Effects of Biochar and Compost on Cocoa (*Theobroma Cacao*) Seedlings Growth

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***Abstract*—** *The research was carried out at the experimental field of the Kumasi Institute of Tropical Agriculture (KITA) to evaluate the effect of biochar and compost on the growth of cocoa seedlings. There were four (4) treatments including biochar, compost, a combination of biochar + compost, and a control. Treatments were applied at a rate of 0 g (control), 60 g compost, 60 g biochar, and 30 g each of biochar and compost combination into 60 kg soil in polybags. The treatments were laid out in a randomized complete block design (RCBD) with three replications. Data were collected on the number of leaves, plant height, stem girth, and leaf area, all analyzed using analysis of variance. Significant treatment means were separated LSD at $P \leq 0.05$. The analysis of variance indicated significant differences among treatment types in plant height ($P<0.00001$), the number of leaves ($P<0.034$), stem girth ($P<0.044$) and leaf area ($P<0.012$). The highest seedlings height was recorded in soil amended with biochar (55.3 cm) and the least in the control (28.1 cm). Soils amended with compost (15.3) recorded the highest numbers of leaves while a relatively low number was recorded by control (9.0). Stem girth was very high in soils amended with compost+biochar (0.76 mm) and the least in the control (0.62 mm). The highest leaf area was recorded in soils amended with biochar (84.6 cm^2) while the control recorded 57.0 cm^2. It can be recommended that the application of 60g biochar influences significantly growth parameters of cocoa seedlings at nursery.*

***Keywords*— cocoa, biochar, compost, seedlings, growth, soil, treatments, nursery.**

I. INTRODUCTION

Soil amendments are materials, which are worked into the soil to improve the soil's properties. The use of fertilizers (organic and inorganic) over the years on Ghanaian soil has been found to aid crop growth and yield tremendously. Synthetic fertilizers according to Chen (2006) have high nutrient contents, are relatively cheap, and also quickly taken by plants when applied. However, the increasingly continuous use of inorganic fertilizers in the soil results in soil acidity, decrease microorganisms, pollution of underground water, and nutrient loss (Aciego Pietri & Brookes, 2008). The use of biochar and compost as organic products has become an important technique for enhancing soil structure and also for improving soil water availability and holding capacity for plant growth. Biochar is an organic product partially burnt (carbonated with little or no oxygen) through a process called pyrolysis (Duku et.al.,2011, Zheng et.al.,2010). According to Braida et.al., 2003, the large pore spaces and high specific capacity possessed by make it a highly strong absorption material. Additionally, biochar is made up of major soil nutrient constituents such as Ca2+, K+, Mg2+ which help to improve soil base saturation and also increase the soil pH values (Chen et.al., 2013). The use of biochar has been confirmed to increase activities of beneficial microorganisms in the soil (Zheng et.al.2010), reduce greenhouse emissions through carbon sequestration (Crombie et.al., 2015), improve moisture or water holding capacity (Duku et.al., 2011) and also provide nutrients (Paz-Ferreiro et.al., 2014). To produce quality cocoa seedlings, there is a need to use an amendment that improves the quality of soil media. Amending soils with organic materials have been proven to improve soil quality and structure over the years. However, fewer studies have been done on the use of biochar made from cocoa pruned branches and compost in raising seedlings. The research work is carried out to evaluate the effect of biochar and compost (ACARP) on the growth of cocoa seedlings.

1.1 Statement of Problem

The use of infertile soil as a medium for the raising cocoa seedlings is major factor affecting large production of seedlings. Application of soil amendments is one major solution to improving the quality of growing medium and hence improving significant production of cocoa seedlings. Organic amendments improve soil fertility, increases aeration and water holding capacity of soil, improves effective nutrient use and plant growth. The study sought to investigate the impact of organic amendments such as compost and biochar on growth of cocoa seedlings.

1.2 Purpose of the Study

The purpose of the study was to evaluate the effect of biochar and compost(ACARP) on cocoa seedlings growth parameters such as height, number of leaves, stem girth and leaf area.

1.3 Research Questions

In order to achieve the purpose of the study, the following research questions were formulated to guide the study:

1) What impact do compost, biochar, biochar+compost and control have on cocoa seedlings height?

2) What are the differences in the number of leaves when growth of cocoa seedlings is amended with compost, biochar and biochar +compost?

3) What are the differences in stem girth of cocoa seedlings through the application of compost, biochar and biochar+compost?

4) What impact do compost, biochar, biochar+compost and control have on cocoa seedlings leaf area?

