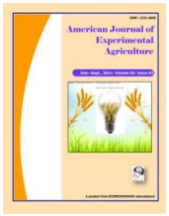

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Response of Maize Varieties (*Zea mays*) to Biochar Amended Soil in Lafia, Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author SND designed the study, wrote the protocol and wrote the first draft of the manuscript. Author EN reviewed the experimental design and all drafts of the manuscript. Authors SND and EDA managed the analyses of the study. Author EN identified the plants. Authors EN and SND performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

The experiments were conducted during 2010 and 2011 at the research and teaching farm of the college of agriculture, Lafia, Nasarawa state, Nigeria. To determine the effect of biochar-amended soil on the performance of maize varieties (*Zea mays)*. The study was carried out in screen house and field. The first phase of the experiment: treatment consist of three rates of biochar: 0, 100, 200g/pot and maize varieties (Oba 98 and Sammaize 18). The second phase of the experiment was carried out in the field; the treatment consisted of three levels of biochar: 0, 5, 10t/ha and two varieties of maize (oba 98 and sammaize 18) factorialy combined to form six treatments. The experimental design used was Randomized Complete Block Design (RCBD). The result showed that 10t/ha Biochar had a significant (P=0.05) effect on the percentage germination, seedling height, seedling stem girth, number of roots, length of roots and seedling vigour index. Application of 10t/ha of biochar produced the highest grain weight of 5.05 t/ha and 5.54 t/ha in both years; which is at par with application of 5t/ha of biochar, but higher than control (3.5t/ha and 3.32t/ha) in both years. However, maize varieties did not showed any significant effect in both cropping season, but oba 98 proofs to be superior to the other variety in most of the character assessed. Interaction between biochar and maize varieties did not produced any significant effect.

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1. INTRODUCTION

Biochar is a stable form of charcoal produced from heating natural organic materials (crop biomass, woodchips, manure and other agricultural waste) in a high temperature of bellow 1000℃ and low oxygen; the process is known as pyrolysis [1]. The addition of biochar as amendment materials to agricultural soils is receiving much attention due to the apparent benefits of biochar to soil quality and enhanced crop yields, as well as the potential to gain carbon credits by active carbon sequestration [2]. Studies conducted by these scientists [3-9] have shown that biochar can aid in: soil nutrients improvement, cation exchange capacity in the soil, decrease soil acidity, improve soil structure, nutrient use efficiency, improve water-holding capacity and carbon sequestration. The problem of infertile soils and variable climatic condition makes it difficult to reach higher crop yields especially with essential cereal crop like maize which is an exhaustive and vigorous growing crop [10]. Maize is one of the main cereal crops of West Africa, and the most important cereal food crops in northern Nigeria. Maize has established itself as a very significant component of the farming system and determines the cropping pattern of the predominantly peasant farmers in northern Nigeria [11]. Maize has been of great importance in providing food for man, feed for livestock and raw materials for some agro-based industries. Maize consists of 71% starch, 9% protein and 4% oil on a dry weight basis [12]. Despite the importance of maize to the teeming population of Nigerians, its production has not met the food and industrial requirement of the country [13]. This may be attributed to soil deterioration from depletion of organic matter which is a serious global problem. When the soil is intensively cultivated with high levels of chemical fertilization, the organic matter in the soil is quickly decomposed into carbon dioxide by soil microbes and this gas released into the atmosphere, leaving the soil compacted and nutrient-poor as well as adding to global warming [14]. One feasible measure to increase soil fertility is addition of biochar [15]. There are a number of experiments conducted to examine the yield of maize with biochar-amended soils. In most of these studies, biochar application increased crop yields of maize over the control between 2.2 tonnes per hectare [16-18]. Other studies found increases in maize yield due to biochar amendment ranging from 20% to 140% above control plots [19-21]. However, all these experiment were not conducted in the Guinea savanna agro ecological zone of Nigeria; which is one of maize producing zone. Therefore, the objective of this research is to evaluate the effect of biochar amended soil on growth and yield of maize varieties.

