EFFECTS OF *ALBIZIA ZYGIA* CHARCOAL ON THE GROWTH AND PERFORMANCE OF MAIZE (*ZEA MAYS* L.)

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ABSTRACT

Biochar is a charcoal material produced by the thermochemical pyrolysis of biomass materials. It can be used in soil amendment, for improving soil properties/quality and enhancing significant increases in crop yields, thus promoting plant productivity. In this study the application of wood biochar (charcoal) from *Albizia zygia* to soil medium was investigated on the growth and performance of *Zea mays* L. Treatments ranging from 5%, 10%, 15% and 20% concentrations of wood charcoal from *A. zygia* tree were mixed with sandy loam soil samples to serve as the planting medium. The result indicated that 5% treatment gave the highest value in terms of plant height (127cm), number of leaves (10), leaf area (771cm^2), stem girth (1.8cm) and chlorophyll content (0.42) compared to other treatments and the control. However, the 20% treatment gave the highest value of root length (60.2cm) when compared to other treatments and the control. This study revealed that for optimum growth and performance of *Z. mays,* 5% concentration of charcoal is the best treatment however, increasing the charcoal concentration decreases the growth and performance. The enhancement of growth indicators monitored in *Z. mays* with the application of 5% wood biochar of *A. zygia* in the soil may be attributed to increased pH and ions in the soil, increased nutrient uptake, better water retention and increased microbial activity. Thus the result demonstrated the potential of wood biochar of *A. zygia* to improving plant growth of *Z. mays*, this finding has positive implication to food security and sustainability in Sub-Saharan Africa in general and Nigeria in particular

Keywords: Charcoal, *Zea mays*, *Albizia zygia,* Growth.

INTRODUCTION

The need to increase agricultural productivity, food security and sustainability in Sub-Saharan Africa in general and Nigeria in particular cannot be taken for granted due to rapid nutrient depletion, soil erosion, limited organic matter; soil degradation and limited agricultural land (Diagana, 2003; Asenso-Okyere and Jemaneh, 2012), coupled with rapid population growth with its attendant consequences on land use for agricultural purposes. The Niger Delta region of Nigeria is the hub of crude oil exploration and production (E&P) activity in Nigeria, and Port Harcourt town plays host to oil companies and their facilities with well documented account of widespread oil pollution in the soils of the region, resulting in negative impacts on the physiochemical attributes of the soils.

Furthermore, the traditional farming practice (bush fallow system) of allowing the soil to lie fallow for 2-5 years to regain fertility may negate the concept of sustainably in food production. In addition, lack of arable farm land reduces the fallow period. The use of chemical fertilizer (NPK) also comes with its problems in Nigeria, namely the cost and its unavailability for the peasant farmers. All these factors militate against the sustainability of food production in Sub-Saharan Africa in general and Nigeria in particular. Thus the need to increase food production through the use of cheaper and available organic energy source of biochar (charcoal) material was investigated.

ISSN 2056-5879

Biochar can be used as soil amendments for improving soil properties and crop yield; provides potential carbon storage strategy in the soil; relatively stable and with long turnover in the soil. These attributes of biochar is of particular relevant to tropical soils and for climate change solutions (Glasser, et al, 2002; Lehmann, et al, 2006; Kookana, 2010; and Uzoma, et al, 2011). It has been known to have a positive effect on plant growth and germination. Studies have shown that the addition of wood charcoal enhances the growth and performance of some plants and increase in crop yield with charcoal application have been reported in crops such as cowpea and maize (Yamato et al, 2006; Rodríguez et al., 2009), soybean (Tagoe et al, 2008), upland rice (Asai et al., 2009), paddy rice (Shackley et al, 2011; Sokchea et al., 2013) and water spinach (Sisomphone et al., 2012a, b). The chemical elements contained in the wood charcoal help in enhancing plants growth and thus give maximum yield (Fowles, 2007; Lehmann et al., 2003; Lehmann, 2007; Laird, 2008). Charcoal increases the amount of water available to plant and it improves soil pH so that plant can get more nutrients from the soil. Charcoal is also known to maintain a more favorable pH in the rooting medium of plants, (Vantsis and Bond, 1950). Charcoal significantly increased total N, P, Mg and Ca uptake by plant, (Lehmann, 2007). It helps plants by soaking up toxic chemicals in the soil secreted from the roots of noxious weeds, (Vantsis and Bond, 1950; Anderson et al., 2011). Also, it helps plants by boosting the activity of beneficial fungi and bacteria in the soil. It enhances special fungi that infect a plant's roots and help it get more nutrients from the soil, (Yamato et al., 2006). Some of the elements present in the charcoal help increase pest and pathogen resistance, drought and heavy metal tolerance and also improves quality and yield of agricultural crops. Charcoal gives a significant increase in dry weight of pea plants and helps in nitrogen fixation, (Lehmann and Glaser, 2003).

