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Coconut Husk Biochar Application on Increasing Growth and Yield of Maize Plant, and Improvement Fertility of Ultisol Dry Land

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ABSTRACT

Maize plant (*Zea mays* L.) aside from being a staple food, is also the main feed ingredient for poultry farms and processed industrial raw materials. To increase maize plant production and productivity, it is necessary to use marginal lands such as Ultisol dry land. Ultisol dry land is a land whose water availability depends on rainfall has a low content of organic matter and nutrients and high soil acidity. Therefore, to improve Ultisol dry land and increase the growth and yield of the maize plants, biochar used as soil organic ameliorant. Indonesian coconut production averages 15.5 billion coconuts per year, equal to 31.8 million tons of husk. Therefore coconut husk has good potential used as raw material for biochar.

Research for examining the effect of biochar on growth and yield of the maize plant, and improvement Ultisol dry land fertility, was conducted in April to September 2018, in Pematang Sulur Village, Telanaipura, Jambi- Indonesia (35 m asl). The study used a randomized block design with four replication. The treatment that was tried was the coconut husk biochar dose (0 tons ha^{-1}, 3 tons ha-1,6 tons ha^{-1}, 9 tons ha^{-1}, 12 tons ha^{-1}, 15 tons ha^{-1}). Giving biochar increased maize yields (seed weight per plant) is 36-69% compared to without biochar. Increased growth and yield of maize plants are in line with increased nutrient content (P and K) and a decrease in the total sugar content of maize. Increased growth and highest yields obtained in coconut husk biochar 15 ton ha^{-1}. The application of coconut husk biochar improves physical (w/v, TPS, SWC) and chemical properties of Ultisol (pH, CEC, C, P and K).

Key words: Ameliorant organic, *zea mays*, marginal land, nutrient content, sugar content

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INTRODUCTION

The maize plant is one of the important carbohydrate-producing plants in the world besides wheat and rice. The maize plant is also a raw material for animal feed that has a fairly dominant composition (40% - 50%). Production of maize plant in Indonesia at 2017 amounted to 28.9 million tons, this high enough production needs to be maintained and increased to make sure national livestock industry sustainability, the food and beverage industry, and export destinations. It estimated that in 10 years it will require 16 million tons of maize plant for animal feed or an increase of twice compared to 2017 which was 7.8 - 8.5 million tons (Ministry of Agriculture, 2018).

Increased maize plant production could be done through the development of maize planting in marginal lands including Ultisol dry land which is still quite extensive, namely 11,876,881 ha in 2013 (Pahlevi *et al*., 2017). Important constraints in agricultural systems in tropical drylands are limited water availability, low soil organic matter content and low soil pH, and low nutrient retention. C-organic poor soils have a low buffering capacity so that nutrients added to fertilizer become susceptible to leaching, so fertilizer efficiency is low. Tropical conditions accelerate the process of oxidation/mineralization of organic matter so that carbon compounds cannot last long in the soil because most of it is released in the form of CO_2 into the atmosphere. The use of biochar could a choice in improving soil quality and maize productivity in Ultisol dry land.

Biochar is a carbon product produced from the pyrolysis process of various organic materials such as plant residues under oxygen-limited conditions (Lehmann, 2007). Biochar supplies and maintains plant nutrients, and improves soil physical and biological properties (Downie *et al*., 2009). Biochar significantly decreases soil density (Zhang *et al.*, 2012); decrease soil acidity (Chintala *et al*. 2013), increase the available P and K exchangeable (Maftu'ah and Nursyamsi, 2019); and increasing cation exchange capacity and soil water retention (Sukartono and Utomo, 2012).

Indonesian coconut production averages 15.5 billion coconut per year, equal to 31.8 million tons of husk, and 3.3 million tons of dust. Coconut husk has a thickness ranging from 5-6 cm consisting of an outer layer and an inner layer. The chemical composition of coconut husk includes cellulose, lignin, pyroligneous acid, gas, charcoal, tar, tannin, and potassium (10.25%) (Indonesian Center for Agricultural Research and Development, 2017). Therefore coconut husk has good potential used as raw material for biochar.