2. MATERIALS AND METHODS

The study was carried out at the teaching and research farm of college of agriculture Lafia; Nasarawa state. Nigeria. The study falls within the guinea savanna zone of North central Nigeria and is located between latitude 08.33 N and longitude 08.32 N. The mean annual temperature and rainfall of the study area for 2010 is 30-31℃ and 118.56 mm [22]. The soil type of the study area composed of highly leached ultisols with low base saturation. The soil is strongly acidic and has high content of iron and Aluminium oxides hence reddish brown in colour with very low organic matter content and low total nitrogen and available phosphate. The dominant clay type is Kaolinite. The vegetation of the study area is that of the southern Guinea Savanna with interspersion of thicket, grassland, trees, fringing woodlands or gallery forest along the streams. The study was carried out in two phases (screen house trial and field trials) during the wet seasons of 2010 and 2011. The treatments of the first phase of the experiment consist of three rates of biochar: 0, 100, 200g/pot and oba 98, Sammaize 18 varieties of maize. Then 3kg of soil samples obtained from teaching and research farm of college of agriculture Lafia; were filled in each plastic pot and replicated three times giving the total number of 18pots. The experimental design used was complete randomized design (CRD) and five Maize seeds of Oba 98 and sammaize 18 were planted in each pot and other agronomic practices were applied. The second phase of the experiment was done in the field; the treatment consisted of three levels of biochar: 0, 5, 10t/ha and two varieties of maize: oba 98 and sammaize 18 factorialy combined together to form six treatments. The experimental design used was Randomized Complete Block Design (RCBD) and replicated three times to form eighteen plots. The plot size was 4m by 4m and 0.5m between plots and 1m between replicates. Soil samples were taken at a depth of 0-15cm before planting and after harvesting of maize in the second season and were analyzed as presented in Table 1. The land was cleared,

ploughed and harrowed; then Charcoal of hard wood bought from a local distributor was manually crushed to particle sizes smaller than 2 mm and incorporated at different rates into the soil. Oba 98 and sammaize 18 were planted on the same plots at spacing of 70cm X 25cm at the same time. The same quantity of NPK fertilizer was applied on each plot; weeding and other agronomic practices were done timely.

3. DATA COLLECTION

The data taken in the experiment include: days to first germination. Number of leaflets, seedling height, number of roots, length of roots, seedling stem girth, and seedling vigour index (percent germination x seedling height). In the field experiment, four plants were selected in the net plot for collection of the following data in both years: Number of leaves, plant height (cm), days to first cob formation, days to 50% cobs formation, 100 grain weight(g), grain weight (g/plant), grain weight(t/ha).

4. DATA ANALYSIS

The data collected were subjected to analysis of variance using GENSTAT, and where there is a significant difference; the means were separated using F-LSD at 5% probability level.

5. RESULTS AND DISCUSSION

The chemical analysis of the soil before planting showed that nitrogen, phosphorus, potassium, organic carbon and cation exchange capacity are very low (Table 1). However, the soil was acidic in nature (5.04). The biochar material contained higher quantities of carbon and carbon/nitrogen ratio. This signified that the decomposition of the material will continue at the maximum rates and nitrogen will be released for crops to absorb.

Table1. Analysis of soil and woody biochar before experiment

Soil properties @ 0- 15cm	Soil sample before planting	Woody biochar
Mechanical composition		
Clay (g/kg)	8.64	-
Silt	11.14	-
Sand	80.22	-
Textural classification (USD)	Sandy loam	-
Chemical composition		
pH(H2O)	5.18	8.15
pH(0.01MCaCl2)	5.04	7.82
T N%	0.13	0.82
Avail. P(ppm)	18.08	3.84
K(mg/kg)	0.16	5.4
OC(mg/kg)	0.42	64
C/N	3.23	78
Mg(mol/kg)	1.45	1.9
Ca(mol/kg)	2.21	1.5
Na(mol/kg)	0.85	1.8
CEC(mol/kg)	4.67	10.60

The result of soil properties under different biochar treatment sampled after two years of maize cropping are presented in Table 2. The result showed that increased biochar application resulted to gradual increase in most of the chemical properties in the soil except H+Al (acidity).

