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Research Article

Effect of Different Types of Biochar on Growth of Cocoa Seedlings (*Theobroma cacao* L.)

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Abstract

Background and Objective: Biochar as a soil amendment is used to improve soil fertility and ultimately enhances the plant growth. This study aims to determine the effect of different types of biochar on soil nutrients and plant growth of cocoa seedlings. **Materials and Methods:** The study was carried out in the glasshouse of Agricultural Faculty, Halu Oleo University, Kendari, Southeast Sulawesi from June to September, 2018. The study was conducted besed on a randomized block design with 4 replications. Biochar treatment consisted of cocoa pod husk biochar, durian shell biochar, rice straw biochar and without biochar. The variables observed were plant height, leaf area, number of leaves, shoot dry weight and soil fertility. **Results:** The results showed that types of biochar significantly improved growth of cocoa seedling. Cocoa pod husk biochar showed better effect in improving soil nutrient and growth of cocoa seedlings as compared to the durian shell biochar and rice straw biochar. **Conclusion:** Cocoa pod husk biochar can be recommended for improving the cocoa production and soil-C sequestration in the study region.

Key words: Biochar, cocoa pod, durian, rice straw, fertility

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Cocoa is the 3rd leading commodity of all superior commodities in Southeast Sulawesi and is the 1st leading commodity for plantation crops[1]. The area of cocoa plantations in Southeast Sulawesi which is dominated by smallholder plantations is 255,350 ha with a productivity[2] of 810 kg ha^{-1}, lower than Sabah, Malaysia's cocoa productivity, which reached >2 t ha^{-1}/year with better soil management practices[3].

The low productivity of cocoa plantations is caused by low soil fertility, the presence of pests and diseases and not applying proper cultivation practices such as the use of good and healthy seedlings, fertilization and irrigation[4].

Increasing cocoa production, among others, can be done by using quality cocoa seeds and using good planting media. Cocoa production is very closely related to the implementation of cultivation and quality of seedlings so that the provision of good quality cocoa seedlings can be pursued, one of which is by providing nutrients in the growing media[5]. Fertilizers are an important part of nurseries, especially fertilizers that contain organic matter. At present, the management of soil organic matter getting wider attention for improving soil fertility, increasing fertilizer efficiency and increasing crop production[6].

One of the organic materials that can be used for improving cocoa productivity is biochar. Biochar is a biological charcoal as a result of incomplete combustion of organic material from crop residues that can improve soil quality and can be used as an alternative treatment for soil. Biochar is useful in storing carbon stably by immersing it in the soil. The use of crop residue biochar as fresh organic material in soil management help in attaining the purpose of restoring and improving the quality fertility of degraded soils of critical agricultural land[7].

Different types of agricultural waste that can be used as biochar include cocoa pods husk, durian shell and rice shell. Utilization of cocoa pod compost increased cocoa production[8] up to 19.48%. Durian shell compost at a dose of 20 t ha^{-1} has a very significant effect to neutralize some of the toxic effects of aluminium (Al) in soil solution and also to increase soil cation exchange capacity (CEC) and soil-pH[9]. Meanwhile, nutrient content from rice husk waste has organic C content >35% and macro nutrient content such as N, P and K which is quite high[10]. Therefore, underutilized agricultural waste products such as cocoa shells, durian and rice husk have the potential to be used as biochar which can be returned to the soil as soil amendments[11]. However, studies that compare various types of biochar to determine the type of biochar that is good for the growth of cocoa seedlings have not been done much. Based on the description above, a study was conducted to assess the effect of application of biochar type of cocoa pod husk, durian shell biochar and rice straw biochar on the growth of cocoa seedlings (*Theobroma cacao* L.). This study aims to determine the effect of different types of biochar on soil nutrients and plant growth of cocoa seedlings.