II. MATERIALS AND METHODS

2.1 Soil media preparation

The soil (growth media) was taken from the Research Centre of College of Tropical Agriculture. The experimental soil was sandy clay loam with a pH of 5.0 and a bulk density of 1.6 g cm^{-3}. The soil was air-dried for one (1) week, grounded to obtain finer particles and sieved in a 2mm mesh. The soil was sent to the laboratory for various analyses. Organic carbon, soil pH, total nitrogen, exchangeable bases, and other important soil properties were all determined using standard procedures.

2.2 Biochar preparation

The biochar used was made from pruned cocoa branches, which was chard in an oven with zero or no oxygen as documented by (Lehmann, 2007). The biochar was crushed and subsequently sieved to pass through a 2- mm sieve.

2.3 Experimental Design and Treatments

2.3.1 Experimental Design

The design for the study was Randomized Complete Block Design (RCBD). The RCBD is the standard design for agricultural experiments where similar experimental units are grouped into blocks or replicates. It is used to control variation in an experiment by accounting for spatial effects in field (Trudi, 2010). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications; the distances between the plots were 60cm and 5cm between nursery bags.

2.3.2 Treatments

The following treatments were applied:

1) 0g=control (T1)

2) 60g=compost (T2)

3) 60g=biochar (T3)

4) A mixture of 30g biochar +30g compost=60g (T4)

The research was carried out in an open field. Shade was provided using palm fronds and structure fenced with bamboo.

The polybag was filled with 1600g of the soil and top dressed with 60g compost, 60g biochar, and (60g mixture) 30g compost + 30g biochar. The setup was watered to stabilize for 72 hours before the sowing of the cocoa seeds. Hybrid cocoa (PA7 X POUND7) seeds were sown at a seeding rate of two per polybag, which was later thinned to one seedling per polybag.

2.4 Parameters Assessed

Data were taken on the following growth parameters;

Stem girth (using digital vernier calipers taken at 3cm above soil surface at 4weeks Interval).

Stem height (using meter rule at 4weeks interval) measuring from the base (soil surface) to the tip of the apical leaf.

Leaf number (flushes) fully developed leaves was counted on each plant and recorded at 4weeks Interval).

Leaf Area (using Easy Leaf Area Free app).

2.5 Data Analysis

Data collected were subjected to statistical analysis by using GENSTAT discovery edition 3.0. analytical software. Means were separated by LSD test at 5% probability level.

III. RESULTS

3.1 Properties of planting media and various amendments used in the experiment

The results presented in Table 1.0 show that the soil has several fertility constraints: slightly acidic soil, high exchangeable Al content, low exchangeable base cations content (K, Ca, and Na). Aluminum (Al) toxicity is the main feature limiting plant growth in acidic soil especially cocoa crops, therefore the amelioration needs to be applied in this soil to alleviate the Al toxicity, increase pH and nutrient availability and improve the other soil properties. Results also showed that the organic materials (ACARP compost) had slightly alkaline properties with a pH of 7.5. The pH of biochar made from pruned cocoa branches (9.51) was higher than that of the compost (7.5).

TABLE 1
SELECTED SOIL PROPERTIES OF THE MEDIA AND AMENDMENTS

Properties	pH	Organic C	Total N	Available P	Exch. Al	Exch. K	Exch. Ca	Exch. Mg	Exch. Na
Units		(%)	(%)	mg/kg	(cmol kg-1)	……… (cmol (+) kg-1) …………..			
Soil	5.0	1.60	0.26	1.77	19.82	0.27	1.62	1.68	0.2
Biochar	9.51	8.61	0.33	7.96	-------	0.86	3.95	2.06	0.68
Compost (ACARP)	7.5	15-25	1.0-1.75	0.5-1.20	--------	-------	-------	-------	------

3.2 Mean germination percentage of cocoa seedlings using various amendments at 10 days.

The mean germination percentages of cocoa seedlings on the 10th day after sowing in the different treatments are reported in Table 2. Significant differences were observed in the various treatments. The type of growing media significantly ($p<0.05$) affected the emergence percentage of cocoa seedlings at ten days. Percentage emergence in T2, T3, and T4 was significantly ($p<0.05$) higher than control (T1). This shows that the amended soils (T2, T3, T4) released additional nutrients to aid the cocoa seedlings growth than the control soil (T1).

TABLE 2
MEAN GERMINATION PERCENTAGES OF COCOA SEEDLINGS USING VARIOUS AMENDMENTS AT 10 DAYS.