Biochar had a significant (P=0.05) effect on the percentage germination, seedling height, seedling stem girth, number of roots, roots length and seedling vigour index (Table 3).

Table 2. Chemical analysis of soil incorporated with different rates of biochar after experiment

Treatment	pH ratio		(%)		(ppm)	(Cmol/kg)					
Biochar (t/ha)	H_2O	0.01 $Cacl_2$	OC	TN	Av. P	Ca	Mg	K	Na	H+Al	CEC
0	6.25	5.54	0.37	0.18	12.16	4.43	1.00	0.70	0.45	0.59	6.58
5	6.65	5.77	0.44	0.27	14.21	4.22	1.22	0.86	0.41	0.48	6.71
10	6.91	5.83	0.56	0.38	13.87	5.34	1.50	1.59	0.42	0.43	8.85

Table 3. Effects of biochar on maize seedling germination and growth at three weeks after sawing

Treatment	Days to first germination	Percent germination (%)	Number of leaflets	Seedling height (cm)	Seedling stem girth (cm)	No. of roots/plnt	Roots length (cm)	Seedling vigour index (%)
Woody biochar (g/pot)								
0	4.53	71.24a	4.64	20.54b	1.24b	10.23b	8.97b	1463.26
100	4.67	85.71b	4.67	22.45b	1.27a	12.53a	9.89b	1924.18
200	4.60	85.71b	4.67	27.68 a	1.39a	12.93a	13.19a	1924.18
LSD(0.05)	0.45	8.25	0.46	4.15	0.13	1.42	3.30	243.24
SE	0.22	4.16	0.24	2.07	0.07	0.72	1.71	121.62
%CV	3.12	1.45	1.32	2.12	2.52	2.41	3.15	5.56
Maize varieties								
Oba 98	4.72	85.71	4.52	23.10	1.24	12.56	12.45	1924.18
Sammaize 18	4.62	85.71	4.50	23.00	1.35	12.67	12.24	1924.18
LSD(0.05)	0.35	2.21	0.40	11.30	0.24	0.45	0.25	253.42
SE	0.18	1.10	0.20	5.65	0.12	0.23	0.13	126.72
%CV	2.23	3.12	1.45	2.65	2.23	1.67	2.12	4.56
Interaction								
WBXMV	NS	NS	NS	NS	NS	NS	NS	NS

WB= Woody biochar, MV= Maize Varieties

Application of 10t/ha of biochar generally produced the highest improvement in the above parameters assessed which was better than the control. However, 5t/ha of biochar produced statistically comparable effect with control in seedling height (22. 45cm and 20. 54cm); roots length (9.89cm and 8.97cm) respectively. There was no significant different among the maize varieties used.

There was no significant (p=0.05) difference in application of biochar on number of leaves and plant height produced in both years (Table 4). However, increased application of biochar produced a graduate increase in number of leaves and plant height. Also, interaction between biochar and maize varieties did not produced any significant (p=0.05) effect on number of leaves and plant height in both years of cropping. 2011 cropping season produced higher number of leaves and plant height.

Table 4. effect of Woody biochar on growth parameters of maize varieties at 6 weeks after planting

Treatment	Number of leaves		Plant height	
Woody biochar(t/ha)	2010	2011	2010	2011
0	9.44	9.50	89.96	88.87
5	9.47	9.69	90.32	89.15
10	9.61	9.75	91.91	91.42
LSD(0.05)	0.25	0.50	13.84	12.33
SE	0.13	0.25	7.23	6.12
%CV	1.53	2.12	2.24	1.89
Maize varieties				
Oba 98	9.52	9.67	90.10	88.05
Sammaize 18	9.50	9.63	91.00	91.52
LSD(0.05)	0.40	0.41	11.30	10.07
SE	0.20	0.21	5.65	5.05
%CV	2.12	3.25	2.45	2.54
Interaction				
WBXMV	NS	NS	NS	NS

WB= Woody biochar, MV= Maize Varieties

Biochar showed a significant (p=0.05) effect on general grain weight and 100 grain weight of maize in 2010 and 2011 cropping season (Table 5). Application of 10t/ha of biochar produced the highest grain weight of 5.05 t/ha and 5.54 t/ha in both years; which is at par with application of 5t/ha of biochar, but higher than control (3.5t/ha and 3.32t/ha) in both years. However, maize varieties did not showed any significant effect in both cropping season. Interaction between biochar and maize varieties did not produced any significant (p=0.05) effect.