This study aims: 1) to examine the growth and yield of maize plant in various doses of biochar coconut husk; 2) asses changes in plant nutrient and total sugar content due to the application of coconut husk biochar; 3) assess changes in the physical and chemical properties of Ultisol due to coconut husk biochar application; and 4) get a dose of coconut husk biochar which gives the best growth and yield to maize plant.

MATERIALS AND METHODS

The study was conducted in Pematang Sulur Village, Telanaipura, Jambi- Indonesia with a height of 35 m above sea level (asl), starting from April 2018 to September 2018, using a Randomized Block Design with four replications. The treatments that were tried were coconut husk biochar doses consisting of 0 tons

ha^{-1}, 3 tons ha^{-1}, 6 tons ha^{-1}, 9 tons ha^{-1}, 12 tons ha^{-1}, and 15 tons ha^{-1}. The maize plant variety used is Sukmaraga.

Simple pyrolysis method used to make biochar (Indonesian Center for Agricultural Research and Development, 2017). Biochar is given to the field one week before planting, and the amount is under the dose that tried. Planting and maintaining maize plant follows the standard method of planting and maintaining maize in the field.

Observations made when the plants were 4, 6 and 8 weeks after planting (WAP), by observing plant height, number of leaves, leaf area, total dry weight of plants, number of seeds per cob, the weight of 100 seeds, and weight of seeds per plant. Observations were 8 WAP on plant tissue N, P, and K nutrient content, total sugar content, physical properties (weight/volume (w/v), Total Pore Space (TPS), Soil Water Content (SWC) and soil chemistry (pH, Capacity Exchange Cation (CEC), N, P, K, C-organic).

Data were analyzed using Analysis of Variance (Anova) and continued with the Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

1. Research results

Effect of coconut husk biochar on plant growth and nutrient content

The results showed that coconut husk biochar did not effect on all growth parameters observed at ages 4 and 6 WAP, but at age 8 WAP coconut husk biochar gave a significant effect on plant height, leaf area and total dry weight of the plant.

Application of coconut husk biochar to a dose of 15 tons ha^{-1} increases the height of the maize plant. The highest increase in maize plant height was found in coconut husk biochar 15 tons ha^{-1} (18.33%), and the smallest was found in coconut husk biochar 3 tons ha^{-1} (9.86%), compared to without biochar. Likewise, leaf area and total dry weight of maize plant, the greatest increase was found in coconut husk biochar 15 tons ha^{-1} (Table 1).

Maize plant which was given coconut husk biochar produced higher plant height compared to those not given coconut husk biochar, however, among the plant's given coconut husk biochar gave plant height that was not significantly different (Figure 1). Coconut husk biochar 15 tons ha^{-1} gives a plant height of 277.55 cm, while the biochar coconut husk 0 tons ha^{-1} (without biochar) is 234.55 cm.

The leaf area of maize planted with coconut husk biochar was higher than the leaf area without coconut husk biochar. Among the biochar doses of coconut husks, a dose of 15 tons ha^{-1} gives the highest leaf area (24769.12 cm2), but doses of biochar up to 9 tons ha^{-1} provide leaf area that is no different from without coconut husk biochar (Figure 2).

Increased plant height and leaf area by applying coconut husk biochar, followed by increasing total plant dry weight. Maize plant with the highest total dry weight was obtained at a biochar dose of coconut husk 15 tons ha^{-1} (102.79 g), While maize plant with the lowest dry weight is 0 tons ha^{-1} (68.42 g) (Figure 3).

The increase in plant height, leaf area, and total dry weight of the plant, in line with the increase P and K content in plant tissue at 8 WAP. Biochar application increases P and K compared to without biochar (Table 2).