MATERIALS AND METHODS

The experiment was conducted from June to September, 2018 in the glasshouse of Agricultural Faculty, Halu Oleo University, Kendari, Southeast Sulawesi, Indonesia. The location of the experimental site was at the geographical coordinate 122°31'32.89"E, 04°00'33.90"S and the altitude at 25 m a.m.s.l. The experimental design was a randomized block design with 4 levels of biochar type (i.e., without biochar (control), cocoa pod husk (CPH) biochar, durian shell (DS) biochar, rice straw (RS) biochar) in 4 replications. The mean daily temperatures in the glasshouse varied from 22-32°C and the relative humidity ranged from 69-87%.

Biochar was produced from cocoa pod husk (CPH), durian shell and rice straw by using a drum kiln, in which carbonization was done[12] within 4-6 h. The hot biochar produced after pyrolysis was quenched with distilled water, collected, air-dried, crushed and sieved through a 2 mm sieve before being used[13]. The soil (37% sand, 44% silt and 19% clay) for trial was collected from the experimental farm of Agricultural Faculty, Halu Oleo University.

Cocoa seedlings were raised on germination media for 14 days and each seedling was then transplanted into a polybag of 20×30 cm size which had been filled with seedling media of 3.5 kg dry soil and 10 g kg^{-1} manure mixed with a treatment-based rate of type of biochar (10 g biochar kg^{-1} soil each) at planting space of 20×20 cm. One seedling was raised in one polybag. The amount of water applied was 120-240 mL/plant for 3 months under glasshouse conditions with every 2 days of water frequency. Seedling growth attributes and soil nutrient content were monitored for 3 consecutive months. The data collected for seedling growth attributes included: Seedling height, number of leaves, leaf area and shoot dry weight.

Table 1: Chemical properties of durian shell biochar, cocoa pod husk biochar and rice straw biochar

Chemical properties	DS biochar	CPH biochar	RS biochar
pH	12.30	12.50	6.10
Organic-C (%)	30.00	28.20	9.90
Total N (%)	0.36	0.57	0.35
P_2O_5 (%)	0.78	0.13	0.84
K_2O (%)	0.47	0.52	0.58
Mg (ppm)	3429.00	3429.00	550.00
Na (ppm)	1610.00	410.00	15.00
CEC (me/100 g)	41.65	36.34	5.30

Seedling height, number of leaves and leaf area were measured 85 days after planting. Thereafter, seedlings were removed from the nursery and sent to the laboratory, in order to obtain their shoot dry weight. Dry weight was obtained after drying the material at 85°C for 48 h. At 85 days after planting, 3 soil samples were taken from each polybag at random positions, mixed, carried to the Laboratory to measure pH, soil organic-C, nitrogen, phosphorus and potassium contents and chemical properties are listed in Table 1.

Statistical analysis: To detect effect of the treatments on soil parameters and seedlings growth analysis of variance (ANOVA). Least significance differences (LSD) at 0.05 level of significance was applied when the ANOVA results were found significant at $p<0.05$ level.

RESULTS

Table 2 showed that cocoa seedlings treated with CPH biochar were significantly higher in seedlings height and shoot dry weight than control and the other treatments. Soil media of cocoa seedlings without biochar was significantly lower in seedlings height and shoot dry weight than soil media of cocoa seedlings treated with CPH biochar and DS biochar, but soil media of cocoa seedlings without biochar was insignificantly different with soil media of cocoa seedlings treated with RS biochar. Soil media of cocoa seedlings treated with CPH biochar were significantly higher in leaf area than control and soil media of cocoa seedlings treated RS biochar, but insignificantly different from soil media of cocoa seedlings treated with DS biochar. Soil media of cocoa seedlings without biochar was significantly lower in leaf area than other treatments, but soil media of cocoa without biochar was insignificantly different with soil media of cocoa seedling treated with RS biochar.

