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EFFECT OF *PENTACLETHRA MACROPHYLLA* BIOCHAR ON SOME GROWTH INDICES OF *CAPSICUM ANNUUM* L. IN PORT HARCOURT, NIGERIA

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ABSTRACT

Studies on some growth indices of *Capsicum annuum* L. species in loamy soil amended with wood biochar (charcoal) of *Pentaclethra macrophylla* was investigated in the Ecological Centre, University of Port-Harcourt, Port Harcourt, Nigeria with a view to elucidate its potential for enhancing crop yields and plant productivity. Six treatments viz; 0, 5, 10, 15, 20 and 30 percent of biochar concentrations were used in a randomized complete block design with four replicates per treatment. The effects of these treatments on plant height, leaf number and leaf area were monitored weekly while the root length and dry weight of *C. annuum* were determined 5 weeks after planting. The study showed that 10% biochar treatment gave the highest values for plant height, number of leaves, leaf area, root length and dry weight when compared to the other treatments. The control treatment (0%) gave higher values for growth parameters determined when compared to 5%, 20% and 30% treatments. The 30% treatment recorded the lowest values for growth indices determined. The optimum biochar concentration of 10% treatment gave the highest values in all the parameters measured; higher and lower concentrations led to reduced plant growth of *C. annuum* species. The increase in growth indices parameters of *C. annuum* species due to the application of 10% wood biochar may be attributed to increased nutrient uptake, better water retention capacity, increased pH and ions. This study demonstrated the potential of wood biochar of *P. macrophylla* in promoting growth of *C. annuum* species by enhancing soil fertility, and thus higher crop yields and productivity. Therefore charcoal which was once considered an agricultural waste could be beneficial in agriculture. The study recommends that the use of wood charcoal should be incorporated in farming practices.

Keywords: *Pentaclethra macrophylla*, Biochar, growth indices, *Capsicum annuum*.

INTRODUCTION

Food crisis is a global challenge and a great trait to the existence of human race. According to Akinrinde (2006), the soil is a very crucial factor in food production, and negative impacts on soil can result in decline food production and consequently food crisis. The most important challenge of tropical agriculture is the inability of the land to sustain annual food crop for more than a few years at a time. In areas where crop production is limited by low soil quality, improving soil quality and consequently, crop production, without damage to the environment, is a priority. Considering the cost of inorganic synthetic fertilizers for poor local farmers, and poor organic matter, new fertilizing techniques in the tropics increasingly relying on the management of soil biota is a key factor in soil fertility (Lavelle et al., 1989; Beare et al., 1997). The Niger Delta region of Nigeria is the hub of crude oil exploration and production (E&P) activity in Nigeria, and Port Harcourt City plays host to several oil companies and their facilities. It has been documented in several Environmental Impact Assessment (EIA) Reports, Environmental Evaluation Reports (EER) and Post Impact Assessment (PIA) Reports that the activities of these oil companies via oil pollution have negatively impacted the crop yields and plant productivity in this region by altering the physicochemical attributes of the soils (Mobil, EIA-2001; SPDC-2000; SPDC, EIA, 1999; SPDC, EIA-1999; SPDC, EIA-1997; SPDC, EIA-

, 1997; SPDC, Env. Monitoring-1977; NNPC, PIA-1997; SPDC, PIES-1992). Furthermore, with population increase and its attendant consequences on land use for agricultural purposes, the available arable land is continuously decreasing. These pressures, among others, such as soil erosion, climate change have prompted the need to investigate other cheaper, environmental friendly methods, available and affordable means of improving soil fertility and hence plant productivity.

