

## Original Research Article

### RESPONSE OF MAIZE VARIETIES (*Zea mays*) TO BIOCHAR AMENDED SOIL IN LAFIA, NIGERIA.

#### ABSTRACT

The experiments were conducted during 2010 and 2011 rainy seasons 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 performances of maize varieties (*Zea mays*). The study was carried out in ~~screen two phases (green house trial and field trials)~~. 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). ~~3kg of soil samples from teaching and research farm of college of agriculture Lafia; were filled in each plastic pot and replicated three times. The experimental design used was complete randomized design (CRD); and five Maize seeds of Oba 98 and sammaize 18 were planted in each pot.~~ 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 ~~obtained~~ 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. 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) and stem girth respectively. ~~There was no significant ( $p=0.05$ ) difference in application of biochar on number of leaves and plant height produced in both years. 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 in both years of cropping. Biochar also showed a significant ( $p=0.05$ ) effect on 100grain weight, cobs weight/plot and cobs weight/ha in 2010 and 2011 cropping season. Application of 10t/ha of biochar produced the highest 100grain weight of 31.17g and 33.39g, cobs weight/plot of 2.28kg and 2.39kg; cobs weight/ha of 1.45t/ha and 1.73t/ha in both years. This is statistically at par with application of 5t/ha of biochar, but higher than control (1.34t/ha and 1.31t/ha) in 2010 and 2011 cropping season. 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 ( $p=0.05$ ) ~~difference~~ differences.

KEY WORDS: Biochar, Maize, Amended soil, Varieties

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46 **INTRODUCTION**

47 Biochar is a stable form of charcoal produced from heating natural organic materials (crop  
48 biomass, woodchips, manure and other agricultural waste) in a high temperature of below  
49 1000<sup>0</sup>c and low oxygen; the process is known as pyrolysis [1]. The addition of biochar as  
50 amendment materials to agricultural soils is receiving much attention due to the apparent  
51 benefits of biochar to soil quality and enhanced crop yields, as well as the potential to gain  
52 carbon credits by active carbon sequestration [2]. Studies conducted by these scientist [3; 4; 5;  
53 6; 7; 8 and 9] have shown that biochar can aid in: soil nutrients improvement, cation exchange  
54 capacity in the soil, decrease soil acidity, improve soil structure, nutrient use efficiency, improve  
55 water-holding capacity and carbon sequestration. The problem of infertile soils and variable  
56 climatic condition makes it difficult to reach higher crop yields especially with essential cereal  
57 crop like maize which is an exhaustive and vigorous growing crop [10]. Maize is one of the main  
58 cereal crops of West Africa, and the most important cereal food crops in northern Nigeria.  
59 Maize has established itself as a very significant component of the farming system and  
60 determines the cropping pattern of the predominantly peasant farmers in northern Nigeria [11].  
61 Maize has been of great importance in providing food for man, feed for livestock and raw  
62 materials for some agro-based industries. Maize consists of 71% starch, 9% protein and 4% oil  
63 on a dry weight basis [12]. Despite the importance of maize to the teeming population of  
64 Nigerians, its production has not met the food and industrial requirement of the country [13].  
65 This may be attributed to soil deterioration and depletion of organic matter which is a serious  
66 global problem. When the soil is intensively cultivated with high levels of chemical fertilization,  
67 the organic matter in the soil is quickly decomposed into carbon dioxide by soil microbes and

68 this gas released into the atmosphere, leaving the soil compacted and nutrient-poor as well as  
69 adding to global warming [14]. One feasible measure to increase soil fertility is addition of  
70 biochar [15]. There are a number of experiments conducted to examine the yield of maize with  
71 biochar-amended soils. In most of these studies, biochar application increased crop yields of  
72 maize over the control between 2.2 tonnes per hectare [16; 17; 18]. Other studies found  
73 increases in maize yield due to biochar amendment ranging from 20% to 140% above control  
74 plots [19; 20 and 21]. However, all these experiment were not conducted in the Guinea savanna  
75 agro ecological zone of Nigeria; which is one of maize producing zone. Therefore, the objective  
76 of this research is to evaluate the effect of biochar amended soil on growth and yield of maize  
77 varieties.