Soil-pH, C, N, P and K were significantly increased with the addition of different types of biochar (Fig. 1-3). Soil media of cocoa seedlings treated with CPH biochar were significantly

Table 2: Effects of different type of biochar on cocoa seedling growth

Treatments	Seedling height (cm)	Leaf area (cm^2)	Leaf number	Shoot dry weight (g)
Without biochar	26.25^c	46.08^c	14.13^b	16.73^c
CPH biochar	29.64^a	49.18^a	16.13^a	24.31^a
DS biochar	27.83^b	48.49^a	14.50^b	17.73^b
RS biochar	26.86^{bc}	47.25^b	14.75^b	17.21^{bc}

Values in the same column with different superscript letters are significantly different according to LSD test at $p<0.05$ for each variable

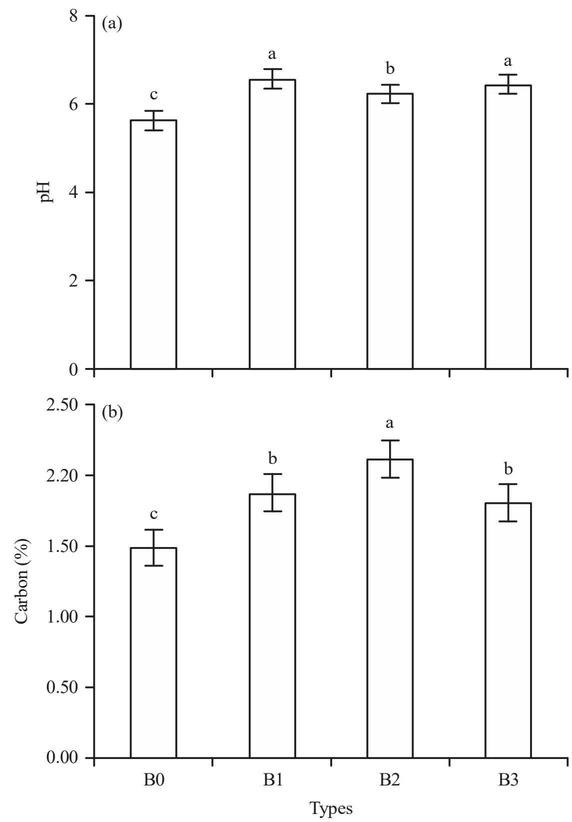

Fig. 1(a-b): Variation in pH and carbon content under different types of biochar

Error bars indicate standards deviations and different letters on bars indicate significant differences due to different type of biochar treatment, B0: Without biochar, B1: CPH biochar, B2: DS biochar, B3: RS biochar

higher in pH than control and soil media of cocoa seedlings treated DS biochar, but insignificantly different from soil media of cocoa seedlings treated with RS biochar. Soil media of cocoa seedlings treated with CPH biochar were significantly higher in pH than control and soil media of cocoa seedlings treated DS biochar, but insignificantly different from soil media of cocoa seedlings treated with RS biochar. The lowest soil-pH was found in the control without biochar (Fig. 1a). Soil media of cocoa seedlings treated with DS biochar were significantly higher in carbon than control, soil media cocoa seedlings treated CPH biochar and soil media of cocoa