Davis and Wilson (2005) defined soil amendment as any material added to a soil to improve its physicochemical properties. Charcoal, which is referred to as 'biochar' when it is intended for use on the soil has been discovered by scientists as a means of replenishing soil fertility in degraded soils. Lehmann and Joseph (2009) defined 'biochar' as the carbon-rich product obtained when biomass, such as wood, manure or leaves, is heated in a closed container with little or no available air. Yilangai *et al.* (2014) reported that charcoal application has been used by indigenous people in time past as a soil amendment, to improve the fertility of their soil. Biochar has the potential characteristic of increasing water retention capacity and nutrient especially in depleted tropical soils (Bakewell-Stone, 2011). Unlike most conventional soil organic materials, which are readily decomposed, the recalcitrant nature of biochar increases its potential value as a soil amending material for the longer duration (Chan *et al*., 2008), hence it does not need to be supplied repeatedly, being persistent in the soil (Glasser *et al.*, 2002). Soils around the world contain charcoal deposited through natural events such as forest and grassland fires (Skjemstad et al., 2002; Krull et al., 2008). In some countries like Nigeria, wood charcoal has been regarded as agricultural waste used for domestic purposes or left unused. Several studies have reported enhancement of crop yields and plant productivity in plants/crops grown in soil amended with biochor, such as *Zea mays*, *Glycine max*, *Raphanus sativus*, *Sorghum bicolor*, *Solanum tuberosum*, *Triticum aestivum*, *Pissum sativum*, *Avena* sp., *Oryza sativa*, *Vigna unguiculata*, *Ipomea batatas*, *Solanum lycopersicum* and water spinach (Lehman et al., 2003b; Chan et al., 2008; Asai et al., 2009; Shackley et al., 2011; Dou et al., 2012; Sokchea et al., 2012; Sisomphone et al., 2012a; Sisomphone et al., 2012b; Sisomphone et al., 2012c; Yilangai et al. 2014). Some biochar contain high quantities of ash, which are enriched with a number of plant nutrients, especially cationic elements such as potassium, calcium and magnesium (Deenik et al., 2011; Yuan et al., 2011a; Rajkovich et al., 2012). When biochar is applied to the soil, these nutrients and elements are added to improve crop growth. However, physical and chemical properties of biochar produced from a variety of feedstock and production conditions have been found to vary widely (Keiluweit et al., 2010; Enders et al., 2012; Rajkovich et al., 2012; Schimmelffennig and Glaser, 2012).

Sweet pepper, *Capsicum annuum* L. belongs to Solanaceae family. Stems of most sweet pepper plants are glabrescent and usually grow to 20-80 cm tall. They are herbaceous, erect, and hairy with simple, estipulate leaves which are alternately arranged but occur opposite in flora regions (Nwachukwu et al., 2007). The leaves of sweet pepper plants are oval and taper to a point, are usually bright to dark-green, but can also be mottled while fruits of *C. annuum* come in a variety of vivid colours, such as green, red, yellow, orange, purple, brown and black (Department of Agriculture, Forestry and Fisheries, 2013). Sweet pepper is an important agricultural crop not only because of its economic importance but also due to the nutritional and medicinal value of its fruits as well as being an excellent source of natural colours and antioxidant compounds (Howard et al., 2000). The fruits are rich in minerals like iron, potassium, calcium, magnesium, phosphorus, sodium and selenium, and are also rich sources of vitamin C and A (Agarwal et al., 2007). The fruits are eaten raw in salads or cooked as vegetable (Janick and Paull, 2008). Peppers have also been used in various countries such as Japan as remedy for toothache and sore-throat (Leung and Foster, 1996). Its potential uses and benefits to mankind cover many areas such as food and nutrition, medicine, cosmetics. According to Erinle (1989) and Alegbejo (2002), consumption of pepper accounts for 20% of the average vegetable consumption per person per day in Nigeria. Sweet peppers prefer deep, fertile, well-drained soils and grow best in a soil with a pH between 6.0 and 7.0, although they can tolerate slightly alkaline conditions near 7.5 (Department of Agriculture, Forestry and Fisheries, 2013).

Studies have shown that biochar can enhance the growth performance of a large number of crops. In the light of this and in the view of the fact that no known study has been carried on the effect of biochar on the growth of *C. annuum*, this study was undertaken to investigate the effects of biochar, if any, on some growth parameters of *C. annuum* species.

