of compost- biochar on soil properties. Mete et al. (2015) also reported that the combined application of biochar and NPK increased soybean growth by 84% against the control. Agboola and Moses, (2015) reported that the combined application of biochar and cow dung significantly increased the growth of Soybean. Adissie et al. (2020) reported that Boron as Micronutrient enhanced the biomass of Soybean compared to the control. El-Haggan, (2014) reported that foliar application of the combination of Fe, Zn, Mn and B produced the highest values of plant height and number of branches per plant per hectare compared to the control treatment. The positive influence of the combined application of biochar and micronutrient to soil observed on some plant parameters tested could be explained that the combined application contributed better to improving soil nutrients and could be used to improve soil fertility for sustainable Soybean crop production in the study area.

Table 1: Integrated Effect of Biochar and Micronutrient on Soybean Plant Height (cm) during 2018 and 2019 Cropping Seasons

Biochar (tons/ha)	Micronutrient (L/ha) 2018			Micronutrient (L/ha) 2019		
	0	0.5	1.0	0	0.5	1.0
0	37.9d	40.1c	38.7b	38.9c	41.6c	39.4c
4	38.9b	41,6b	37.6b	40.6a	44.8b	41.0a
8	39.4a	42.4a	40.2a	40.4a	47.5a	41.1a
12	38.4c	39.2d	38.8b	39.4b	40.3d	40.2b
LSD (0.05)	0.24			0.38		

Values within a column followed by the same alphabet are not significantly different at 5% level of probability.

The result of the combined effect of biochar and micronutrient on a number of branches per soybean plant indicated that biochar at the rates of 4 tons and 8 tons per hectare produced a similar number of branches (3.5) when combined with micronutrients at the rate of 0.0 litre per hectare (control) while biochar at the rate of 8 tons per hectare recorded significantly (P<0.05) highest number of branches per soybean plant when integrated with micronutrient at the rates of 0.5 litre/ha (4.5) and 1.0 litres/ha (3.5) during 2018 cropping season (Table 2). The result also showed that biochar at the rates of 4 and 8 tons per hectare when integrated with micronutrients at the rates of 0.5 and 1.0 litres per hectare recorded similar number of branches per soybean plant while biochar at the rate of 4 tons per hectare recorded significantly (P<0.05) highest number of branches per soybean plant (3.8) when combined with micronutrient at the rate of 0.0 litre per hectare during 2019 cropping season. This finding is in line with the finding of Ali *et al.* (2021) who reported that integrating biochar with compost considerably enhanced soybean growth parameters probably due to the positive effect of compost-biochar on soil properties. Mete *et al.* (2015) reported that total biomass production of Soybean increased on average by 67% as a result of the combined application of biochar and NPK fertilizer compared to the control. Agboola and Moses (2015) also reported that the combined application of biochar and cow dung significantly increased soybean growth parameters. Similarly Vyas et al. (2003) reported that combined application of 5kg Zn/ha and 10 tons FYM/ha increased the growth parameters of Soybeans.

Table 2: Integrated Effect of Biochar and Micronutrient on Soybean Number of Branches during 2018 and 2019 Cropping Seasons

Biochar (tons/ha)	Micronutrient (L/ha) 2018			Micronutrient (L/ha) 2019		
	0	0.5	1.0	0	0.5	1.0
0	2.5b	3.5c	3.0c	3.0b	3.3b	2.8a
4	3.5a	3.7b	3.0b	3.8a	4.3a	3.0a
8	3.5a	4.5a	3.5a	3.0b	4.7a	3.0a
12	2.3b	3.0d	3.3c	3.0b	3.3b	2.7a
LSD (0.05)	0.30			0.51		

Values within a column followed by the same alphabet are not significantly different at 5% level of probability.

