Maintaining the sustainability of fertile agricultural soil using bamboo biochar in tropical volcano area

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Abstract. There has been massive information on the success of biochar application in increasing agricultural productivity marginal soil. It is generally believed that biochar improves soil physical, chemical, and biological properties, consequently, increase crop yield. There was almost no information on the use of biochar for fertile soils. On the other hand, Magelang Regency the agricultural lands lay in the area of the volcano. These areas are the main supplier of agricultural products for Central Jawa and other places. Therefore, a strategy is needed to maintain the sustainability of agricultural land productivity. The aim of the present experiment was to introduce the use of biochar to maintaining the fertility of the soil in this area. Our first experiment dealing with the use of bamboo biochar in reducing the use of phosphorus (P) fertilizer in fertile soil. The experiment was carried out in the Bandongan District of Magelang Regency. An area which is surrounded volcanoes. The experiment involved a series of P applied, namely, 0, 25, 50, 100, 200 and 400 kg of SP3 ha-1. They were applied with and without biochar. Mung bean (Vigna radiata) was used as an indicator plant. The results showed that the presence of biochar (1) reduces the use of P fertilizer up zero, (2) decrease in the need of P fertilizer from 50 kg SP36 ha-1 to obtain the optimum yield of Mung bean. and (3) the optimum yield of Mung bean was consistently higher in bamboo biochar treated soil than without biochar. The decrease of Mung bean yields due to application bamboo biochar without P applied. Moreover, the reduction P application in bamboo biochar treated soil than without biochar to obtain optimum yield, indicating, that bamboo biochar may be able to dissolve insoluble P residue from the previously applied P. It may be presumably that the increase of P availability of P to plants due to the rise soil pH caused the increases in soil soluble P and activity of P solubilizing bacteria.

Keywords: bamboo biochar, fertile soil, sustainability, Tropical, Volcano

1. Introduction
Magelang Regency is surrounded by four volcanoes, namely, Sindoro, Sumbing, Merbabu, and Merapi mountains. Therefore, most of the agricultural lands lay in highland areas. These lands are mostly fertile due to the effect of volcano ash during the eruption of the volcanos. However, these lands are prone to nutrient loss due to leaching and erosion. Biochar application is expected able to decrease nutrient loss. There was massive information on the success of biochar application in increasing agricultural productivity marginal soil [1,2,3,4]. It is generally believed that biochar improves soil physical, chemical, and biological properties, consequently, increase crop yield [5,6].

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The work of [7] showed that biochar reduced the amount of nitrogen (N) leached. There was almost no information on the use of biochar for fertile soils in the highland area. In the highland area, the application is expected to conserve the soil nutrients in the soil through the increase of cation exchange capacity and water holding capacity [8,9]. Therefore, the sustainability of agricultural land's productivity will be maintained. An opportunity was taken to introduce the use of biochar to maintaining the fertility of the soil in this area.

2. Methods

The experiment dealing with the use of bamboo biochar in reducing the use of phosphorus (P) fertilizer in fertile soil. The experiment was carried out in the Bandongan District of Magelang Regency. An area which is surrounded volcanoes. The soil in the experimental site was classified as a latosol. Some selected soil properties are showed later.

The experiment involved a series of P applied, namely, 0, 25, 50, 100, 200 and 400 kg of SP3 ha\(^{-1}\). They were applied with and without biochar. The biochar was made from Petung bamboo (Dendrocalamus asper). The rates of bamboo biochar applied were 0 and 5 tons ha\(^{-1}\). Mung bean (Vigna radiata) was used as an indicator plant. The plants were grown until the harvest period.

To describe the relationship between SP36 applied and yield of mung bean, the study used a Cate and Nelson method to estimate the optimum rate of SP36. The variation of mung bean yields was shown using the standard error of 3 means.

3. Results and Discussion

3.1. Selected properties soil and bamboo biochar

The selected soil properties of soil in the field were shown in table 1. From the soil properties measured, the soil was considered fertile. It was noticed that the soil contained a very high total P content. This indicated that farmers in this area often applying P fertilizer.