The studies on organic farming in Japan, encouraged the application of charcoal in agriculture in 1980s (Makoto, 2011). According to Akinrinde (2006) the soil is a very crucial factor in food production. Negative impacts on soil can result in food crises. The most important problem of tropical agriculture is the inability of the land to sustain annual food crop for more than a few years at a time. Since animals, in turn, depend on plants, it becomes obvious that all agricultural activities directly or indirectly depend on the soil. The fertility of soils is important in agriculture particularly in making decisions on planting of crops. Maize requires rich loamy soil for cultivation and pH of 6 to 6.5 (Farrel and O'Keeffe, 2007). Globally, maize is one of the most important cereal crop ever cultivated after rice and wheat. In Nigeria, it has variety of uses viz. animal feed, vegetable, starch, food, vitamin B, etc. (Khawar et al, 2007).

Worldwide production of maize is 785 million tons, with the largest producer, the United States, producing 42%. Africa produces 6.5% and the largest African producer is Nigeria (10th largest producer of maize in the world) with nearly 8 million tons, followed by South Africa. Africa imports 28% of the required maize from countries outside the continent (IITA, 2009; 2001). In Nigeria, there is need to exploit every way in which the soil can produce more crops needed for the sustenance of the nation. Since charcoal is said to help in soil fertility and thereby improve crop yield. This study investigates the effects of charcoal amendment on the growth and performance of *Zea mays*.

MATERIALS AND METHODS

Soil Collection and Preparation: Top soil (0-15cm) samples were collected from the University of Port Harcourt Biodiversity Center and Botanical Garden, Port Harcourt, Rivers State, Nigeria. The samples were composited (mixed properly) and weighed into planting

ISSN 2056-5879

bags as shown in Table 1. The pH, Potassium (K) Conductivity, Available Phosphorus (PO_4^3) Nitrate (NO_3^-), organic matter (OM), Nitrogen (N) and soil type were determined using standard methods (AOAC, 1970; 1980).

Treatment Types: The different percentages of charcoal were prepared using a weighing balance calibrated in kilogram. Generally for each treatment, the soil and charcoal from *A. zygia* were mixed thoroughly with a standard weight of (5kg). Different treatments ranging from 0%, 5%, 10%, 15% and 20% were prepared as shown in Table 1.

Table 1: Different concentrations of Charcoal used for the experiment

Treatment	Weight of charcoal (kg)	Weight of soil (kg)	Total weight (kg)
0% (Control)	0.00	5.00	5.0
5%	0.25	4.75	5.0
10%	0.50	4.50	5.0
15%	0.75	4.25	5.0
20%	1.00	4.00	5.0

These treatments were placed in planting bags and left to stabilize for 7 days after labeling. Each treatment consists of five replicates.

Planting: Five (5) viable seeds of *Zea mays* were planted in each of the nylon bags for each treatment and kept in a greenhouse (controlled environment) where they were all exposed to the same environmental conditions such as sunlight and rainfall in an open field. The plants were watered as required after perforating the planting nylon bag and a total of 5 replicates were planted for each treatment. After germination, the plants were thinned to 2 plants per pot.

Plant Height and Root Length: This was determined using a ruler calibrated in centimeters. The ruler was placed vertically from the soil surface to the terminal bud of the plant and the measurement recorded. Root lengths were measured using a ruler calibrated in centimeters at the end of the study. The root length was determined by using a thread to trace the length of the root from the base of the stem to the tip of the root. Thereafter, the length of the thread was determined and recorded using meter rule.

Number of Leaves: This is carried out by counting the number of leaves on the plants of each of the treatment and their replicates after the plants had been thinned to two (2).

Leaf Area: This was determined using the formula A (cm^2) = KLB. Where A is the leaf area; L is the leaf length; B is the leaf breath/width and K is a constant which is 0.740 (k is a regression coefficient determined from variation of leaf against width).

Dry Weight: The fresh plant samples were gathered and oven dried at 80^oC for 24 hours and then weighed on a weighing balance. The weighing was carried out at two hours interval until a constant weight was obtained.