MATERIALS AND METHODS

The viable seeds of *Capsicum annuum* and the wood charcoal of *Pentaclethra macrophylla* were obtained from the Choba market in Port Harcourt, Nigeria. The top soil (0-15 cm) samples were collected from the University of Port Harcourt Botanical Garden. The soil pH, potassium (K), nitrate (NO_3^-), available phosphorus (PO_4^{3-}), nitrogen (N), organic matter (OM), conductivity, and soil types were determined using standard methods (AOAC, 1970; 1980). The samples were composited. The various treatments ranging from 0%, 5%, 10%, 15%, 20% and 30% were prepared as follows: 0 kg, 0.25 kg, 0.50 kg, 0.75, 1.0 kg, 2.0 kg of charcoal were mixed 5.0 kg, 4.75 kg, 4.5 kg, 4.25 kg, 4.0 kg, 3.0 kg loamy soil respectively. The various treatments were properly mixed in planting bags and then left for 10 days for the charcoal to be properly incorporated into the soil. The planting bags were perforated, filled with the treatments and watered. Ten seeds of *Capsicum annuum* L. were planted in each planting bag, which were properly kept and exposed to the same environmental conditions such as rainfall and sunlight. Each treatment was replicated 4 times. The experiment was carried at the Ecological Center, University of Port Harcourt. The parameters measured include plant height, leaf area and number of leaves, all of which were measured and recorded on a weekly basis after thinning the plants to two per bag. Other parameters such as the dry weight and root length were determined 5 weeks after planting. The plant height and root length were measured with the aid of metre rule. The leaf area of each plant was determined using the method of Ross (1981) while the number of leaves of each plant was obtained by direct counting. The dry weight was determined by oven-drying the samples until a constant weight was obtained at 80^o for 24 hours and then weighed on a weighing balance. The data obtained were subjected to statistical analysis using Analysis of Variance at $P = 0.05$.

RESULTS

Soil properties: The soil used contain the following physiochemical properties: Potassium (0.90±1.20 mg/kg), available phosphorus (5.68±2.95 mg/kg), nitrate (2.67±0.88 mg/kg), organic matter (6.75±2.04%), nitrogen (0.61±0.34%), pH (4.59±0.16), conductivity (26.93±13.84 µS/cm)

Plant height: The effects of different concentrations of biochar on plant height of *Capsicum annuum* showed that 10% biochar treatment gave the highest height, with a mean height of 12.63cm at the end of the 5^{th} week, followed by the 15% treatment (9.43cm) while the control (0%) recorded 6.7cm. The value for this control was higher than the values recorded for 5% (4.05cm), 20% (4.63cm) and 30% (1.05cm) treatments respectively (Fig. I). The results indicated that 10% treatment gave the highest plant height value. Increasing the concentrations of biochar beyond 10% treatment showed a decline in the plant height. The result obtained showed significant differences among the means.

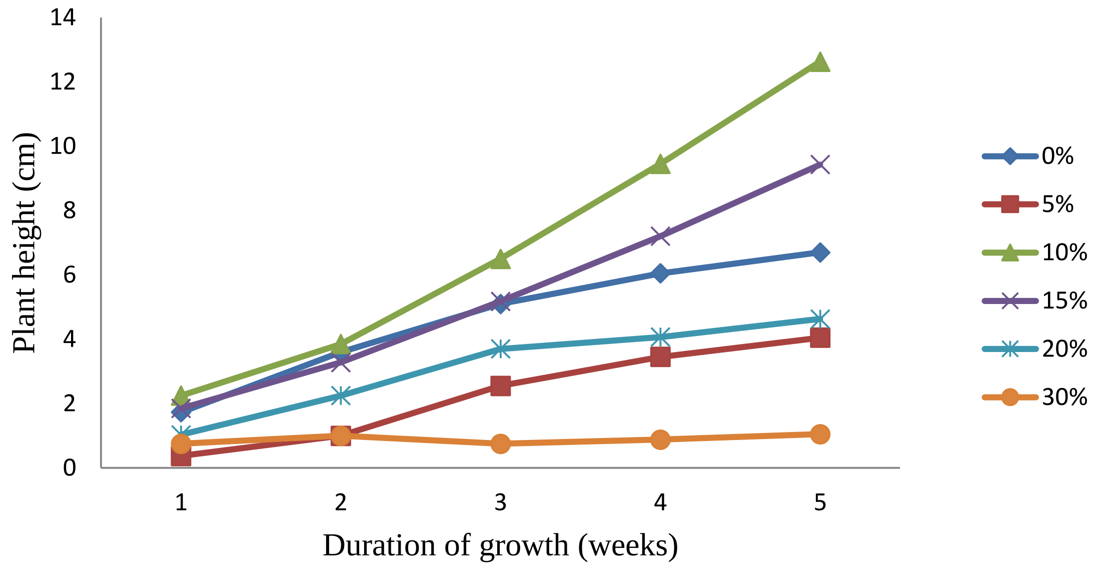

Fig. I: Effects of different concentrations of biochar on the heights of *Capsicum annuum* L. plant after 5 weeks of growth

