The utilization of agricultural waste for peatland management; in case chili cultivation

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Abstract. Peatland are known fragile and having a low bearing capacity for plant growth and production. One of the technologies that could be applied to improve peatland management is agricultural waste utilization. Agricultural waste such as ash and biochar from rice husk could be used as an ameliorant to improve the peatlands fertility. The objective of the experiment is to study peatland properties, carbon dioxide emission and yield of chili due to the application of ameliorant from agricultural waste. The experiment was conducted on the peatland that located around the farmer's settlement. The treatment of experiment was set up with three treatments i.e.: rice husk biochar (RHB), rice husk ash (RHA) and without ameliorant. The results showed that the application of agricultural waste improved some peatland chemical properties, reduced carbon dioxide gas emission, and increased the yield of chili.

1. Introduction

About 3% of peatlands in worldwide are found in Indonesia [1]. Most of them are located in tidal swamp areas and associated with alluvial soil which is utilized by farmers for rice field. A part of peatland has converted to the social and economic infrastructure. Peatland that located around the farmer's settlement has long been utilized by farmers as agricultural land, especially for horticulture commodity such as chili and tomatoes. However, peatlands are known having fragile properties and low bearing capacity for plant growth and production. Low nutrient levels and high acidity become the main problem in optimizing of peatlands to improve farmers' welfare.

Peatland is a nonrenewable natural resource, mismanagement of peatland causes serious land degradation. Drying land, clearing land with frequent burning by farmers causes peat oxidation and increases the danger of peat fires, which leads to peat loss and increases greenhouse gas emissions, and increases the risk of global warming. Instead, technology is needed in managing peatlands for agriculture that is environmentally friendly and economical.

Rice is a staple food for Indonesian, at least 15-20% of rice husk (RH) as agricultural waste is produced from each grain yield production [2], it means that 800 kg of husk could be obtained for each in 4 t ha\(^{-1}\) of grain yield. The utilization of raw RH is generally not recommended as soil ameliorant since it contains high carbon (C) : nitrogen (N) ratio of about 85:1 and is rich in silica and lignin which makes it difficult to be degraded [3]. Keeping in mind the high risk of the environment, as well as the welfare of farmers, a strategy should be adopted for an effective utilization of RH for agricultural management on peatland. However, the presence of high lignin content makes the RH less vulnerable to microbial attack. Pre-treatments are required for effective utilization RH as agricultural waste. A simple technology for utilization of RH is converted of RH to be rice husk biochar (RHB) or rice husk ash (RHA). The research was conducted to study the changes in peatland soil chemical
properties, carbon dioxide emission, and yield of chili due to the application of ameliorant from agricultural waste.

2. Methods
The experiment was conducted on moderate peatland that located around the farmer's settlement, Kalampangan Village, Central Kalimantan. The experiment consisted of one treatment factor with six replications. The factor was soil amelioration with RH as raw material, which consisting of RHA, RHB and without amelioration (control) (table 1).

| Treatment code | Ameliorant (t ha\(^{-1}\)) | Base fertilizer (kg ha\(^{-1}\)) |
|---------------|-----------------------------|----------------------------------|
|               | RHA                         | RHB                              | Lime | Cattle manure | Urea | SP 36 | KCl  |
| RHA           | 16.5                        | 0                                | 2    | 15            | 125  | 125   | 125  |
| RHB           | 0                           | 15                               | 2    | 15            | 125  | 125   | 125  |
| Control       | 0                           | 0                                | 2    | 15            | 125  | 125   | 125  |

Soil parameters such as soil pH, soil C, soil electrical conductivity (EC), phosphorus (P), calcium (Ca), magnesium (Mg) and cation exchange capacity (CEC) in soil were analyzed in a laboratory based on Balai Penelitian Tanah [4]. All of the parameters were observed at the end of the experiment.

3. Results and discussion
Ameliorant application increased peat soil pH, higher neutralizing power of ameliorant shown by RHA (figure 1). Previously Masulili et al [5] also reported that RHB and RHA increased soil pH. The higher pH of RHA is possibly related to the presence of carbonates formed during the heating process [6]. According to Islabão et al [7] and Okon et al [8] application RHA improve soil pH of acid soil. This condition related to high base cations contained in RHA [7] as reflected in EC value (figure 3). According to Demeyer et al [9] while organic matter combustion is mineralized and basic cations are converted to their oxides, which can be hydrated and carbonated by exposure to atmospheric conditions after burning. Potassium and Na oxides in ash are mainly responsible for the neutralizing power of acidity [10].

![Figure 1](image-url)  
**Figure 1.** Peat soil pH due to soil amelioration with RHB and RHA.

Total C in peat soil determined with lost on ignition method. Ameliorant application decreased carbon in peat soil (figure 2), it was related to increasing mineral content in peat soil due to RHB and RHA application, as reflected in EC value (figure 3). Although EC did not provide a direct measurement of specific ions or salt compounds, it has been known that EC is correlated to
concentrations of sodium (Na), ammonium (NH$_4$), K, Ca, Mg, iron (Fe), aluminium (Al), copper (Cu), zinc (Zn) and manganese (Mn). At least ameliorant such as RHB containing 50-70% mineral (as ash content) [5;11] and RHA contain 20-38% mineral (as ash content) [12; 13].

Figure 2. Soil C content due to soil amelioration with RHB and RHA.