Although there was an increase in the P content of plants by giving coconut husk biochar, the P content was still below the critical limit of the plant except for coconut husk biochar application by 15 tons ha^{-1} (0.35%). Coconut husk biochar application increases the K content of plants, and it exceeds the critical limits of the plant. The highest K content of plants was obtained at 15 tons ha^{-1} (1.99%). The plant N content remains below the critical limit even though it is given biochar up to 15 tons ha^{-1}.

Effect of coconut husk biochar on yield and total sugar of plants

Various doses of coconut husk biochar on maize plant significantly affected the yield of plants in the form of the number of seeds per cob and weight of seeds per plant, meanwhile giving various doses of coconut husk biochar had no significant effect on the 100 seed weight.

Coconut husk biochar can increase the number of seeds per cob of maize in the range of 32 - 55%, compared with no biochar application. The largest increase in the number of seeds due to coconut husk biochar was found in biochar the dose of 15 tons ha-^{1} (54.97%), while the smallest increase in number of seeds per cob was found in coconut husk biochar at a dose of 3 tons ha^{-1} (Table 3).

An increase in the number of seeds per cob followed by an increase in seed weight per plant. Increased seed weight per maize due to biochar application ranged from 36-69% compared to without biochar. In line with the number of seeds per cob, the highest increase in seed weight per plant was found in the biochar dose of coconut husk 15 tons ha^{-1} (Table 3).

Application of coconut husk biochar reduces the total sugar content of the maize plant. The increased dose of biochar given reduced total sugar content by 26%. The greatest decrease in total sugar content is found in coconut husk biochar 15 tons ha^{-1}. The total sugar content of maize at various doses of biochar could be seen in Table 4.

Effect of coconut husk biochar on improving physical and chemical soil properties

Coconut husk biochar given into the soil can improve the physical and chemical properties of the soil. Coconut husk biochar dose up to 15 tons ha^{-1} improves soil physical properties by reducing w/v, but increases TPS and SWC compared to without coconut husk biochar (Table 5).

Application of the coconut husk biochar can improve soil chemical properties by increasing soil pH, CEC, C, P, and K soils compared to without coconut husk biochar (Table 6).

DISCUSSION

Growth of maize plant expressed in the form of the total dry weight of plants showed an increase by giving various doses of coconut husk biochar. The results showed that coconut husk biochar application significantly affected the total dry weight of the plant, and the 15ton ha^{-1} gave the highest total dry weight.

The increase in the total dry weight of maize plant due to various doses of biochar coconut husk is closely related to the increase in leaf area, compared to the increase in plant height, this could be seen from the results of correlation analysis (R = 0.706 ** and R = 0.649 **; $p < 0.01$).

The leaves are plant organs that carry out photosynthesis, so the size of the leaf area will determine the amount of substrate produced during photosynthesis. Giving biochar with various doses can increase the leaf area of plants. An increase in plant leaf area closed related to an increase in plant P and K nutrient content. The biochar dose of 15 ton ha^{-1} has the highest percentage increase in P and K content (40.20% and 58.05%). The effects of biochar addition on plant dry biomass and nutrition were dependent upon the biochar type and application rate. Soil treated with coconut husk biochar at an equal rate of 30ton ha^{-1} resulted in a 90% increase in maize biomass and plant N and P concentrations of 0.88 and 0.12%, respectively (Gonzaga *et al.*, 2018).

Phosphorus (P) in plants is an energy transfer component (ADP, ATP and nuclei protein), genetic information systems (DNA and RNA), cell membranes (phospholipids) and phosphoproteins (Gardner *et al.,* 1985). P also plays a role in the photosynthetic intermediaries phosphorylation and respiration (Loveless, 1991). The increase in P maize plant increases the ability of plants to carry out photosynthesis in line with the increase in leaf area.