![Table 1. Selected soil properties of paddock used in the experiment.](image)

| Soil properties\(^{1}\) | Value | Category |
|------------------------|-------|----------|
| Soil texture           |       |          |
| Sand (%)               | 52    | Loam     |
| Silt (%)               | 38    |          |
| Clay (%)               | 10    |          |
| Organic C (%)          | 2.57  | Moderate |
| Total N (%)            | 0.28  | Moderate |
| Total P\(_2\)O\(_5\) (mgkg\(^{-1}\)) | 111  | Very high |
| Cation exchange capacity (cmol[+]kg\(^{-1}\)) | 25    | High     |

\(^{1}\) all methods are described in [6]

The selected bamboo biochar properties used in the experiment were demonstrated in table 2. Among the parameters measured, carbon (C) content was the highest. The total potassium (K), calcium (Ca) and magnesium (Mg) contents, however, were very low, they may be lost during the bio-charring process which had a temperature range of 600-700\(^{\circ}\) C.
Table 2. Selected bamboo biochar properties used in the experiment

| Bamboo biochar properties | Values (%) | Category | Method                        |
|--------------------------|------------|----------|-------------------------------|
| C organic (%)            | 32.62      | Very high| Ashed 600°C                   |
| Total K₂O (%)            | 1.70       | Very low | Wet digestion, HNO₂+ClO₄, measured using AAS |
| Total Ca (%)             | 0.38       | Very low |                                          |
| Total Mg (%)             | 0.35       | Very low |                                          |

3.2. Effect of bamboo biochar on the amount of P fertilizer used
Figure 1 demonstrates the response of mung bean to P applied without and with biochar application. First of all, we observed that the mung bean yields were much higher than the potential yield on the mung bean. This indicates that the soil in the research area is fertile. Secondly, in every level P applied, the yield of mung bean was always consistently higher in the presence of bamboo biochar compared without bamboo biochar. Finally, it also observed that there was a reduction in the use of P fertilizer as affected by bamboo biochar application. In biochar without P applied; the mung bean yield was equal with the yield at 100 kg SP36 without biochar. It is plausible that the bamboo biochar decreases the amount of P applied up to 100 kg SP36 ha⁻¹. The significant increase of mung bean of yield due to biochar may be explained by [5,6,8,9] as follow, biochar increase (a) soil pH lead to Al-P dissolution and activity of rhizobium, (b) soil pores fill with dissolved make possible to a better home soil microorganism, (c) soil water and (d) soil nutrient availability.

![Figure 1](image_url)

Figure 1. Effect of bamboo biochar application on P applied. Bars indicate standard error of 3 means

3.3. P applied to obtain the optimum yield of mung bean
Figure 2 showed the estimation of P applied to obtain the optimum yield of mung bean as affected by bamboo biochar. It was shown that (a) the optimum yields obtained were different, the optimum yield of mung bean treated with biochar higher than without biochar. (b) the amount of P applied was different, the optimum yield of mung bean was achieved by apply 25 kg SP36 ha⁻¹ when treated with biochar. However, without biochar, it needed 75 kg SP36 ha⁻¹. So, biochar application decreased in the
need of P fertilizer to 50 kg SP36 ha\(^{-1}\), and (c) the optimum yield of Mung bean was consistently higher in bamboo biochar treated soil than without biochar. The reasons for biochar in decreasing optimum rate and increasing optimum yield have been previously explained.

![Figure 2. Estimation P applied to obtain the optimum yield of mung bean. Bars indicate standard error of 3 means](image)

4. Conclusion

There was a significant increase of mung bean yield due to application bamboo biochar without SP36 applied. Moreover, there was reduction P application rate in bamboo biochar treated soil than without biochar to obtain optimum yield, indicating, that bamboo biochar may be able to dissolve insoluble P residue from the previously applied P. It may be presumably that the increase of P availability of P to plants due to the rise soil pH caused the increases in soil soluble P and activity of P solubilizing bacteria.

5. References

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