The result of the combined effect of biochar and micronutrient on nodule number per soybean plant (Table 3) indicated that biochar at the rate of 8 tons per hectare when combined with all micronutrient levels produced significantly ($p<0.05$) the highest number of nodules per soybean plant in the 2018 and 2019 cropping seasons respectively except where biochar at the rate of 4 tons per hectare, when combined with micronutrient at the rate of 1.0 litre per hectare, produced significantly ($p>0.05$) highest number of nodules per soybean plant (15.2) followed by biochar at the rate of 8 tons per hectare (13.5) in 2019 cropping season. This result is in line with the finding of Geeta et al. (2008) who reported a significant increase in the nodule number, nodule dry weight and nodule N content as a result of seed treatment with the combination of zinc and molybdenum and significantly higher dry matter production with the combination of zinc, iron and molybdenum against the control. Adissie et al. (2020) reported that boron as a micronutrient enhanced nodule number, nodule dry weight, biomass of Soybean compared to the control. El-Haggan (2014) reported that foliar application of the combination of Fe, Zn, Mn and B produced significantly highest values of plant height, number of branches per plant, compared to the control treatment. Adissie *et al.* (2020) reported that boron as a micronutrient enhanced nodule number, nodule dry weight of soybean compared to control. The positive influence of the combined application of biochar and micronutrient to soil observed on some plant parameters tested could be explained that the combined application contributed better to improving soil nutrients and could be used to improve soil fertility for sustainable soybean crop production in the study area.

Table 3: Integrated Effect of Biochar and Micronutrient on the Number of Nodules per Plant during 2018 and 2019 Cropping Seasons

Biochar (tons/ha)	Micronutrient (L/ha) 2018			Micronutrient (L/ha) 2019		
	0	0.5	1.0	0	0.5	1.0
0	11.5d	13.5d	13.2d	10.3c	11.5d	11.8d
4	16.2c	19.5b	16.8c	13.7b	17.0b	15.2a
8	18.7a	24.2a	19.5a	15.2a	20.5a	13.5b
12	18.0b	18.0c	18.2b	13.2b	13.2c	12.7c
LSD (0.05)	0.67			0.57		

Values within a column followed by the same alphabet are not significantly different at 5% level of probability.

The result of the integrated effect of biochar and micronutrient on fresh weight of nodules per soybean plant (Table 4) indicated that biochar at the rate of 8 tons per hectare, when combined with at all levels of micronutrient, recorded significantly ($p>0.05$) highest weight of fresh nodule per soybean plant in 2018 and 2019 cropping seasons except micronutrient at the rate of 1.0 litre per hectare in 2019 cropping season where biochar at the rate of 4 tons per hectare produced significantly ($p>0.05$) heaviest weight of fresh nodules (3.3) per soybean plant against other treatment combinations of biochar and micronutrient. The results also showed that biochar at the rate of 0.0 ton per hectare (control) recorded the lowest nodules fresh weight across all levels of micronutrient in both cropping seasons. This finding is in line with the finding of Geeta et al. (2008) who reported a significant increase in the nodule number, nodule dry weight and nodule N content as a result of seed treatment with the combination of zinc and molybdenum and significantly higher dry matter production with the combination of zinc, iron and molybdenum against the control. Adissie et al. (2020) reported that Boron as Micronutrient enhanced nodule number, nodule dry weight and biomass yield of soybean compared to the control. El-Haggan (2014) reported that foliar application of the combination of Fe, Zn, Mn and B produced significantly ($P<0.05$) highest values of plant height, number of branches per plant, compared to the control treatment. Adissie et al. (2020) reported that Boron as a micronutrient enhanced nodule number, nodule dry weight of soybean compared to control. The positive influence of the combined application of biochar and micronutrient to soil observed on some plant parameters tested could be explained that the combined application contributed better to improving soil nutrients and could be used to improve soil fertility for sustainable soybean crop production in the study area.

Table 4: Integrated Effect of Biochar and Micronutrient on the Fresh Weight of Nodules per Plant during 2018 and 2019 Cropping Seasons

Biochar (tons/ha)	Micronutrient (L/ha) 2018			Micronutrient (L/ha) 2019		
	0	0.5	1.0	0	0.5	1.0
0	2.2d	2.6c	2.0d	1.8d	2.1d	2.2d
4	2.6c	3.5b	2.4c	2.9b	4.2b	3.3a
8	3.2a	4.6a	3.6a	3.1a	4.6a	3.0b
12	2.6c	2.7c	2.5c	2.7c	3.0c	2.7c
LSD (0.05)	0.18			0.17		

Values within a column followed by the same alphabet are not significantly different at 5% level of probability.