Potassium (K) plays an important role in the process of photosynthesis by increasing plant growth and leaf area index, increasing CO_2 assimilation and photosynthate translocation (Gardner *et al.,* 1985). Increased growth of maize plants caused by increased K content in plant tissue. K also plays a role in regulating the opening and closing of stomata, so increasing the K content of plant tissue is very important in plants cultivated in dry soil where water availability is limited.

Increased growth of maize plant is in line with Ultisol fertility improvement due to various doses of biochar coconut husk application. According to Harsanti and Ardiwinata (2011) biochar can improve soil physical properties such as soil aggregates and the ability of soil to bind water. The results showed that there was an improvement in the physical properties of the soil by applying coconut husk biochar, this could be seen by decreasing soil w/v, increasing total pore space (TPS), and increasing soil water content (SWC). In the coconut husk biochar 15 tons ha^{-1}, the greatest decrease in soil w/v (7.66%), while the greatest increase in TPS and SWC was also found in the biochar dose of 15 tons ha^{-1} (11.11% and 10.60%). Aslam *et al*. (2014) showed that the application of biochar at 1 – 2% (W/W) decrease the soil bulk density, increase soil porosity and infiltration rate by increasing the total soil porosity. The application of biochar improves water retention through a change in soil porosity, pore size, bulk density, and soil wetting ability (Devereux *et al*. 2012). The results of the study by Dariah *et al*. (2012) showed that biochar application enriched with biological fertilizers could increase the pore of available soil water. Suwardji *et al*. (2012) showed that biochar application 15 tons ha^{-1} for one year (three cycles of maize plant growing season) could increase the value of soil aggregate stability comparable to the 15 tons ha^{-1} manure given every planting season in the dry soil of North Lombok. Furthermore Nurida *et al.* (2013) showed that the application of several types of biochar to acid mineral soils produced lower bulk density and higher total pore space.

The application of coconut husk biochar also improves the chemical properties of Ultisol. The results showed an increase in soil pH, CEC soil, C, P and K-soil that were given coconut husk biochar. Soil pH increased by 1.36% - 6.32% (pH 5.41 - 5.68). Soil pH, CEC, total organic carbon, total potassium (total K), available phosphorus (available P), and available potassium (K) content are increased with the biochar application (Gao *et al*. 2017). The high biochar exchange cation capacity (CEC) can bind the cations of the soil which in turn increases the CEC soil, which can be utilized for plant growth (Mulyadi, 2013). Increased value of soil C-organic due to biochar application because biochar has a very high carbon content and can release carbon slowly in the soil so that its availability in the soil will be maintained until the next planting season (Yamato, *et al.*, 2006). The results showed that coconut husk biochar application could increase soil C-organic to 15.41% and biochar at a dose of 15 tons ha^{-1} gave the highest increase in soil C-organic content.

The results of the study Tambunan *et al.* (2014) who used a mixture of 20 tons ha^{-1} of biochar from maize plant litter and 40 tons ha^{-1} of maize plant litter were able to increase P available by 242.95%, increase 10.40% CEC, and provide the highest maize plant height. Bahrun *et al.* (2018) stated that there was an increase in soil temperature, soil moisture, and growth of cocoa seedlings by applying chocolate pod husk into the planting media. Biochar increases soil pH, C-soil, P-soil, and CEC soil. Increased growth of maize plant due to the application of various doses of biochar increases crop yields in the form of the number of seeds per cob and weight of seeds per plant. The application of coconut husk biochar increased the number of seeds by 32.70% - 54.98% and 35,545 - 68.97%. The greatest increase in yield was found in the application of coconut husk biochar by 15 tons ha^{-1}. The K content of the plant tissue is thought to influence the increase in the yield of a maize plant. Plants that were given coconut husk biochar at a dose of 15 tons ha^{-1} had the highest increase in K and the content in plant tissues exceeded the critical limits of the plant (1.99%). Increasing the K content of plant tissue increases the ability of plant translocation, thereby increasing crop yield, this is due to the role of K in photosynthate translocation (Gardner *et al*., 1985).

