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Research Article

The application of biochar and organic matter for proper cultivation on paddy soil

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Abstract: Top soil was rich in nutrients for plant growth. Upper soil loss due to mining is a serious problem. The remaining soil was subordinate land which has poor soil characteristics and low productivity. This study aimed to improve the characteristics of mined soils by providing soil amelioration. The study was conducted in a former brick mining area in the village of Potorono Banguntapan, Yogyakarta, Indonesia. The study consisted of two stages. The first stage was a pot experiment using soils from a former brick mining area. The soil was mixed with coconut shell biochar as an ameliorant material at doses of 0, 10, 15 and 20 t/ha and incubated for 1, 2 and 3 months. The second phase of research was a demo farm. The demo farm aimed to compare the best results of the use of biochar in the first stage of this study with organic matter application in the second phase of the study. The organic matters used were cow dung and bagasse. Each of the two types of organic matter was applied at a rate of 15 t/ha. The organic matters were incorporated into the soil in a demo farm plot of 4 x 4 m^2 size in 1, 2 and 3 months. The results showed that application of coconut shell biochar ameliorant at a dose of 15 t/ha increased soil organic-C by 0.78% at two months of incubation, while soil cation exchange capacity increased at three months of incubation. The yield of plants obtained from the soil previously applied with coconut shell biochar was better than that applied with cow dung and bagasse as organic matters.

***Keywords**: biochar, environment, marginal soil, organic waste, paddy soil*

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Introduction

The application of biochar material aims to improve marginal soils. Biochar is biological charcoal obtained from carbon-rich from pyrolysis combustion. The raw material for biochar is organic material derived from wood tissue or other materials with high lignin content, while the organic matter is a nutrient-rich material obtained without going through the combustion process. Biochar is one of the soil ameliorants that can be used for improving the productivity of marginal soils (Liang et al., 2006; Singh et al., 2010; Singh et al., 2012). Former mining land is marginal land which needs soil ameliorant to restore soil function aspects due to loss of topsoil. The topsoil loss results in the less function of the soil from the physical, chemical and biological aspects for agricultural purposes (Głąb et al., 2016). The restoration of soil functions is expected to be able to store soil nutrients until plants can use them for growth. Biochar is a supplier material of C-stable to the soil that can reduce the occurrence of nutrient leaching.

Land damage due to mining and continuous use of land without replacement of nutrients will inhibit plant growth. This, in turn, results in low nutrients and C-organic contents the soil. Soil C-organic is important as structures of a framework for soil nutrient bonding structures that serves to slow the loss of soil nutrients due to leaching or nutrient transfer process. Soil improvement can be done by the provision of biochar and organic matter to the soil.

Materials and Methods

Biochar was made by the pyrolysis combustion process i.e. combustion with minimum oxygen supply. The study was conducted on ex-brick mine soil on an Inceptisol of Potorono Yogyakarta. Ameliorant used for ex-brick mine soil was that contained high C. The characteristics of the soil used for this study s presented in Table 1.

Table 1. Characteristics of ex-brick mine soil at Potorono Yogyakarta.

Parameter	Value	Grade
C - organic (%)	0.45	very low
N - total (%)	0.048	very low
P -available (ppm)	9.5	very low
K-available (ppm)	60	hight
C N ratio	9.38	low
pH H_2O	6.14	medium
CEC (cmol (+) kg-1)	5.49	Low
Texture		
Sand (%)	59	
Silt (%)	30	Sandy Loam
Clay	11	

The material used for this study was coconut shell biochar which was processed by pyrolysis at 600 ^{o}C without oxygen. The study was conducted in two stages. The first stage was a pot experiment with the application of coconut shell biochar material at doses of 0,10,15 and 20 t/ha, and incubation for 1,2 and 3 months. This first stage of the study used a completely randomized design. The technique application was mixing soil and coconut shell biochar. The second stage of the study was a demo farm. The best results obtained from the first stage of the study was applied to the demo farm. The best dose of 15 t biochar/ha was applied to the ex-brick mine soil. The coconut shell biochar and organic matters from cow dung and bagasse were incorporated into the soil with a dose of each of 15 t/ha. The application of those organic materials to the soil was aimed to improve the soil productivity for paddy. Soil organic-C and cation exchange capacity analyses were carried out after the incubation period of the first stage of the study. Harvested paddy grain weight was measured at the end of the first stage of the study. The data obtained were statistically analyzed using Duncan's Multiple Range Test at 5% level.