Treatment	Mean (%)
T1	52.2
T2	80.6
T3	80.6
T4	87.8

3.3 Growth parameters of Hybrid cocoa (PA7 X POUND7) seedlings grown in different media.

Growth parameters of Hybrid cocoa (PA7 X POUND7) seedlings amended with compost, biochar, compost+biochar, and control were assessed at 4 weeks, 8 weeks, and 12 weeks at nursery. The analysis of variance indicated a significant difference among treatments types in plant height ($P<0.00001$), the number of leaves ($P<0.034$), stem girth ($P<0.044$) and leaf area ($P<0.012$).

The highest seedlings height was recorded in soil amended with biochar (55.3 cm), followed by compost (44.0 cm), compost+biochar (43.3 cm), and control (28.1 cm). However, no significant differences were indicated between seedlings from soils amended with compost and compost+biochar (Table 3).

Soils amended with compost (15.3) recorded the highest numbers of leaves, followed by compost+biochar (15.0), biochar (14.7) while a relatively low number was recorded by control (9.0). No significant differences in the number of leaves were observed between seedlings amended with compost, biochar, and compost+biochar (Table 3).

Stem girth was very high in soils amended with compost+biochar (0.76 mm), followed by compost (0.73 mm), biochar (0.71 mm), and control (0.62 mm). However, no significant differences in stem girth were observed between seedlings amended with compost, biochar, and compost+biochar (Table 3).

The highest leaf area was recorded in soils amended with biochar (84.6 cm^2), followed by compost (82.7 cm^2), compost+biochar (74.0 cm^2) while control recorded 57.0 cm^2. No significant differences were observed in seedlings from compost, biochar, and compost+biochar amended soils (Table 3).

TABLE 3
GROWTH PARAMETERS OF HYBRID COCOA (PA7 X POUND7) SEEDLINGS GROWN IN DIFFERENT MEDIA

Treatments	Plant height(cm)	Number of leaves	Stem girth (mm)	Leaf area(cm^2)
Control	28.1c	9.0b	0.62b	57.0b
Compost	44.0b	15.3a	0.73a	82.7a
Biochar	55.3a	14.7a	0.71a	84.6a
Compost+Biochar	43.3b	15.0a	0.76a	74.0a
LSD	**5.24**	**4.37**	**0.09**	**14.45**
CV(%)	**6.14**	**16.20**	**6.58**	**9.7**

Means with different letters are significantly different at P<0.05

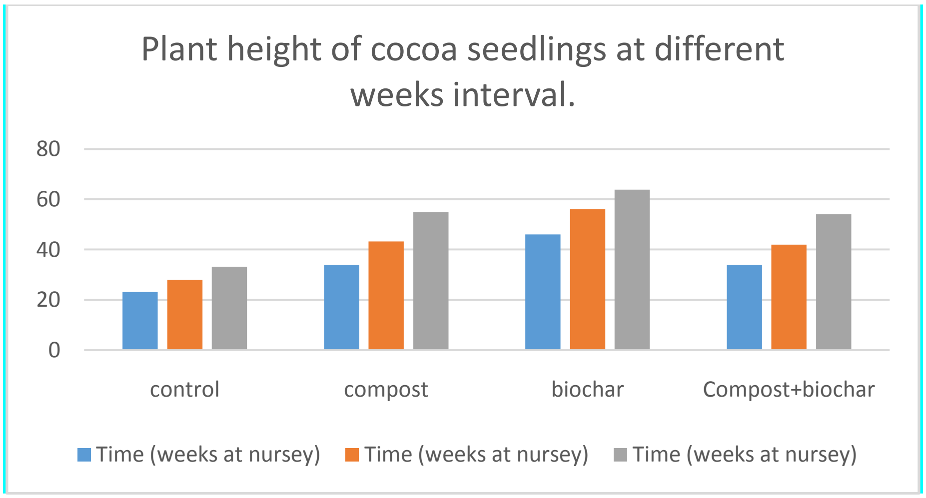

FIGURE 1: Plant height (cm) of 'Hybrid cocoa (PA7 X POUND7)' seedlings recorded from 4 weeks to 12 weeks at nursey.