## 78 MATERIALS AND METHODS

79 The study was carried out at the teaching and research farm of college of agriculture Lafia;  
80 Nasarawa state. Nigeria. The study falls within the guinea savanna zone of North central Nigeria  
81 and is located between latitude 08.33 N and longitude 08.32 N. The mean annual temperature  
82 and rainfall of the study area for 2010 is 30- 31°C and 118.56 mm [22]. The soil type of the  
83 study area composed of highly leached ultisols with low base saturation. The soil is strongly  
84 acidic and has high content of iron and Aluminium oxides hence reddish brown in colour with  
85 very low organic matter content and low total nitrogen and available phosphate. The dominant  
86 clay type is Kaolinite. The vegetation of the study area is that of the southern Guinea Savanna  
87 with interspersed of thicket, grassland, trees, fringing woodlands or gallery forest along the  
88 streams. The study was carried out in two phases (~~screening~~ house trial and field trials)  
89 during the wet seasons of 2010 and 2011. The treatment of the first phase of the experiment  
90 consists, treatment consist of three rates of biochar: 0, 100, 200g/pot and oba 98, Sammaize 18  
91 varieties of maize. Then 3kg of soil samples obtained from teaching and research farm of  
92 college of agriculture Lafia; were filled in each plastic ~~pot~~<sub>2</sub> and replicated three times giving  
93 the total number of 18pots. The experimental design used was complete randomized design

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94 (CRD) and five Maize seeds of Oba 98 and sammaize 18 were planted in each pot and other  
95 agronomic practices were applied. The second phase of the experiment was done in the field;  
96 the treatment consisted of three levels of biochar: 0, 5, 10t/ha and two varieties of maize: oba  
97 98 and sammaize 18 factorially combined together to form six treatments. The experimental  
98 design used was Randomized Complete Block Design (RCBD) and replicated three times to  
99 form eighteen plots. The plot size was 4m by 4m and 0.5m between plots and 1m between  
100 replicates. Soil samples were taken at a depth of 0-15cm before planting in the first season and  
101 were analyzed as presented in table 1. The land was cleared, ploughed and harrowed; then  
102 Charcoal of hard wood bought from a local distributor was manually crushed to particle sizes  
103 smaller than 2 mm and incorporated at different rates into the soil. Oba 98 and sammaize 18  
104 were planted on the same plots at spacing of 70cm X25cm at the same time. The same quantity  
105 of NPK fertilizer was applied on each plot; weeding and other agronomic practices were done  
106 timely.

#### 107 **DATA COLLECTION**

108 The data taken in the experiment include: days to first germination. No. of leaflets, seedling  
109 height, no. of roots, length of roots, seedling stem girth, and seedling vigour index (percent  
110 germination x seedling height). In the field experiment, four plants were selected in the net plot  
111 for collection of the following data in both years: number of leaves, plant height (cm), days to  
112 first cob formation, days to 50% cobs formation 100 grain weight/plot (kg/ha), weight/plot  
113 (kg/ha), and grain weight(t/ha).

#### 114 **DATA ANALYSIS**

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

#### 117 **RESULTS AND DISCUSSION**

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

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Table 1. Soil sample and woody biochar