Results and Discussion

The soil of the study area (Inceptisol) is considered as a marginal soil in the catena of Mount Merapi slope that is affected by volcanic materials erupted from the Mount Merapi. The soil has a depth of 1.5-10 m above the parent material, with soil pH of 4.5-6.5, and moderate base saturation. The soil texture is sandy loam, and the soil structure is crumbs. In general, soil fertility of the soil studied is relatively low, but it can still be improved by technology for paddy soil. The Inceptisol of Potorono belongs to has suborder Ustepts where it has good drainage, grass vegetation and is managed as farmland. As the soil does not have duripan and calcic horizon the soil is grouped into Haplusteps. Continuous use of the soil for paddy cultivation results in a decrease in soil nutrients. In Potorono Village there are brick mining areas with taking up topsoil continuously for brick industries so that the physical and chemical functions of the soil are damaged. As shown in Tabel 1, the Inceptisol of Potorono has a very low content of organic-C (0.45%). This is because of the low content of organic matter in the soil. This makes the Inceptisol has low nutrients, low aggregation, and susceptible to erosion. Inceptisol is an undeveloped soil and still much resembles its parent material so it contains less than organic matter (Głąb et al., 2016; Tesfaye et al., 2016; Wu et al., 2017).

Results the experiments showed that the application of cow dung and bagasse as sources of organic matters had significantly affected the growth of paddy. Application of coconut shell biochar increased soil C-organic (Table 2). The growth of paddy was significantly influenced by giving biochar as a soil ameliorant. Indicators of soil fertility are one of the determining factors in crop production. The use of nutrients for plant growth at every planting period requires the substitution of nutrients. As soil organic matter is a material that contains complete nutrients, the level of soil organic matter must be maintained about 1.5 to 2%. Lack of soil organic matter can cause to marginal soil in agricultural land. Application of biochar on marginal soil is an effort to supply of soil carbon.

The application of coconut shell biochar at a dosage of 15 t/ha which had been incubated for two months resulted in the highest organic-C content of 0.78% (Table 2). The lowest content of organic-C of 0.48% was obtained at a dosage of 10 t/ha which had been incubated for one month. The application of biochar soil ameliorant has a positive effect on soil organic carbon. The application of biochar increased the level of organic-C in the soil. This is because biochar material is rich in lignin so that the carbon supply is high. The application of biochar that had been incubated for three months in the ex-brick mine soil increased cation exchange capacity of the soil compared to that incubated for 1 and 2 months in the soil (Figure 1). The more prolonged the incubation of biochar material in the soil the higher the interaction between material organic and clay minerals. The cation exchange capacity of the soil may still be improved with the clay content of 11% (Table 1). It is well known that soil cation exchange capacity is influenced by two factors, i.e. inorganic colloids such as clay minerals and organic colloids such as humus.

Table 2. The soil organic-C content (%) upon the application of biochar in the incubation experiment.

Incubation	Treatment				
	B0	B1	B2	B3	Mean
I1	0.64 a (pq)	0.48 bc (q)	0.45 c (q)	0.62 ab (p)	0.55
I2	0.54 c (q)	0.59 bc (pq)	0.78 a (p)	0.71 ab (p)	0.66
I3	0.70 a (p)	0.69 a (p)	0.67 a (p)	0.64 a (p)	0.68
Mean	0.63	0.59	0.63	0.66	(+)

Note: Numbers followed by the same letters in the same row (a, b, c) and the same column (p, q) show no significant difference, and the sign (+) shows an interaction, based on Duncan's Multiple Range Test at 5% level.

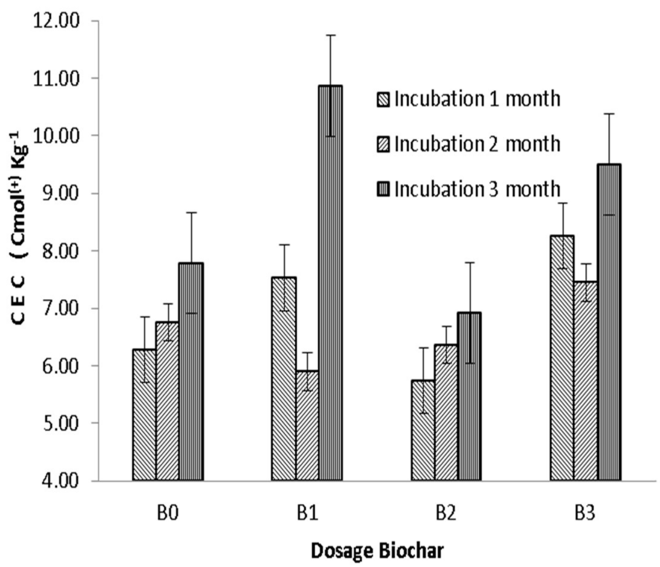

Figure 1. Cation exchange capacity of the soil upon the application of biochar.

The application of organic matter at a dose of 15 t/ha and the application biochar at a similar dose (15 t/ha) to ex-brick mine soil showed a positive influence on paddy yield. The application of biochar and organic matter increased the weight of 1000 grains of paddy (Figure 2). Increasing the weight of 1000 grains of paddy was due to due to the increase of stable of organic-C in the soil so it increased the sufficiency nutrients.