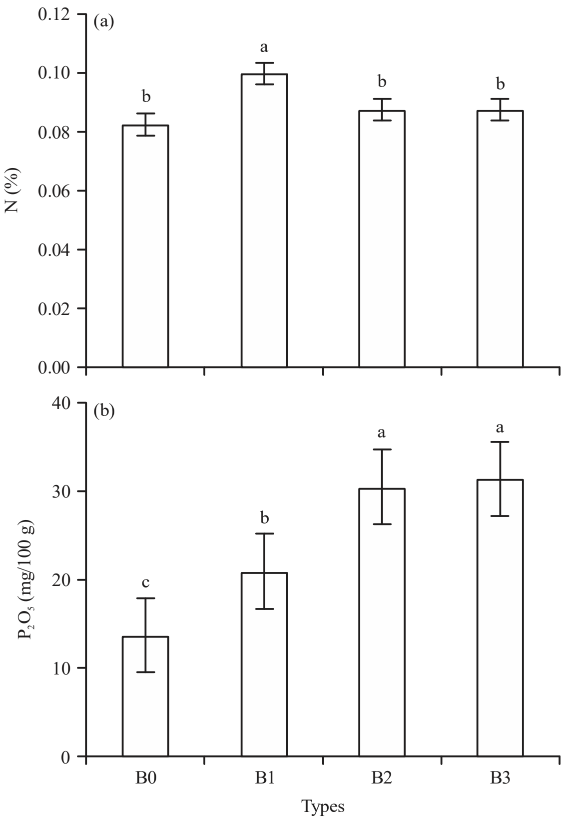

Fig. 2(a-b): Variation in N and P_2O_5 content under different types of biochar

Error bars indicate standards deviations and different letters on bars indicate significants differences due to different type of biochar treatment, B0: Without biochar, B1: CPH biochar, B2: DS biochar, B3: RS biochar

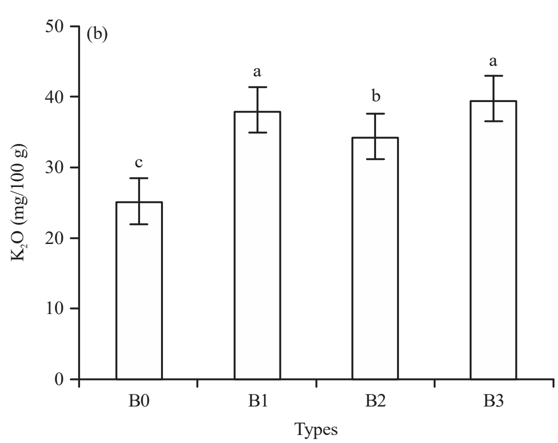

Fig. 3: Variation in K_2O content under different types of biochar

Error bars indicate standards deviations and different letters on bars indicate significants differences due to different type of biochar treatment, B0: Without biochar, B1: CPH biochar, B2: DS biochar, B3: RS biochar

seedlings treated RS biochar, while, soil media cocoa seedlings treated CPH biochar was insignificantly different from soil media of cocoa seedlings treated with RS biochar in carbon content, but significantly different from control without biochar. The lowest carbon content was found in the control without biochar (Fig. 1b).

Soil media of cocoa seedlings treated with DS biochar were significantly higher in phosphorus content than control and soil media cocoa seedlings treated CPH biochar, but insignificantly different from soil media of cocoa seedlings treated RS biochar. However, soil media cocoa seedlings treated DS biochar was insignificantly different from soil media of cocoa seedlings treated with RS biochar in phosphorus content. The lowest phosphorus content was found in the control without biochar (Fig. 2a). Soil media of cocoa seedlings treated with CPH biochar were significantly higher in nitrogen content than control, soil media cocoa seedlings treated DS biochar, soil media cocoa seedlings treated RS biochar. However, soil media cocoa seedlings treated DS biochar, RS biochar and control were in significantly different to each other (Fig. 2b).

Figure 3 showed that soil media of cocoa seedlings treated with CPH biochar were significantly higher in K_2O content than control and soil media of cocoa seedlings treated DS biochar, but insignificantly different from soil media of cocoa seedlings treated with RS biochar. The lowest K_2O was found in the control without biochar.

DISCUSSION

Biochar derived from cocoa pod husk (CPH), durian shell (DS) and rice shell (RS) significantly influenced seedlings height, leaf area, leaf number and shoot dry weight as shown in Table 2. This indicates that adding biochar could significantly affect cocoa seedling growth. The above result was supported by other previous studies which also reported that adding biochar increased aboveground production and crop yield[14-18]. The positive effects of biochar on seedling growth are related to changes in soil nutrient conditions[13,18-21]. This indicates that CPH biochar strongly influenced root growth. The application of CPH biochar increased seedling height, number of leaves, leaf area and shoot dry weight by 12.91, 6.72, 14.15 and 45.31%, respectively, as compared to the control. The application of DS biochar increased seedling height, number of leaves, leaf area and shoot dry weight by 6.02, 5.23, 6.62 and 5.98%, respectively, as compared to the control. The application RS biochar increased seedling height, number of leaves, leaf area and shoot dry weight by 2.32, 2.54, 4.39 and 2.87%, respectively, as compared to the control. This is consistent with previous study of Bahrun *et al.*[13] that biochar significantly influenced seedling height, number of leaves, leaf area, root dry weight and shoot dry weight. This results also stand in accordance to the previous study reporting that biochar increased plant biomass by 189%[22] and promoted plant growth[13,16,23,24]. This is a consequence of the changes in soil-pH, C, N, P and K content (Fig. 1-3), as reported by Alburquerque *et al.*[25] that biochar improved plant growth due to increased plant nutrient availability. After biochar application of Kraska *et al.*[26] also found an increase in plant biomass because of an increase of the soil-pH and the P, K and Mg availability. Plants cultivated in the soil treated with biochar response better in growth through modifications in soil CEC and nutrients retention[27].