An increase in yield is also related to a decrease in the total sugar content of the plant tissue. Increased photosynthate translocation in the form of carbohydrates decreases the total sugar content of plants. Giving biochar 12 tons of ha^{-1} can increase the yield of a sweet maize plant by 24.60% when compared to without biochar (Sandiwantoro, 2017).

CONCLUSION

1. Application of coconut husk biochar with various doses increases the growth and yield of maize plant in the form of plant height, leaf area, total dry weight of plants, number of seeds, and weight of seeds.
2. Increasing the biochar dose to 15 ton ha^{-1} increases the nutrient content of P and K plants, but decreases the total sugar content of maize plant plants.
3. Application of coconut husk biochar improves the nature of Ultisol with decrease w/v, and increase soil

water content, total pore space, pH, CEC, C, P and K of soil.

4. Biochar a dose of 15 tons ha^{-1}, produces the highest growth and yield of maize plant.

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TABLES AND FIGURES

Table 1. Increased growth of maize plant at various doses of coconut husk biochar at 8 WAP.

Biochar doses (ton ha^{-1})	Increased growth (%)		
	Plant height	Leaf area	Total dry weight
3	9.86	7.77	22.14
6	10.48	8.35	29.12
9	11.32	23.15	28.94
12	11.39	30.19	34.60
15	18.33	36.05	50.24

Table 2. Increased P and K nutrient content of maize plant at various doses of coconut husk biochar at 8 WAP

Biochar doses (ton ha^{-1})	Increased (%)	
	P	K
3	5.88	15.71
6	6.86	16.50
9	20.59	15.71
12	13.72	26.44
15	40.20	58.05

Table 3. Increased maize yield at various doses of coconut husk biochar

Biochar doses (ton ha^{-1})	Increased (%)	
	Seed number	Seed weight
3	32.70	35.54
6	33.89	30.80
9	36.20	41.35
12	54.72	67.46
15	54.98	68.97

Table 4. The total sugar content of maize plant at several doses of coconut husk biochar at 8 WAP

Biochar doses (ton ha^{-1})	Total sugar content (%)
0	0.94
3	0.90
6	0.89
9	0.77
12	0.76
15	0.69

Table 5. Changes in soil physical properties at various doses of coconut husk biochar

Biochar doses (ton ha^{-1})	Changes in soil physical properties (%)		
	Decreased (%)		Increased (%)
	w/v	TPS	SWC
3	1.50	4.76	0.12
6	6.17	6.35	3.64
9	4.86	10.05	8.39
12	7.10	12.17	9.89
15	7.66	11.11	10.06

Table 6. Changes in soil chemical properties at various doses of coconut husk biochar

Biochar doses (ton ha^{-1})	Increased (%)				
	pH	CEC	C	P	K
3	1.36	16.02	2.20	0.79	30.33
6	1.64	20.72	10.03	2.36	30.74
9	1.97	32.88	7.43	0.26	78.28
12	2.76	29.16	8.96	4.68	227.05
15	6.32	43.56	15.41	10.63	281.27

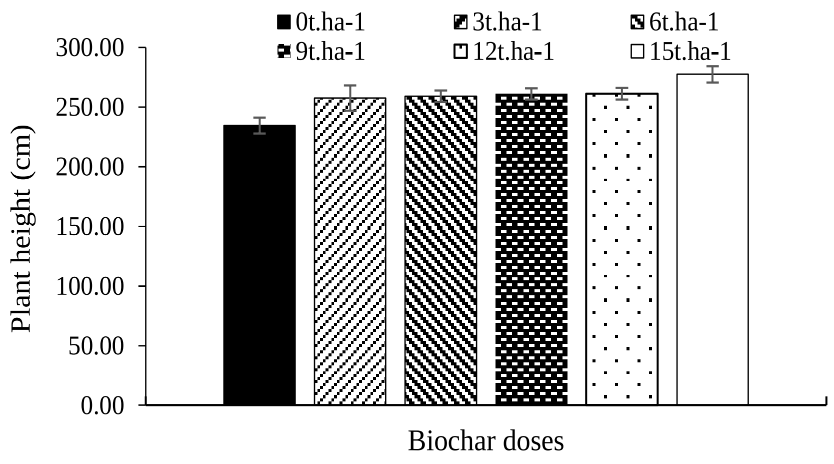

Figure 1. Maize plant height at various doses of coconut husk biochar at 8 WAP. Error bars indicate the standard error (n = 4).