| Soil properties<br>@ 15cm     | Soil sample<br>before planting | Soil sample after<br>two years of cropping | Woody biochar |
|-------------------------------|--------------------------------|--------------------------------------------|---------------|
| <b>Mechanical composition</b> |                                |                                            |               |
| Clay (g/kg)                   | 8.64                           | 7.67                                       | -             |
| Silt                          | 26.21                          | 7.67                                       | -             |
| Sand                          | 65.22                          | 88.55                                      | -             |
| Textural classification (USD) | Loamy Sand                     | sand                                       | -             |
| <b>Chemical composition</b>   |                                |                                            |               |
| pH(H <sub>2</sub> O)          | 5.18                           | 6.25                                       | 8.15          |
| pH(0.01M CaCl <sub>2</sub> )  | 5.04                           | 5.54                                       | 7.82          |
| T N%                          | 0.13                           | 0.18                                       | 0.82          |
| Avail. P(ppm)                 | 18.08                          | 14.16                                      | 3.84          |
| K(mg/kg)                      | 0.16                           | 0.70                                       | 5.4           |
| OC(mg/kg)                     | 0.42                           | 0.37                                       | 64            |
| C/N                           | 3.23                           | 2.05                                       | 78            |
| Mg(mol/kg)                    | 4.49                           | 1.00                                       | 1.9           |
| Ca(mol/kg)                    | 4.34                           | 4.43                                       | 1.5           |
| Na(mol/kg)                    | 0.85                           | 0.45                                       | 1.8           |
| CEC(mol/kg )                  | 8.75                           | 6.51                                       | 78.25         |

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130 Biochar had a significant (P=0.05) effect on the percentage germination, seedling height,  
 131 seedling stem girth, number of roots, roots length and seedling vigour index (table 2).  
 132 Application of 10t/ha of biochar generally produced the highest improvement in the above  
 133 parameters assessed which was better than the control. However, 5t/ha of biochar produced  
 134 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.

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Table 2: effects of biochar on maize seedling germination and growth at three weeks after sowing in pot experiment

| 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 (%) |
|------------------------------|---------------------------|-------------------------|--------------------|----------------------|-------------------------|-------------------|-------------------|---------------------------|
| <b>Woody biochar (g/pot)</b> |                           |                         |                    |                      |                         |                   |                   |                           |
| 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                    |
| <b>Maize varieties</b>       |                           |                         |                    |                      |                         |                   |                   |                           |
| 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                    |
| <b>Interaction</b>           |                           |                         |                    |                      |                         |                   |                   |                           |
| WBXMV                        | NS                        | NS                      | NS                 | NS                   | NS                      | NS                | NS                | NS                        |

WB= Woody biochar, MV= Maize Varieties

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There was no significant ( $p=0.05$ ) difference in application of biochar on number of leaves and plant height produced in both years (Table4). However, increased application of biochar

157 produced a graduate increase in number of leaves and plant height. Also, interaction between  
 158 biochar and maize varieties did not produced any significant ( $p=0.05$ ) effect on number of  
 159 leaves and plant height in both years of cropping. 2011 cropping season produced higher  
 160 number of leaves and plant height.

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166 Table 3: effect of Woody biochar on growth parameters of maize varieties at 6 weeks after  
 167 planting

| Treatment                  | Number of leaves |      | Plant height |       |
|----------------------------|------------------|------|--------------|-------|
| <b>Woody biochar(t/ha)</b> | 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 |
| <b>Maize varieties</b>     |                  |      |              |       |
| 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 |
| <b>Interaction</b>         |                  |      |              |       |
| WBXMV                      | NS               | NS   | NS           | NS    |

168 WB= Woody biochar, MV= Maize Varieties

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170 Biochar showed a significant ( $p=0.05$ ) effect on 100grain weight, cobs weight/plot and cobs  
 171 weight/ha in 2010 and 2011 cropping season (Table 4). Application of 10t/ha of biochar  
 172 produced the highest 100 grain weight of 31.17 and 33.39g; cobs weight/plot of 2.28kg and  
 173 2.39kg; cobs weight/ha of 1.45t/ha and 1.73t/ha in both years. Which is **at par with** application  
 174 of 10t/ha of biochar, but higher than control (1.34t/ha and 1.31t/ha) in 2010 and 2011 cropping  
 175 season. However, maize varieties did not showed any significant effect in both cropping  
 176 season, ~~but oba 98 proofs to be superior to the other variety in most of the character assessed.~~  
 177 Interaction between biochar and maize varieties did not produced any significant ( $p=0.05$ ) effect