The result of the combined effect of biochar and micronutrient on 100 seed weight of soybean (Table 5) showed that biochar at the rate of 12 tons/ha, when combined with micronutrient at the rates of 0.0 (control) and 1.0 litre/ha, recorded significantly ($p<0.05$) heaviest weight (13.7 and 14.0g) per 100 seed of soybean while biochar at the rate of 8 tons per hectare when combined with micronutrient at the rate of 0.5 litre/ha recorded significantly ($p>0.05$) heaviest weight (22.4g) per 100 seed of soybean in 2018 cropping season. The result also showed that biochar at the rate of 8 tons/ha, when combined with micronutrient at the rate of 0.5 litre/ha, recorded significantly ($p<0.05$) heaviest weight (17.3g) per 100 seed of soybean while biochar at the rate of 4 tons/ha recorded significantly heaviest weight per 100 seed of soybean when combined with micronutrient at the rates of 0.0 (13.4g) and 1.0 litres/ha (14.3g) during 2019 cropping season. The result further showed that biochar at the rate of 0.0 ton/ha (control) recorded the lowest weight per 100 seed weight when combined with all levels of micronutrient in both cropping seasons. Mete et al. (2015) reported that seed yield of Soybean increased on average by 84% as a result of the combined application of biochar and NPK fertilizer compared to the control. Agboola and Moses ,(2015) also reported that the combined application of biochar and cow dung significantly increased yield parameters. Similarly, Ali et al, (2021) reported that integrating biochar with compost considerably enhanced Soybean yield. Vyas et al. (2003) reported that the combined application of 5kgZn/ha and 10 tons FYM/ha increased grain yield of soybean (1790 kg/ha) by 18% over the control (1515 kg/ha). This result revealed the advantage and benefit of integrating biochar and micronutrient for soybean production as reflected in all parameters tested probably because of soil improvement by one or all of them and could be used to improve soil nutrients and soil fertility for sustainable soybean crop production in the study area.

Table 5: Integrated Effect of Biochar and Micronutrient on 100 seed Weight of Soybean during 2018 and 2019 Cropping Seasons

Biochar (tons/ha)	Micronutrient (L/ha) 2018			Micronutrient (L/ha) 2019		
	0	0.5	1.0	0	0.5	1.0
0	12.4d	13.1d	12.5d	11.9c	12.8d	13.2c
4	13.2c	20.0b	13.0c	13.4a	14.9b	14.3a
8	13.5b	22.4a	13.9b	12.8b	17.3a	13.7b
12	13.7a	14.4c	14.0a	12.8b	13.8c	12.8c
LSD (0.05)	0.16			0.43		

Values within a column followed by the same alphabet are not significantly different at 5% level of probability.

The results of the integrated effect of biochar and micronutrient on seed yield per hectare (Table 6) indicated that biochar at the rate of 8 tons/ha recorded significantly ($p<0.05$) heaviest weight of soybean seed per hectare when combined with all levels of micronutrient (1306.3, 1388.3 and 1221.7 kg/ha) in 2018 and 2019 cropping seasons respectively. The result also showed that biochar at the rate of 4 tons/ha recorded significantly ($p<0.05$) heaviest weight (1312.0 and 1398.7 kg/ha) of seed of soybean per hectare when combined with micronutrient at the rates of 0.0litre/ha (control) and 0.5 litre/ha and biochar at the rate of 8 tons/ha recorded significantly ($p<0.05$) heaviest weight (1227.3kg/ha) seed yield of soybean per hectare when combined with micronutrient at the rate of 1.0 litre/ha during 2019 cropping season. The results further revealed that biochar at the rate of 0.0 ton/ha (control) recorded lowest seed yield per hectare across all levels of micronutrient in both 2018 and 2019 cropping seasons respectively. Mete et al. (2015) reported that seed yield of Soybean increased on average by 84% as a result of the combined application of biochar and NPK fertilizer compared to the control. Agboola and Moses (2015) also reported that combined application of biochar and cow dung significantly increased soybean yield parameters. Similarly, Ali et al. (2021) reported that integrating biochar with compost considerably enhanced Soybean yield. Vyas et al. (2003) reported that combined application of 5 Kg Zn/ha and 10 tons FYM/ha increased grain yield of Soybeans (1790 kg/ha) by 18% over the control (1515 kg/ha). Geeta et al. (2008) reported a significant increase in yield in soybean with the combination of zinc, iron and molybdenum against the control. Adissie et al. (2020) reported that boron as micronutrient enhanced the yield of soybean compared to the control. El-Haggan (2014) reported that foliar application of the combination of Fe, Zn, Mn and B produced the highest values of 100 seed weight, seed yield per plant and hectare compared to the control treatment. This result revealed that integrating biochar and micronutrient has a strong influence on the growth and yield parameters of soybean tested probably because of soil improvement by one or all of them and could be used to improve soil nutrients and soil fertility for sustainable soybean crop production in the study area.