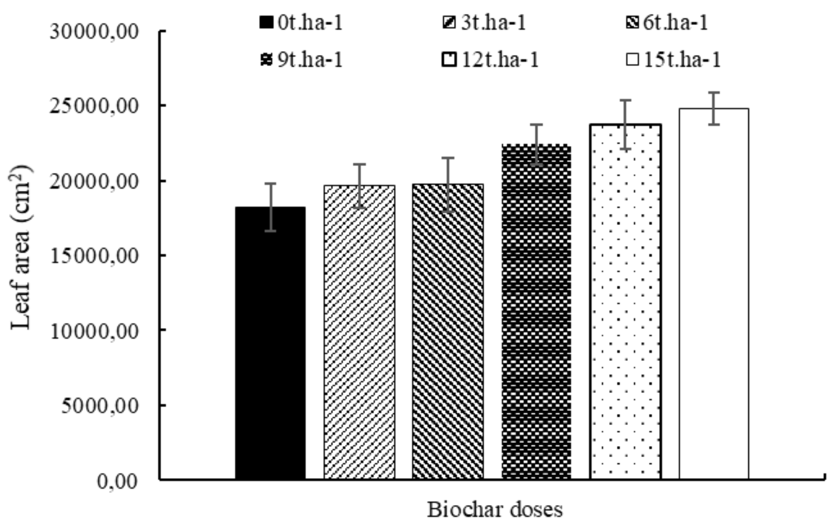

Figure 2. Leaf area of maize plant at various doses of coconut husk biochar at 8 WAP. Error bars indicate the standard error (n = 4).

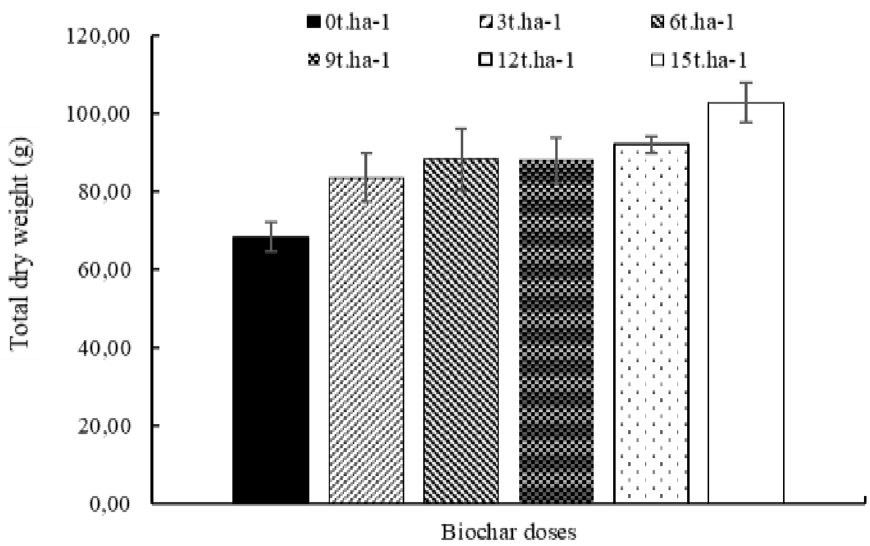

Figure 3. Total dry weight of maize plant at various doses of coconut husk biochar at 8 WAP. Error bars indicate the standard error (n = 4).