Chlorophyll Content: Fresh plant samples of each of the treatments were finely cut and weighed. 10ml of Acetone was added to 0.1g of the plant sample in a test tube and was monitored until samples became colorless. After a period of three (3) days, the chlorophyll was extracted with aqueous acetone and placed on a slide and transferred to a DR-2004 spectrophotometer where the optical density was measured at 660nm and 643nm and the values for chlorophyll content was obtained.

RESULTS

Soil Characteristics: The soil used for this sandy loam soil and the physiochemical analysis of the soil showed Potassium, K, (0.90±1.20mg/kg), pH (4.59±0.16), conductivity (26.93±13.84µS/cm), available Phosphorus, PO_4^{3-} (5.68±2.95mg/kg), nitrate NO_3^- (2.67±0.88mg/kg), Organic matter, OM (6.75±2.04%) and Nitrogen, N (0.61±0.34%).

Leaf Number and Leaf Area: The results indicated that 5% and 10% charcoal treatments had the highest number of leaves (10 leaves and 9 leaves respectively) after 7 weeks of growth when compared to the control (7 leaves). There was a gradual decrease in the number of leaves from 15 % to 20 % treatments (Fig. 1A). Figure 1B showed the leaf area after 7weeks of growth, the samples treated with 5% charcoal gave the highest value for leaf area (771cm^2), followed by 10% treatment (656cm^2). The leaf area value recorded for 15% treatment did not show any remarkable increase at the 7th week of growth (no difference in leaf area). However, leaf area decreased for 20% treatment when compared with the control at the 7 week growth duration.

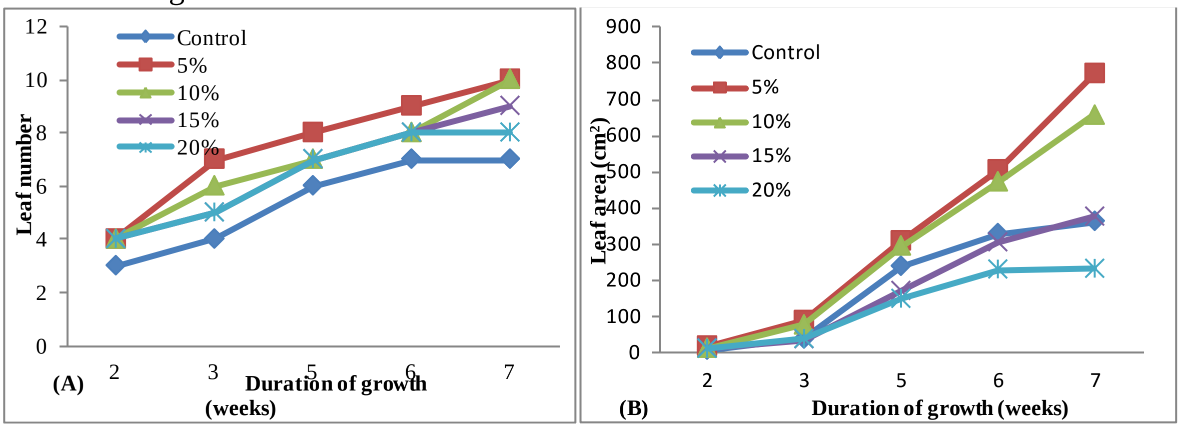

Figure 1: Effects of different concentrations of charcoal on the *Z. mays*. (A) Leaf number and (B) Leaf area

Root Length: Figure 2A showed that the results of root length of *Z. mays* treated with different concentrations of charcoal indicated that 5% charcoal treatment had the highest value (56.7cm) compared to other treatments and the control. There was a progressive increase in the root length from the control (5%) to 20% treatment.