Table 6: Integrated Effect of Biochar and Micronutrient on Seed Yield per Hectare during 2018 and 2019 Cropping Seasons

Biochar (tons/ha)	Micronutrient (L/ha) 2018			Micronutrient (L/ha) 2019		
	0	0.5	1.0	0	0.5	1.0
0	732.0d	1300.7d	1150.3d	734.7d	1309.7d	1163.3d
4	1186.7b	1342.3b	1197.7b	1312.0a	1398.7a	1203.0b
8	1306.3a	1388.3a	1221.7a	1193.7b	1353.7b	1227.3a
12	1067.3c	1317.0c	1186.0c	1073.3b	1321.0c	1192.0c
LSD (0.05)	0.20			0.43		

Values within a column followed by the same alphabet are not significantly different at 5% level of probability.

CONCLUSION AND RECOMMENDATION

From the results of this study, it can be concluded that combined application of biochar and micronutrient significantly (P<0.05) and positively influenced soybean plant growth and yield parameters. The results of this study showed that the combined application of biochar at the rate of 8 tons/ha and micronutrient at the rate of 0.5 litre/ha was found to have performed significantly (P<0.05) best as reflected in all the variables measured compared to all other treatment combinations. The results further revealed that the combined application of the highest dose of biochar (12 tons/ha) and micronutrient (1 litre/ha) in this study did not necessarily result in increased soybean growth and yield parameters tested. Therefore, integrating biochar at the rate of 8 tons/ha with micronutrients at the rate of 0.5 litre/ha is recommended for sustainable soybean production and yield increase in the study area.

REFERENCES

Adissie, S., Adgo, E., Feyisa, T, Tejada, M. (2020). Effect of Rhizobial Inoculants and micronutrients on yield and yield components of Fababeen (Vicia faba L.) on vertisol of wecillu District, South Wollo, Ethiopia, *Journal of Soil and Crop Sciences*, 6 (1)344-352.

Agboola, K. and Moses, S.A. (2015). Effect of Biochar and Cow dung on Nodulation, Growth and Yield of Soybean (Glycine max L.merrill.). *International Journal of Agriculture and Biosciences*, 3(4)154-160 Retrieved from (www.semomticsscholar.org) 04/02/21.

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.

Aneseyee, A. B., and Wolde, T. (2021). Effect of Biochar and Inorganic Fertilizer on the Soil Properties and Growth and Yield of Onion (Allium cepa) in Tropical Ethiopia. *The Scientific World Journal*, 2021.

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*, 277:111443–111455.

Atli, A. (2019). Nutrition Fact and Health Effects. Iceland: Headline Press.

Brady, N.C. and Weil, R.R. (2014). The Nature and Properties of Soils. 14t Edition. India Subcontinent Version. Dorling Kindersley (India) Pvt.Ltd. Pp 1046.

Clurman A.M, Rodriguez-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*, 402:126277–126289.

Dugje, I.Y., Omoigul, L.O., Ekolene, F., Bandyopadhyay, .R.. Lavakumar, P. and Kamara, A.Y.(2009). Farmers Guide to Soybean Production in Northern Nigeria. IITA- Ibadan 21pp.

El-Haggan, E.A.L.M.A.(2014).Effect of Micronutrients foliar application on Yield and quality traits of Soybean Cultivars. *International Journal of Agriculture and Crop Sciences* (IJACS).7(11):908-914.