Number of leaves: The result showed that 10% biochar treatments recorded the highest number of leaves at the end of the 5th week. This was followed by the 15% biochar treatments. The control (0%) performed better than the 5% and 30% biochar treatments at the end of the 5th week of growth. The least number of leaves was recorded for the 30% biochar treatments. The number of leaves of *C. annuum* at the end of the 5th week of growth under varying treatments is shown in Figure II. At P = 0.05, there was no significant difference among the means.

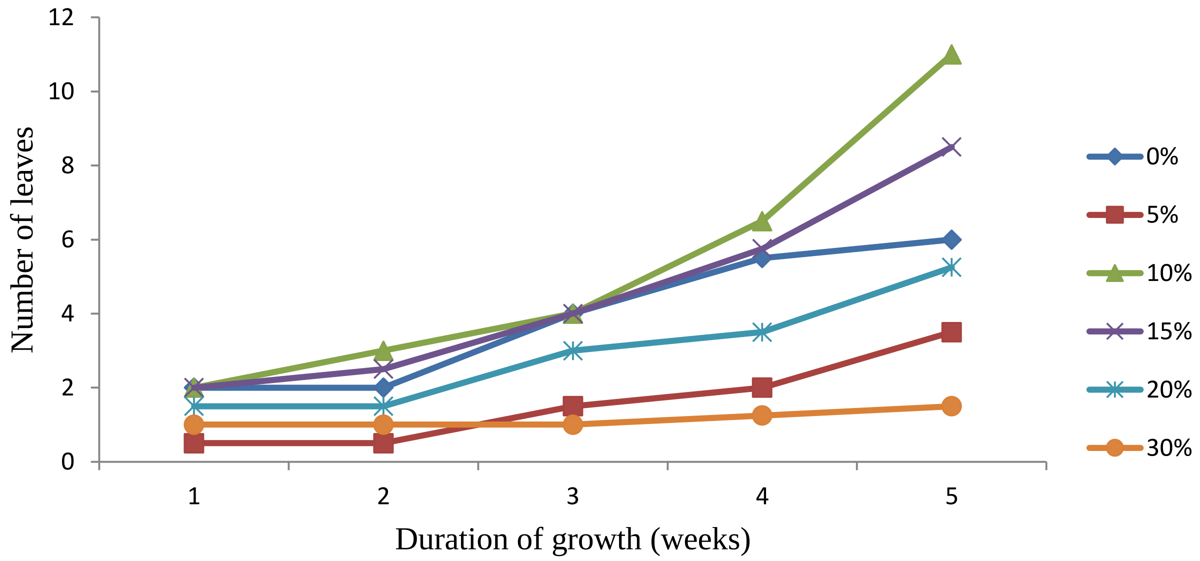

Fig. II: Effects of different concentrations of biochar on the number of leaves of *Capsicum annuum* L. plants.

Leaf area: Figure III shows the effect of different charcoal treatments on the leaf area of *C. annuum* L. It indicated that 10% biochar treatment gave the highest values for leaf area with an average leaf area of 17.03 cm^2 at the end of the fifth week of growth. This was followed by the 15% treatment (9.49 cm^2). The mean leaf area of 0%, 5%, 20% and 30% treatments indicated low values of 3.37 cm^2, 2.19 cm^2, 2.00 cm^2 and 0.11 cm^2 respectively. The results for leaf area generally indicate that 10% treatment recorded the highest values. Statistical analysis showed no significant difference among the mean values.

