Effectiveness of ameliorant and fertilizer on improving soil fertility, growth and yields of red chili in degraded peatland

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Abstract. The research was carried out on degraded peatland in Kalampangan village, Sebangau District, Palangkaraya, from June to October 2017. The treatments given were factor I; Types of ameliorant material (A1;100% cow manure, A2;50% cow manure+50% biochar, A3;50% cow manure+50% compost from weed in situ, A4; 50% cow manure+50% ash from weeds in situ), and factor II; Dosage of NPK fertilization (D0; without NPK, D1;50% of recommended dose; D2;100% of recommended dose, D3;150% recommended dose). The treatment was arranged in a factorial randomized block design (RBD), and repeated 3 times. Observation variables include the soil pH and P-available, The number of fruit per plant, the weight of chili and chili yields. The results showed that the highest soil pH was indicated by A4D1 treatment. However, the highest soil P indicated by the A4D3 treatment, as well as for the highest chili yield indicated by A4D3 treatment reached 19 t/ha or increased 6% from the recommended dose (18 t/ha) on the same ameliorant treatment (A4), and increased up to 43% compared to the ameliorant A1 (100% cow manure) on the same dose of NPK fertilizer.

Key words: ameliorant, chili plant, degraded peatland, fertilizer

1. Introduction
Degradation of peatlands in terms of decreasing their function as a plant growing medium, characterized by one or combination of several the following characteristics ie decreasing of water holding, increasing soil acidity, decreasing total organic carbon (TOC) and total N [1]. Degradation of peatlands is often caused by land drainage. In undisturbed conditions, peatland carbon stocks were generally stable [2].

Degraded peatlands could be seen directly in the field through the type of land cover or the appearance of a field (3). Some characteristics of field sightings were (1) cover crops are shrubs, and (2) ex-mine open land. Usually, the land was not utilized because of its low productivity, lack of supporting facilities, and far from settlements [4] and the higher production inputs needed to produce the same amount of food [5].
Degraded peatlands have the opportunity to be used as productive agricultural areas. However, not all degraded peatlands can be used as productive agricultural areas. According to several studies in several places in Indonesia, peatlands did not always provide encouraging results and even often fail [6]. However, some research results were summarized by [7]; [8]; [9] showed that well-managed peatlands and sufficient inputs could provide good yields for rice, vegetables and plantation crops.

Peatlands had long been used for horticultural crops including red chili plants and the yields were quite beneficial (10). Red chili was a potential commodity that has high economic value and has the potential to continue to be developed [11]. Red Chili commodity is not a staple food for the people of Indonesia. However, its role as a supplement to cooking, supported by its fluctuating price, and chili often contributed to inflation for the national economy [12].

Improvements for soil chemical properties, especially pH and availability of degraded peat nutrients were needed to support the growth and production of chili plants on peatlands, despite the physical characteristic of peatlands. Peat soil could be used for vegetable cultivation such as chili (*Capsicum annum*) [13]. However, must consider the sustainability of land and the environment. Chili would grow very well on loose soil, crumbs, rich in organic matter, enough nutrients and water [14] with acidity levels 6-7 [15]. Therefore, technology is needed to improve soil properties through amelioration and fertilization to improve soil fertility and chili production on degraded peatlands. This study aimed to determine the effectiveness of ameliorant type and the dose of fertilizers for improving soil fertility, growth, and yield of red chili in degraded peatland.

2. Materials and Methods
The research materials used were cow manure, biochar, internal weed compost, inorganic fertilizers (urea, superphosphat, KCl), chili seeds, polybag, mulch, pesticides and chemicals for soil analysis, stationary. The tools used were ruler, tillage tools, sprayer, water machine and water sampling tool and tools for soil analysis.