Fairhurst, T. (ed.) 2012 Handbook for Integrated Soil Fertility Management. Africa Soil Health Consortium, CAB International, Nairobi, Kenya. Pp.124.

Geeta, G., Mudenoor, M.G. and Savalgiv,V.P. (2008).Effect of Micronutrient Supplemented Bradyrhizobium Bio-fertilizers on Nodulation, Dry matter production and Yield of Soybean (Glycine max(L.).merrill). *International Journal of Legume Research*.31(1):20-25.

Havlin, J. L., Tisdale, S. L, Nelson, W. L. and Beaton, J. D. (2014) Soil Fertility and Fertilizers. An Introduction to Nutrient Management. 8th Edition. Pearson Education /India Edition., PHI Learning private Ltd, New Delhi..Pp516.

Kabata-pendias, A. and Pendias, H. (2011).Trace Elements in Soils and Plants. Taylor and Francis Group LLC. Fourth Edition. CRV press, Boca Raton, Florida. Pp505.

Kookana R.S, Sarmah A.K, Van Zwieten L, Krull E, Singh B (2011) Biochar application to soil: agronomic and environmental benefits and unintended consequences. *Advance Agronomy*, 112:103–143.

Kumar,M. and Babel,A.L. (2011). Available Micronutrients Status and their Relationship with Soil Properties of Jhunjhunu Tehsil District Jhunjhunu, Rajasthan, *India. Journal of Agriculture, 3(2):97-106.*

Manral, H.S. and Saxena, S.C. (2003). Organic formulations for effective growth and yield in vegetables. *Indian Journal of Agronomy*, 46(1):135 – 140.

Mete, F. Z, Mia, S., Dijlstra, 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(1): 718 -71 9.

Mustapha, S. and Loks,N.A.(2005).Distribution of Zinc, Copper, Iron and manganese in the Fadama Soils from two Distinct Agro-ecological Zones in Bauchi State, Nigeria. *Journal of Environmental Science.* 9(2): 22-28.

Nazif, W., Perveen, S. and Saleem, I. (2006). Status of Micronutrients in Soils of District Bhimber,Azad Jammu and Kashmir. *Journal of Agriculture and Biological Sciences*,1::34-40.

Schmidt, H. P. and Wilson, K. (2014). The 55 Uses of Biochar. *The Biochar Journal*, 2014, Arbaz, Switzerland, ISSN 2297-1114.

Sun, Q., Meng, J., Lan, Y., Shi, G., Yang, X., Cao, D. and Han, X. (2021). Long-term effects of biochar amendment on soil aggregate stability and biological binding agents in brown earth. *Catena*, 205, 105460.

Vyas, M.D., Jian, A.K. and Tiwari, R.J.(2003).Long-term Effect of Micronutrients and FYM on yield of and Nutrient uptake of Soybean on a Typic Chroustert .*Journal of the Indian Society of Soil Science*.2003.51(1):45-47.

Wang L, Yang, K., Gao, C.C, and Zhu, L.Z. (2020). Efect and mechanism of biochar on CO_2 and N_2O emissions under diferent nitrogen fertilization gradient from an acidic soil. *Science Total Environment,* 747:141265.

Wang. D., Fonte, S.J.,Parikh, S.J., Six, J,and Scow, K.M. (2017). Biochar additions can enhance soil structure and the physical stabilization of C in aggregates. *Geoderma*, 303: 110-117.

Wilson, K. (2014a). How Biochar Works in Soil. *The Biochar Journal* 2(4)101-108.

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 of 24, July 2014) Accessed 24th May, 2021.

Yang, C.D. and Lu, S.G. (2021) Efects of five diferent biochars on aggregation, water retention and mechanical properties of paddy soil: A field experiment of three-season crops. *Soil and Tillage Research.* 205:104798–104808.

Zheng, H., Wang, X., Luo, X.X., Wang, Z.Y, and Xing, B.S. (2018) Biochar induced negative carbon mineralization priming effects in a coastal wetland soil: Roles of soil aggregation and microbial modulation. *Science Total Environment* 610:951–96