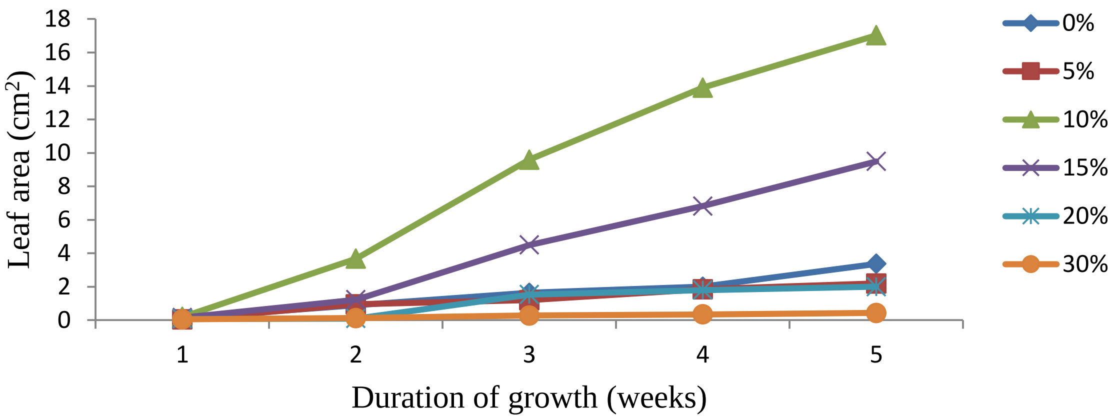

Fig. III: Effects of different concentrations of biochar on the leaf area of *Capsicum annuum* plant

Root length: The result of biochar treatments indicated increase in root length from 5% (4.10cm) to 10% (13.50cm). However, the root length decreased with increase in charcoal treatments recording 5.63cm for 15%; 2.7cm for 20%; and 1.24cm for 30% treatments respectively while the control (0%) recorded 5.50 cm (Fig. IV). This result was comparable to 5% and 15% treatments but appreciably higher than the 20% and 30% treatments. Again, 10% treatment recorded the highest root length value.

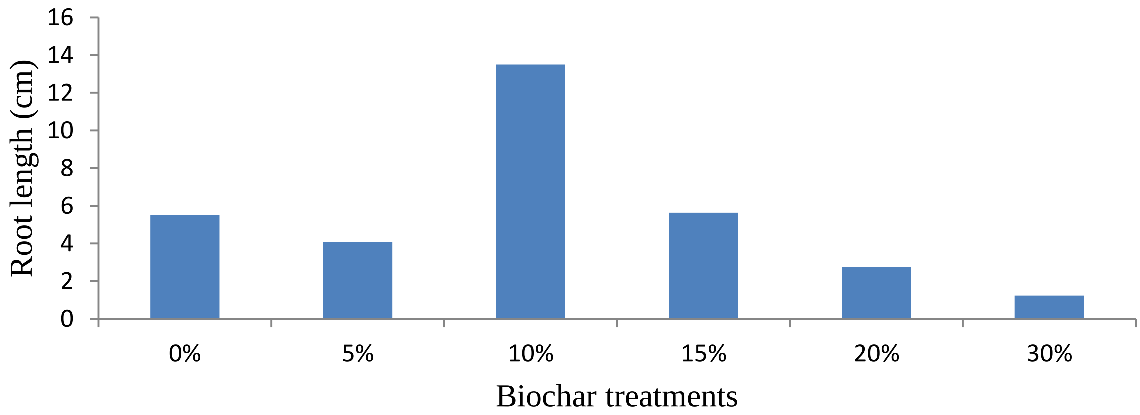

Fig. IV: Effects of biochar treatments on the root length of *Capsicum annuum* plant after 5 weeks

Dry weight: Figure V shows the results of dry weight of *Capsicum annuum* treated with different concentrations of biochar. From the results, it can be seen that the 10% biochar treatment gave the highest dry weight value when compared to the control. It was observed that the dry weight of plants of the 0% treatment was appreciably higher than the 5%, 20% and 30% biochar treatments while the reverse was the case for 15% charcoal treatment.