6. DISCUSSION

The vigorous performance of maize seedling exhibited by application of higher rates of biochar in both years in the pot experiment could be attributed to the fact that the soil in the study area consist of higher quantity of sandy particles, low clay content and deficient in some macro-nutrient (Table 1). When biochar was incorporated into the soil it reduces the sizes of the soil pores thereby increasing water holding capacity, increased Cation Exchange Capacity (CEC), and providing a medium for adsorption of minimal plant nutrients and improved conditions for soil micro-organisms [23]. This explains why amending the soil with biochar brought about visible improvement in the performances of maize seedling. In the field experiment on maize, yield is often reported to increase with biochar application to soil. The significant response of maize to biochar amended soil increases with application of biochar rates on the soil. Increases biochar application increased crop yields of maize over the control between 29.9% to 30% from the first year to the second year of cropping. This improvement in yield is as a result of incorporation of biochar into the soil which aid in: soil nutrients improvement, cation exchange capacity in the soil, decrease soil acidity, improve soil structure, nutrient use efficiency, improve water-holding capacity and carbon sequestration [9]. This result collaborate the findings of [24] who also reported increase in maize yield of 20% to 140% due biochar soil amendment above control. These findings were confirmed by more recent reviews by[25] who published data from 59 pot experiments and 57 field experiments from 21 countries and found crop productivity was increased by 11% on average. Liu also discovered that field application of biochar rates below 30 tons/ha reported increases in crop productivity which varied with crop type with greater increases for legume crops (30%), vegetables (29%), and grasses (14%) compared to cereal crops like corn (8%), wheat (11%), and rice (7%). [26], also reported 10% increases in crop productivity over the control at biochar application rates of 10, 25, 50, 100tons/ha.

Table 5. Effect of Woody biochar on yield parameters of maize varieties

Treatment	Days to 1st cobs formation		Days to 50% cobs formation		Grain weight (g/plant)		Grain weight (t/ha)		100 grain weight(g)	
Woody biochar (t/ha)	2010	2011	2010	2011	2010	2011	2010	2011	2010	2011
0	48.94	48.94	55.78	55.28	63.12	60.65	3.54	3.32	30.06	31.06
5	48.33	47.78	55.44	55.44	82.04	83.45	4.55	4.62	31.39	31.72
10	48.67	48.50	56.11	56.00	91.16	98.54	5.05	5.54	32.17	33.39
LSD(0.05)	1.20	1.19	0.73	0.70	9.85	14.42	1.25	1.36	1.39	1.33
SE	0.51	0.50	0.36	0.30	4.54	7.21	0.51	0.53	0.54	0.16
%CV	2.14	2.45	2.65	3.03	3.25	2.67	2.45	2.13	2.87	3.65
Maize varieties										
Sammaize 18	48.85	48.37	55.78	55.78	76.69	76.15	4.21	4.28	32.74	31.52
Oba 98	47.78	48.44	55.78	55.78	78.12	78.65	4.35	4.42	37.00	32.59
LSD(0.05)	0.98	0.98	0.59	0.60	2.56	2.85	1.45	1.35	2.77	2.35
SE	0.49	0.49	0.29	0.30	1.48	1.42	0.53	0.52	1.34	1.17
%CV	2.56	3.24	4.32	2.14	2.25	3.24	2.12	2.56	2.45	2.32
Interaction										
WBXMV	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

WB= Woody biochar, MV= Maize Varieties, NS= No significant at 0.05 probability

7. CONCLUSION

The results obtained in this study reveal that, addition of biochar improves maize seedling vigour. This is translated into better growth and increased yield of maize in the field. Application of 5t/ha of biochar produced optimal yield of maize. However long time field trials should be conducted to document the effect of biochar on the yield and the soil properties.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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