Previous study of Zheng *et al.*[28] and Bhattarai *et al.*[29] found that biochar can improve soil quality by increasing soil organic-C, pH, CEC and holding nutrients in soil[28,29] and supplies essential plant nutrients[30,31], therefore, soil nutrient content was a crucial component that influenced root growth, with possible effects on leaf growth and cocoa seedling growth as a whole[13].

Biochar significantly influenced the soil-pH, soil-C, N, P and K. Soil-pH, soil-C, N and K were significantly increased with biochar addition as shown in Fig. 1-3. The addition of biochar to soils resulted, on average, in increased soil phosphorus (P), soil potassium (K), total soil nitrogen (N) and total soil carbon (C) compared with control conditions[18]. Similar increase in exchangeable potassium, pH and EC was found by Bhattarai *et al.*[29]. Biochar increases the available P in soils by modulating the soil-pH, which makes immobile phosphorus available[30]. The application of 3 g of CPH biochar kg^{-1} soil up to 18 g of CPH biochar kg^{-1} soil increased soil-pH, soil-C, P and CEC by 5.7, 284.4, 126.7 and 45%, respectively, as compared to the control[13].

This study showed that the application of CPH biochar, DS biochar and RS biochar increased soil nutrient higher soil-pH, soil-C, soil-N, soil-P and soil-K than the control without biochar plots (Fig. 1-3). These results indeed indicate that soil chemical properties increased due to biochar amendment within soil. Similarly, previous studies performed by many researchers found that soil nutrient availability increased due to biochar amendment within soil[32-34]. Researchers all over the world also had reported by Masulili *et al.*[32] and Oladele *et al.*[35] that biochar increased soil-C storage on a large scale and has the potential to improve physical and chemical properties such as soil pH, CEC and nutrient holding capacity[15,36-40]. Figure 1-3 also showed that there are variations in changes in soil fertility by different types of biochar. This was probably due to the different properties of biochar types. The CPH biochar, DS biochar and RS biochar has a pH valueof12.50, 12.30 and 6.30, containing 28.28, 30 and 9.90% of organic C, containing 0.57, 36 and 0.35% of total-N, containing 0.13, 0.78 and 0.84% of P_2O_5, containing 0.52, 0.47 and 0.58% of K_2O, respectively (Table 1). The results further revealed that the degree of changes in soil properties is dependent on the properties of biochar itself[41] and type of biochar[42,43].

CONCLUSION

Results showed that types of biochar significantly improved growth of cocoa seedling. Cocoa pod husk biochar had better effect in improving soil nutrient and growth of cocoa seedlings compared with the durian shell biochar, rice straw biochar. Based on the results, cocoa pod husk biochar can be recommended for improving the cocoa production and soil-C sequestration in the study region.

SIGNIFICANCE STATEMENT

This study discovers the possible effect of biochar that can be beneficial for soil amendment and growth of cocoa seedlings. This study will help the researcher to uncover the critical area of degradation of soil nutrient and its improvement by using different local biochar resources that many researchers were not able to explore. Thus, a new theory on the possibility of type biochar for improving soil fertility and plant growth, may be arrived at.

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