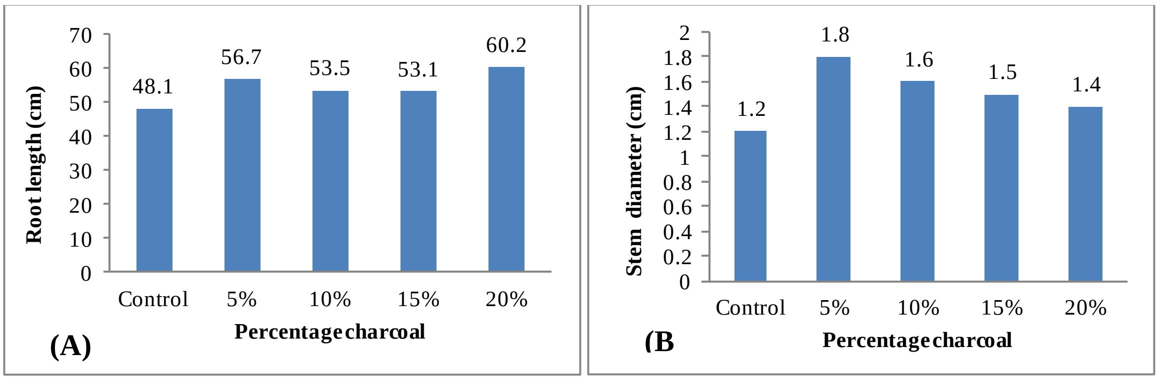

Figure 2: Effects of different concentrations of charcoal on the root length of *Z. mays* at week 7. (A) Root length and (B) Stem girth.

Stem Diameter: The results showed that the effect on average stem girth of *Z. mays* treated 5% charcoal treatment had the highest stem girth value (1.8cm) compared to other treatments and the control (1.2cm). There was a gradual increase in stem girth from control (0%) treatment to 5% treatment, and then a progressive decrease to 20% treatment (Figure 2B). Generally, the stem girth showed enhancement for the charcoal treatments when compared to the control.

Plant Height: Figure 3A showed the effects of different concentrations of charcoal on the plant height of *Z. mays*. The results indicated that 5% charcoal treatment gave the highest plant height value (127cm) after 7 weeks of growth. There was a corresponding decrease in the plant height from 10 % to 20 % treatments. All the treatments showed enhanced plant height when compared to the control after 7 weeks of growth (Figure 3A).

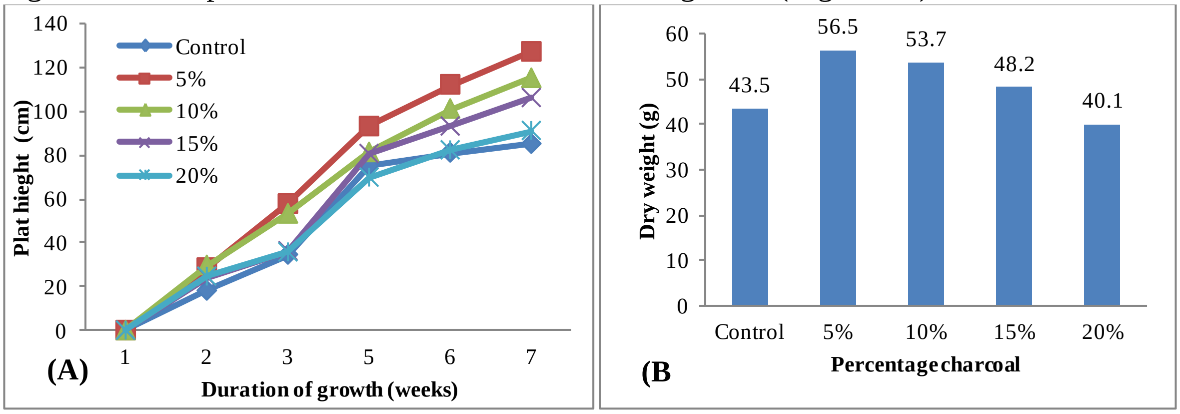

Figure 3: Effects of different concentrations of charcoal on the plant height and dry weight of *Z. mays*. (A) Plant height and (B) Dry weight

Dry Weight: Figure 3B showed the results of dry weight of *Z. mays* treated with different concentrations of charcoal. It indicated an increase in dry weight at 5% charcoal treatment with weight value of 56.5g compared to other treatments and the control (43.5g). After 5% treatment, there was a gradual decrease from 10% to 20% treatment. The control treatment recorded slightly higher value (43.5g) than the 20% treatment (40.1g). Other treatments (5%, 10%, and 15%) gave higher dry weight values than the control.

Total Chlorophyll Content: The results showed that the total chlorophyll content of *Z. mays* treated with different concentrations of charcoal ranged from 0.2 to 0.42g (Figure 4). 5% charcoal treatment gave the highest value of 0.42 for chlorophyll content compared to other treatments and the control (0.20g).