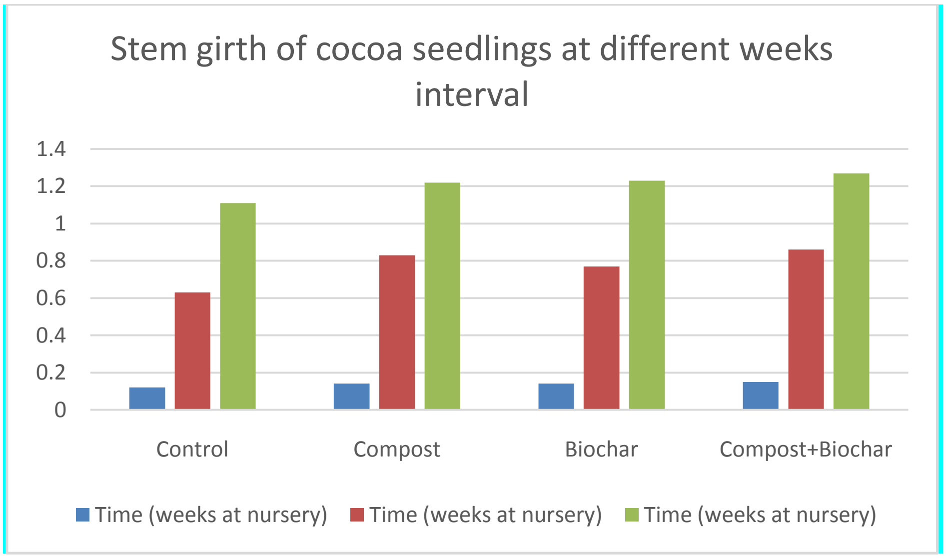

FIGURE 2. Stem girth (mm) of 'Hybrid cocoa (PA7 X POUND7)' seedlings recorded from 4 weeks to 12 weeks at nursey.

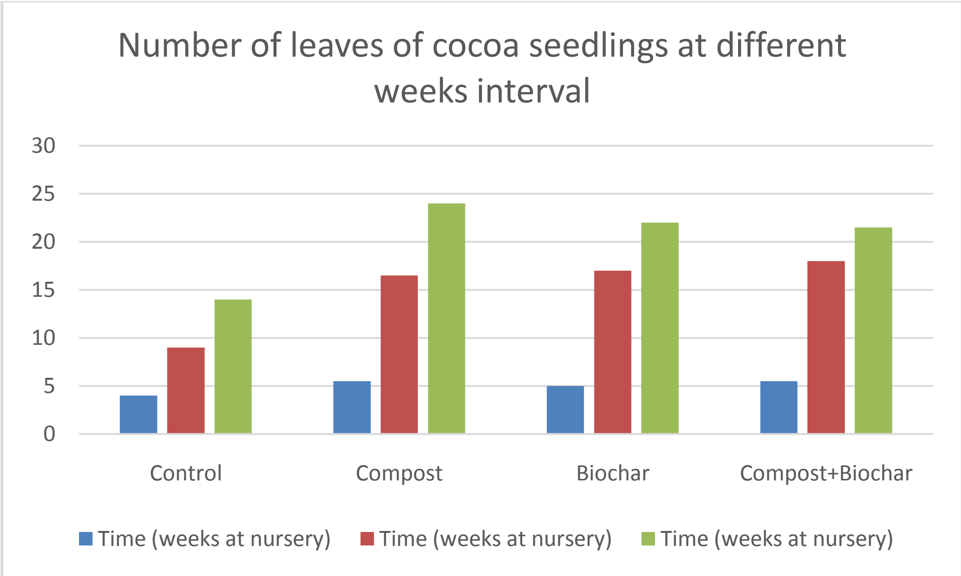

FIGURE 3: Number of leaves of cocoa seedlings recorded from 4 weeks to 12 weeks at nursery