Total C in peat soil determined with lost on ignition method. Ameliorant application decreased carbon in peat soil (figure 2), it was related to increasing mineral content in peat soil due to RHB and RHA application, as reflected in EC value (figure 3). Although EC did not provide a direct measurement of specific ions or salt compounds, it has been known that EC is correlated to concentrations of sodium (Na), ammonium (NH$_4$), K, Ca, Mg, iron (Fe), aluminium (Al), copper (Cu), zinc (Zn) and manganese (Mn). At least ameliorant such as RHB containing 50-70% mineral (as ash content) [5;11] and RHA contain 20-38% mineral (as ash content) [12; 13].

Figure 3. The value of EC due to soil amelioration with RHB and RHA.

Phosphorus and exchangeable K in peat soil increased due to RHB and RHA application (figures 4A and 4B). Similar results were reported by Oladele et al [14] and Okon et al [8]. Increasing concentrations of exchangeable P and K in peat soils are related to the P and K contained in the applied RHB and RHA, chemical analysis in the laboratory shows that RHB [6] and RHA [8] contain P and K which can be utilized by plants. Based on ameliorant types, a higher concentration of P and K in peat soil was shown by RHA application. Phosphorus and K contained in RHA was higher than RHB (table 2), this is in contrary to Masulili et al [5] reported that RHA application caused lower P in acid soil than RHB application. This condition may relate to the difference in P and K contained in RHA and RHB that used in both studies, in which the recent study showed P and K contain in RHA was higher than RHB while the opposite condition is shown from Masulili et al [5].
Figure 4. The concentration of exchangeable P (A) and K (B) of peat soil due to soil amelioration with RHB and RHA.

Table 2. Characteristic of ameliorant used in experiment.

| Ameliorant   | P (%) | K (%) |
|--------------|-------|-------|
| Cattle manure| 1,902 | 3,459 |
| RHA          | 0.297 | 1.310 |
| RHB          | 0.048 | 1.107 |

The opposite of exchangeable P and K concentration in peat soil were shown by exchangeable Ca and Mg concentration, their concentration in peat soil was decreased due to RHB and RHA application (figures 5A and 5B). Previously, Wacal et al [15] also reported a similar condition, they stated that biochar act as a sink rather than a source for exchangeable Ca and Mg. Besides, according to Wacal et al [15] decreased in exchangeable Mg concentration in soil was related to competition between Mg and K in soil solution or adsorption site, RHA application increased the concentration of exchangeable K in peat soil (figure 4). The recent report is similar with Oyama and Hayashi [16] who found that RHA application increase exchangeable K and decreased exchangeable Mg.

Figure 5. The concentration of exchangeable Ca (A) and Mg (B) of peat soil due to soil amelioration with RHB and RHA.

Peat soil has large CEC, ranges 52-160 cmol kg$^{-1}$ [17], Gruba and Mulder [18] stated large CEC of soils relate with large organic C content. Organic matter has been well established as a source of CEC sites in the solid phase of soils [19]. The recent study showed that CEC of peat soil was 176 cmol kg$^{-1}$, RHB and RHA application decreased CEC of peat soil (figure 6). This is contrary to Masulili et al [5] and Okon et al [8], they reported that RHB and RHA application increased CEC of acid soil. These
difference might be explained with soil as research material that used in each study, in which Masulili et al [5] used mineral soil with low CEC as material in their study, whereas recent study used peat soil with large CEC as material. In mineral soil, RHB and RHA application increased organic material content of soil and decreased the proportion of mineral content of soil. While in the peat soil, RHB and RHA application increased mineral content of soil and furthermore decreased the proportion of organic material content of soil.

Figure 6. Soil CEC value due to soil amelioration with RHB and RHA.

As stated in the methodology, all of the experiment units receive 25 t ha\(^{-1}\) of chicken manure. Commonly, the application of organic fertilizer significantly enhanced CO\(_2\) production, Johansen et al [20] reported that CO\(_2\) emissions increased after cattle slurry application, this fact attributed to the supply of high amounts of easily available C and N, which stimulated microbial activity. The application RHB and RHA decreased CO\(_2\) emission (figure 7). Previously, a similar result was reported by Sarkhot et al [21] that soil amendment with biochar resulted in a reduction in cumulative CO\(_2\) flux, and RHB amendment had significantly reduced CO\(_2\) emissions [22]. RHB and RHA have a high potential to sequester atmospheric CO\(_2\) into more stable soil organic carbon as stated by Zimmerman et al [23]. These results suggest that RHB and RHA applications contribute to mitigating global warming.

Figure 7. The CO\(_2\) emission value due to soil amelioration with RHB and RHA.

Application of RHB and RHA increased chili yield, the highest yield (17.6 t ha\(^{-1}\)) was obtained in the RHA application while RHB application obtained 13.86 t ha\(^{-1}\) (figure 8). This result is in line with the report by Priyadharshini and Seran [24] who obtain the highest cowpea result due to applied RHA and chemical fertilizer. The highest result that obtained from RHA application was related to
increasing soil quality mainly exchangeable K as shown in figures 1, 4 and 5. According to Gupta and Sengar [25] significant yield of tomato were increased by increasing application rates of potassium.

![Figure 8](https://example.com/figure8.png)

**Figure 8.** The yield of chili due to soil amelioration with RHB and RHA.

4. Conclusion

The utilization of agricultural waste as ameliorant such as RHB and RHA improved peat soil chemical properties, RHB and RHA application increased peat soil pH, P concentration, and exchangeable K in peat soil, increased chili yield soil, and decreased CO$_2$ emission. We argue that expanding the use of RHB and RHA in agricultural lands would be important for sequestering atmospheric CO$_2$ and mitigating climate change.

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