The application of biochar was proper to yield a higher weight of 1000 grains of paddy. The best dosage treatment was 15 t/ha. The result showed that the application of biochar is proper to restore the ex-brick mine soil. The use of soil organic matter has a positive effect compared to non-treatment, but the result was still lower than the biochar application (Puga et al., 2015). Results of this study indicated that nutrients in soil organic matter are more available but easier to experience leaching compared to those in the biochar. The treatment of biochar can provide organic-C in a sufficient amount to the soil so that the soil can absorb nutrients and can release nutrients when the plants need them.

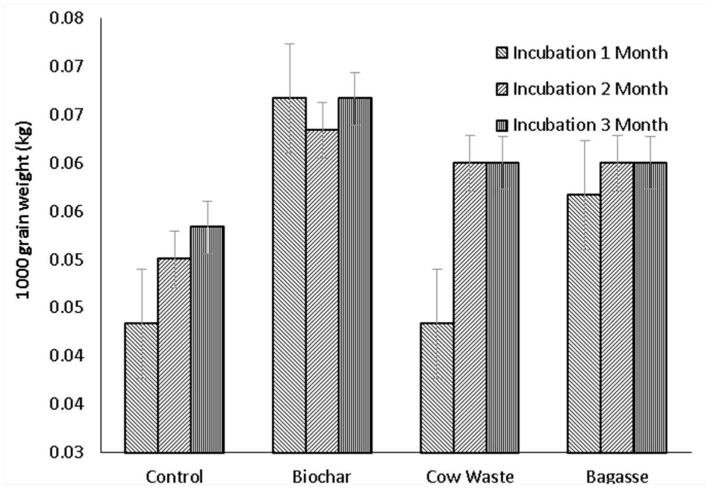

Figure 2. Weight of 1000 grains of paddy upon application biochar and organic matter to the soil.

Biochar can bind nutrients in the form of weak binding so that the nutrients are prevented from leaching (Chen et al., 2017; Li et al., 2018). The organic materials decomposition process becomes faster because of biochar application, thus provide more available nutrients quickly in the soil.

The yield of paddy after application of biochar and organic materials increased 1-2 t/ha (Figure 3). This shows that the application of biochar is effective for increasing paddy grain yield. The production of paddy at ex-brick mine soil due to the application of bagasse was smaller than that of the application of biochar and cow dung. This indicates that the bagasse contains a small number of nutrients and is slowly decomposed. The process of decomposition of organic materials in the soil depends on the levels of lignin contained in the material (Finney et al., 2016; O'Connor et al., 2018). In the decomposition process, microorganisms need nitrogen for their activities. The organic material will absorb much nitrogen for the body's formation process in microorganisms in the soil causing nutrient levels unavailable for plants.

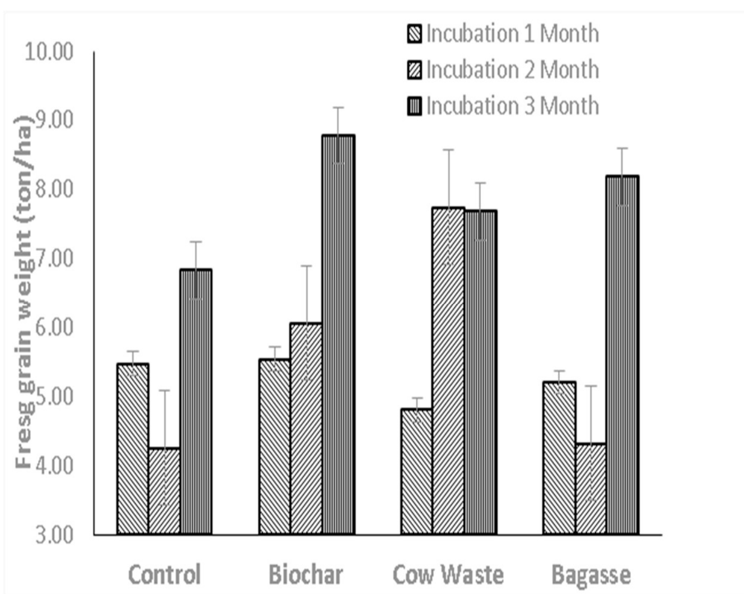

Figure 3. The fresh weight of paddy on the ex-brick mining soil.

Conclusion

Biochar is a biological charcoal that can be used as an ameliorant on marginal soils. Application of coconut shell biochar at a dosage of 15 t/ha with incubation of two months increased soil organic-C content by 0.78%, and increased cation exchange capacity at three months incubation. The harvested paddy grains increased 2 t/ha on the field applied with coconut shell biochar at a dosage of 15 t/ha at three months incubation. The application of coconut shell biochar gave a better paddy yield than organic materials from cow dung and bagasse.

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