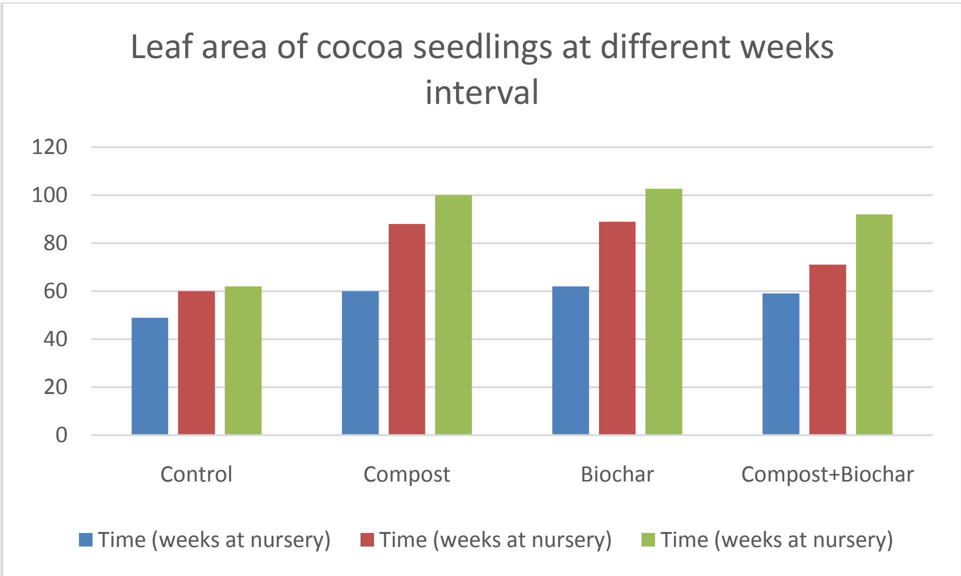

FIGURE 4: Leaf area (cm^2) of the cocoa seedlings from 4 weeks to 12 weeks at nursery.

IV. DISCUSSION

Effects of biochar on growth parameters (plant height and leaf area)

Applying amendments/fertilizers at nursery is very crucial as it helps to improve seedlings' growth and performance (Shen et.al., 2010). The present study results show that seedlings from soils amended with biochar recorded significantly the highest plant heights (55.3) and leaf area (84.6) respectively whereas soil with no amendment recorded the least plant height and leaf area. This positive result might be due to the high content of N and P supplementation available in the biochar. Nitrogen supplementations are needed to improve seedling biomass even in some legume varieties(Harper,1974). In a work by Albregts et.al. (1991) it was revealed that root and shoot development of plants are significantly affected by the level and the kind of fertilizer applied. Works detailing the beneficial effects of producing seedlings with biochar have been carried out by researchers such as Hartz et al., 1996, García-Gómez et al., 2002, and Akanbi et al., 2005 and (Lehmann, 2007). The result is again in conformity with the fact that biochar has low to neutral pH which makes it very efficient in acidic soils by reducing acidity which in turn builds up nutrient uptake and subsequent growth of plants (Lehman et al., 2003). The positive effects of biochar on seedling development for height and leaf area can also be attributed to increasing water holding capacity and availability to the seedlings (Haefele, 2011). Further, other researchers revealed that pot grown lettuce and cabbage plants increased in final biomass, root biomass, plant height, and the number of leaves in all cropping seasons in comparison with treatments with no biochar. Similar results had been reported by a study that biochar application media at plantain nursery stage resulted in increased vegetative growth parameters (height, girth, number of roots/corm, and root diameter) and this was significantly different from sawdust and sawdust and carbonated rice husk media.

Effects of compost on growth parameter (number of leaves)

Results of the study showed that seedlings from soils amended with ACARP compost recorded a significantly higher number of leaves than biochar, biochar and compost and the control. The result is in agreement with the fact that the could be due to the significant N-component in the ACARP compost which is responsible for leaf growth and green coloration of leaves (Jones, 1983). A previous work by Zibilske, (1987) revealed compost improves water availability in the soil, improves organic matter content of the soil, and also enhances shoot and root development. Stoffella and Graetz, (1996) reported tomato seedlings grown in compost media yielded higher shoot and root response parameters than media not amended.

Effects of compost on growth parameter (stem girth)

Results show that seedlings from soils amended with compost and biochar recorded the highest stem girth. The result could be attributed to higher soil pH and hence higher P availability owing to the application of the organic fertilizers. Similar work by Liu et.al. (2012) revealed applications of both biochar and compost results improving nutrient use efficiency, improving water availability, reducing acidity, reducing leaching in soils, enhancing Carbon sequestration, and releasing collective nutrient supply for plant development, compared to applying compost and biochar individually.

V. CONCLUSION

The additions of biochar and compost either alone or in combination were found to increase significantly growth response parameters (plant height, number of leaves, stem girth, and leaf area) of cocoa seedlings. Application of 60g ACARP compost was found to increase significantly the number of leaves of cocoa seedlings, 60g of biochar increased significantly plant height and leaf area whiles 30g compost b+30g biochar increased significantly stem girth of cocoa seedlings. We recommend a study on the effects of the treatments on the yield response parameters of cocoa.

CONFLICTS OF INTERESTS

The authors declare that there are no conflicts of interest regarding the publication of this paper.

AUTHORS' CONTRIBUTION

We wish to state that all the authors have been personally and actively involved in substantive work leading to the research report. All the authors actively took part in the research design and data analysis of the manuscript preparation. We are therefore responsible for the content of this manuscript.

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