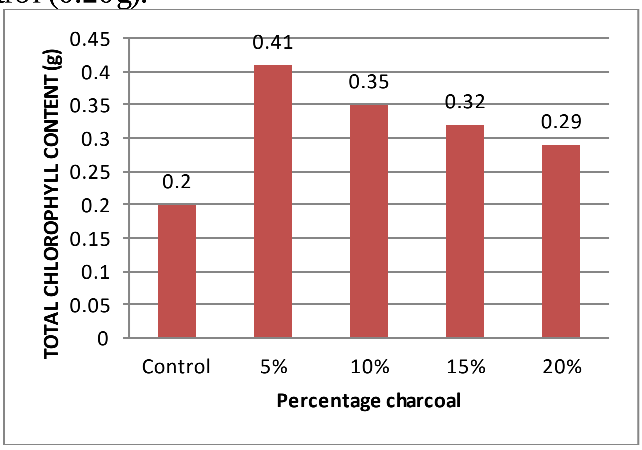

Figure 4: Effect of different concentrations of charcoal on the total chlorophyll content of *Z. mays* after 7 weeks growth duration.

DISCUSSION

The results indicated that 5% charcoal treatment generally gave the highest values for plant height, number of leaves, leaf area and total chlorophyll content when compared to other treatments and the control; followed by 10% and 15% treatments. Also, the stem girth and root length, 5% treatment gave the highest values when compared to other treatments. Generally, these treatments enhanced growth and performance when compared with the control. Therefore, increasing concentration of charcoal beyond 5% reduces plant height, number of leaves, leaf area and the chlorophyll content of *Z. mays*.

Earlier works carried out on the effects of charcoal on the growth and development of other plants including *Z. mays* supported the above findings (Lehmann et al., 2003). The increase in plant height, leaf number and leaf area of *Z. mays* is attributed to the availability of nutrients to the plant due to the retention of these nutrients in the soil by charcoal (Rodriguez et al 2009; Sokchea and Preston 2011; Chidumayo, 1994; Kishimoto and Sugiura, 1985; Ishii and Kadoya, 1994). The immediate beneficial effects of charcoal addition on nutrient availability to plants are largely due to higher potassium, phosphorus and zinc availability and to a lesser extent of calcium and copper (Lehmann et al., 2003). Nutrient analysis of *Acacia magnum* (Fabaceae) indicated high nutrient values for the parameters measured, supporting the view that the charcoal from *Albizia zygia* (Fabaceae) have increased the nutrients in the soil (Yamato et al, 2006).

Longer-term benefits of charcoal application on nutrient availability mainly due to a greater stabilization of organic matter, concurrent slower nutrient release from added organic matter and better retention of all cations due to a greater cation exchange capacity, (Sohi et al, 2010). It has also been suggested that charcoal amendments could lead to change in the microbial community in soils, both in structure, abundance and activity (Lehmann *et al.* 2011;_Anderson et al., 2011). These changes could improve bioavailability of nutrient to the plants and even stimulate the release of plant growth promoting hormones. It has been well documented that charcoal amendment to crop lands enhances crop productivity through improving soil quality (Siregar, 2007; Asai et al 2009; Major et al 2010; Sohi et al, 2010; van Zwieten et al, 2010; Gaskin et al, 2010; Haefele et al, 2011). It was observed that 20% treatment gave the highest root length. This might be due to the accumulation of nutrients in the root and water retention in the soil and supports Ishil and Kadoya (1994) who reported a similar result. Charcoal application increases soil water retention (Piccolo et al., 1996) and the gaseous phase (Ezawa et al., 2002), such amelioration of the soil physical and chemical properties could be effective in enhancing root growth. Also, the application of the *Albizia zygia* charcoal may have increased the pH of the soil and thereby enhanced the growth *Z. mays*. In a similar study, Sisomphon, et al., 2012 noted the increase in soil pH from 4.7 to 6.6 due to addition of biochar and to 6.3 with charcoal. The increase in chlorophyll content is based on the fact that there is an increase in the photosynthetic capacity with increase charcoal concentration. However, the decrease in the growth of *Z. mays* with increase in charcoal concentrations may be attributed to the supra-optimal concentrations of nutrients in the plant (Weerasuriya and Yogaratnam, 1989,_Anderson et al., 2011). Lehmann (2007) also observed that crops respond positively to charcoal additions and may show growth reductions at very high applications. The inhibitory effects of the high charcoal on the plant growth may be due to reduction in soil nitrate production and a general decrease in available nitrogen concentration increased soil basicity or due to potentially toxic ions and microbes.

CONCLUSION

The study revealed that for optimum growth and performance of *Z. mays*, 5% concentration of charcoal is the best treatment however, increasing the charcoal concentration decreases the growth and performance.

ACKNOWLEDGEMENT

The authors appreciate the efforts of the staff of the Department of Plant Science and Biotechnology, Faculty of Science, University of Port Harcourt and more especially the staff of University of Port Harcourt Ecological Centre where the experiment was carried out.

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