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Table 4: effect of Woody biochar on yield parameters of maize varieties

| Treatment              | Days to 1 <sup>st</sup><br>cobs<br>formation |       | Days to 50%<br>cobs<br>formation |       | 100 grain<br>weight(g) |       | Cobs<br>weight/plot<br>(Kg) |      | Cobs<br>weight(t/ha) |      |
|------------------------|----------------------------------------------|-------|----------------------------------|-------|------------------------|-------|-----------------------------|------|----------------------|------|
| Woody<br>biochar(t/ha) | 2010                                         | 2011  | 2010                             | 2011  | 2010                   | 2011  | 2010                        | 2011 | 2010                 | 2011 |
| 0                      | 48.94                                        | 48.94 | 55.78                            | 55.28 | 30.06                  | 31.06 | 2.15                        | 2.09 | 1.34                 | 1.31 |
| 5                      | 48.33                                        | 47.78 | 55.44                            | 55.44 | 31.39                  | 31.72 | 2.22                        | 2.29 | 1.39                 | 1.42 |
| 10                     | 48.67                                        | 48.50 | 56.11                            | 56.00 | 32.17                  | 33.39 | 2.28                        | 2.39 | 1.45                 | 1.71 |
| LSD(0.05)              | 1.20                                         | 1.19  | 0.73                             | 0.70  | 1.39                   | 1.33  | 0.06                        | 0.05 | 0.09                 | 0.32 |
| <b>Maize varieties</b> |                                              |       |                                  |       |                        |       |                             |      |                      |      |
| Sammaize 18            | 48.85                                        | 48.37 | 55.78                            | 55.78 | 32.74                  | 31.52 | 2.03                        | 2.17 | 1.27                 | 1.35 |
| Oba 98                 | 47.78                                        | 48.44 | 55.78                            | 55.78 | 37.00                  | 32.59 | 2.40                        | 2.44 | 1.50                 | 1.53 |
| LSD(0.05)              | 0.98                                         | 0.98  | 0.59                             | 0.60  | 2.77                   | 2.35  | 0.29                        | 0.29 | 0.18                 | 0.18 |
| <b>Interaction</b>     |                                              |       |                                  |       |                        |       |                             |      |                      |      |
| WBXMV                  | NS                                           | NS    | NS                               | NS    | NS                     | NS    | NS                          | NS   | NS                   | NS   |

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

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## 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

204 visible improvement in the performances of maize seedling. In the field experiment on maize,  
205 yield is often reported to increase with biochar application to soil. There was a significant  
206 response of maize to biochar amended soil. Increase application of biochar rates on the soil  
207 resulted to gradual increased in the general performance of maize plant. Increases biochar  
208 application increased crop yields of maize over the control between 3.68% to 9.01% from the  
209 first year to the second year of cropping. This improvement in yield is as a result of  
210 incorporation of biochar into the soil which aid in: soil nutrients improvement, cation exchange  
211 capacity in the soil, decrease soil acidity, improve soil structure, nutrient use efficiency, improve  
212 water-holding capacity and carbon sequestration [9]. This result collaborate the findings of [24]  
213 who reported 10% mean yield increase in crop productivity over the control at biochar  
214 application rates of 10, 25, 50 and 100 tons/ha. These findings were confirmed by more recent  
215 reviews by[25] who published data from 59 pot experiments and 57 field experiments from 21  
216 countries and found crop productivity was increased by 11% on average. Liu also discovered  
217 that field application of biochar rates below 30 tons/ha reported increases in crop productivity  
218 which varied with crop type with greater increases for legume crops (30%), vegetables (29%),  
219 and grasses (14%) compared to cereal crops like corn (8%), wheat (11%), and rice (7%). [26],  
220 also reported increases in maize yield of 20% to 140% due to biochar-soil amendment above  
221 control plots.

## 222 **CONCLUSSION AND RECOMMENDATION**

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

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