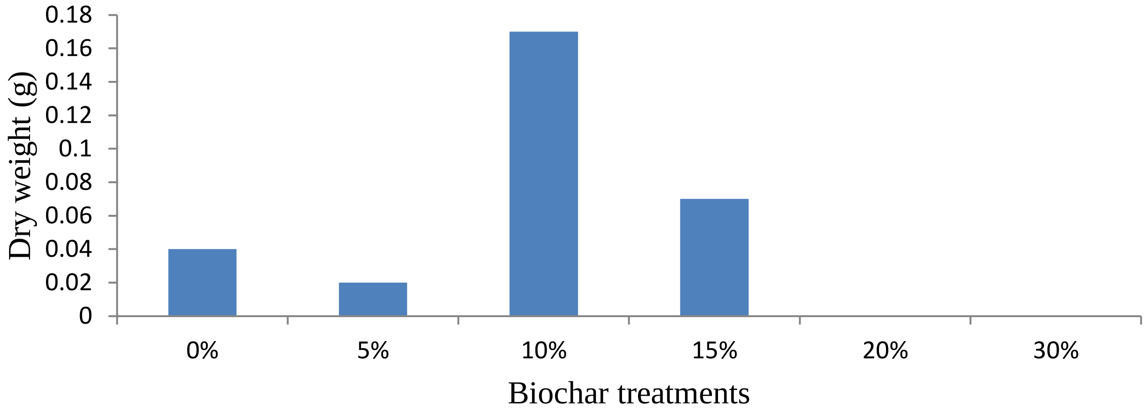

Fig. V: Effects of biochar treatments on the dry weight of *Capsicum annuum* plant after 5 weeks

DISCUSSION

Findings from the study indicated that 10% biochar treatment gave the highest values for plant height, number of leaves, leaf area, root length and dry weight, when compared to the other treatments and the control. The control treatment (0%) gave higher values for growth parameters determined when compared to 5%, 20% and 30% treatments. The 30% treatment recorded the lowest values for growth indices determined. The results obtained is in line with other findings that the addition of wood charcoal results in an optimal increase in plant growth parameters, however, lower concentrations (as seen in the 5% treatment) or high concentrations (20% and above) can lead to decrease in the crop yields of *Capsicum annuum* species. Schultz *et al* (2014) reported that high concentrations of biochar resulted in negative effects on the growth and yield of oat plants. It is possible that at these levels the amount of wood charcoal applied resulted in a net negative effect on the growth and development of *Capsicum annuum* due to increased pH, increased Cation Exchange Capacity (CEC) and over absorption of beneficial nutrients and ions by the charcoal particles.

Charcoal has been reported to enhance plant height, leaf number and leaf area (Rodriguez *et al*, 2009; Sokchea and Preston, 2011; Chidumayo, 1994; Kishimoto and Suguira, 1985; Ishii and Kadoya, 1994). These observations which are in agreement with the present study on *Capsicum annuum* can be attributed to the availability of nutrients to the plants due to the retention of the nutrients in the soil by charcoal. It has also been suggested that charcoal amendments could lead to a change in the microbial community in soils, both in structure, abundance and activity (Lehmann, 2007). These changes could improve bioavailability of nutrients to the plants and even stimulate the release of plant-growth-promoting hormones. Biochar boosts the activity of beneficial fungi and bacteria in the soil, enhancing special fungi that infect a plant's roots and help it get more nutrients from the soil (Yamato *et al.*, 2006), which might be an explanation for the longer root lengths of the 10% charcoal treatment. Although it was expected that higher concentrations of wood charcoal would lead to increasingly better performance of the *Capsicum annuum* plants, the findings of Glasser *et al.* (2002) supported the result obtained in this study that much lower application rates yielded more positive results.

Future experiments could investigate the effect of powdered wood charcoal on the growth of plants after being left to incorporate into the soil for a longer period of time of about 40 days. Wood charcoal application could also be compared with fertilizer addition to evaluate whether biochar amendment helps the plants grow as well as fertilizers do, thus giving farmers an eco-friendly option instead of fertilizers.

CONCLUSION

From the study carried out, it can be concluded that the addition of wood charcoal of *Pentaclethra macrophylla* gives an enhanced growth performance of the growth parameters measured in *Capsicum annuum* species The optimum biochar concentration is 10% treatment, which gave the highest values in all the parameters measured, as it was observed that higher and lower concentrations led to reduced growth and development. Therefore charcoal which was once considered an agricultural waste could be beneficial in agriculture. The study recommends the use of wood charcoal for incorporation in farming practices. However, more information is needed on the agronomic potential of charcoal, the potential to use alternative sources (crop residue) and production of by-products to evaluate the opportunities for adopting a charcoal (biochar) system on a global large scale.

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