The research was carried out on degraded peatlands in the village. Kalampangan, Kecamatan. Sebagau, Municipality of Palangkaraya, in June - October 2017. The treatments given were: (1) types of ameliorant materials and (2) fertilizing doses. The treatment was arranged in factorial randomized block design (RBD), and repeated 3 times. Factor I: Ameliorant material type, i.e; A1: 100% cow manure, A2: 50% cow manure + 50% biochar, A3: 50% cow manure + 50% weed compost in situ, A4: 50% cow manure + 50% weed ash in situ. Factor II; NPK Fertilization Dosage, i.e; D0: Without NPK, D1: 50% of recommended dosage (N; 50 kg ha$^{-1}$, P$_2$O$_5$; 100 kg ha$^{-1}$, K$_2$O; 60 kg ha$^{-1}$), D2: 100% of recommended dosage (N;100 kg ha$^{-1}$, P$_2$O$_5$; 200 kg ha$^{-1}$, K$_2$O; 120 kg ha$^{-1}$), D3: 150% recommended dose (N;150 kg ha$^{-1}$, P$_2$O$_5$; 300 kg ha$^{-1}$, K$_2$O; 180 kg ha$^{-1}$).

The dosage of soil ameliorants was 5 t ha$^{-1}$ for every treatment, with ameliorant type according to the treatment. Soil ameliorant material was given 2 weeks before planting. Basic fertilization in the form of NPK, with doses according to treatment. The recommended dosage of urea (N), SP-36 (P$_2$O$_5$), and KCl (K$_2$O) is 100-200-120 kg ha$^{-1}$ [16]. Urea fertilizer was given 3 stages, 1/3 dose given when planting, 1/3 at 1 month after planting and 1/3 at 1.5 after planting.

Land preparation was done by land clearing and soil tillage as deep as 30-40 cm. The land that had been processed was then made a plot of 5 x 6 m for each treatment so that each plot was 30 m$^2$. The land was made of beds with a width of 1.2 m, a height of 30 cm, and a distance between beds of 30 cm. Planting holes were made with a spacing of 50cm x 40cm and on each bed there are 2 rows of plants. The seeds used are Hot Chili varieties. Seeds were sown in polybags for 20 days. The polibag planting media was using a mixture of peat soil and manure (1: 1).

Initial soil analysis included soil water content, pH, EC, total N, organic C, available P, exc K, exc Ca, exc Mg, Eh, exe H$^+$ and exc Al. Furthermore, periodic soil sampling was carried out at the vegetative phase (1st month), vegetative end (2nd month) and generative (3rd month) for analysis of pH and available P. The growth of chili plants was carried out every 2 weeks. At the end of the
observation (harvest) observed the number of fruit crops, weight of chili fruit and chili production. Data analysis was performed on the observation variables in the form of variance analysis followed by Duncan test 5%.

3. Results and Discussion

3.1. Characteristics of Peatlands

The peatland had been opened and more than 10 years have not been used so that it becomes an idle area. Degradation of peatlands at the research sites is caused by human activities that open up peat forests, thereby changing the structure of peatland vegetation, as well as the result of the construction of drainage channels.

The chemical characteristics of the degraded peat soil studied as presented in Table 1. Soil acidity is classified as very acidic (pH H$_2$O of 4.6 and pH KCl of 3.53). This condition indicates the exchange complex is saturated by acid cations namely H and Al. This is indicated by the value of Al$^{3+}$ and H$^+$ very high, (Al; 15.5 cmol kg$^{-1}$ and H; 3.1 cmol kg$^{-1}$). The content of organic C and N of peat is very high too, which indicates that peatland has not experienced much decomposition. On peatlands that have been cultivated intensively, there has been a marked decrease in total N levels (around 0.6%). The decrease in N content was an indication of high nitrogen mineralization from peat material due to the conversion of functions into cultivated land through the addition of ameliorant and fertilizing materials [17].

Table 1. Initial soil chemical characteristics at the study site

| Chemical properties    | Value   | Category   |
|------------------------|---------|------------|
| pH H$_2$O              | 4.67    | Very low   |
| pH KCl                 | 3.53    | Very low   |
| EC (mS cm$^{-1}$)      | 0.059   | Low        |
| Organic C (%)          | 52.54   | Very high  |
| total N (%)            | 1.215   | Very high  |
| available K (cmol$^{(+)}$kg$^{-1}$) | 0.700   | is being   |
| available Na (cmol$^{(+)}$kg$^{-1}$) | 0.234   | Very low   |
| available Ca (cmol$^{(+)}$kg$^{-1}$) | 4.294   | low        |
| available Mg (cmol$^{(+)}$kg$^{-1}$) | 2.586   | high       |
| CEC(cmol$^{(+)}$kg$^{-1}$) | 135.77  | Very high  |
| Exe Al (cmol$^{(+)}$kg$^{-1}$) | 15.494  | High       |
| Exe H (cmol$^{(+)}$kg$^{-1}$) | 3.099   | High       |
| Total P (mg 100g$^{-1}$) | 176.533 | Very high  |
| Total K (mg 100g$^{-1}$) | 11.543  | low        |
| Water content (%)      | 287.36  | Very high  |

Note: Determination of criteria based on the Soil Research Center Study, 1983

The available P content is high, this condition is related to the level of maturity of peat in the research location classified as sapric. Peat with a high decomposition level has the ability to store P higher than peat with a low decomposition level. The amount of P available in peat material was also determined by the level of decomposition [18]. Availability of K in the study location was classified as moderate (0.70 cmol$^{(+)}$kg$^{-1}$), but total K was classified as low. K content on peatlands varies depending on the level of decomposition and mineralization of peat. The source of acidity of the peat soil studied is dominated by H and Al. The H ion came from the dissociation of organic acids which were usually dominated by fulvic acid and humic acid. Organic acids contributed significantly to the
low pH of peat soils [19]. Decomposition of organic matter has a reactive group, include carboxylates (-COOH) and phenolics (C₆H₄OH) which dominate the exchange complex and can be as organic acids that are strong enough to dissociate and produce large quantities of H⁺.

3.2. Effect of ameliorant type and NPK fertilizer dosage on soil pH

Ameliorant type and NPK fertilizer dosage affect soil pH especially in the 2nd and 3rd month (Figure 1). The highest soil pH in the 3rd month was shown by A4D1 followed by A2D3, while the lowest is indicated by treatment A1D0. In the observation period of the second month there was a decrease in H₂O pH and in the third month pH increased. The increase in pH at the beginning is due to the reaction of giving ameliorant which quickly releases alkaline cations so that it can bind H⁺ and organic acids, so the soil pH increase. Furthermore, the complexation effect weakens, then the peat returns to release acidic organic acids and H⁺ ions so that the pH decrease.

![Figure 1. H₂O pH fluctuations due to the treatment of ameliorant type and NPK fertilizer dosage in several observation periods.](image)

Description
A: Ameliorant material type (A = 100% Cow manure; A2 = 50% Cow manure + 50% biochar, A3 = 50% cow manure + 50% compost from weeds in situ, A4 = 50% cow manure + 50% ash from weed in situ)
D: NPK Fertilization Dosage (D0 = No NPK; D1 = 50% of recommended dosage; D2 = 100% of recommended dosage, D3 = 150% recommended dose)

Low soil pH is caused by hydrolysis of organic acids. These organic acids were usually dominated by fulvic acid and humic acid. Organic acids made a significant contribution to the low pH of peat soil [19]. The reactive groups include carboxylic (-COOH) and phenolics (C₆H₄OH) which dominate the exchange complex and can be as weak acids so that they can dissociate and produce large amounts of
H ions. Low soil pH would affect the availability of other nutrients such as P, K and Ca and a number of micro elements.

3.3. The effect of ameliorant and fertilizer dosage of N, P, K on available P

Ameliorant type and fertilizer dosage N, P, K affect the availability of P. Fluctuations in P availability occurred at each observation period. The pattern of fluctuations in P availability differs depending on the type of ameliorant (Figure 2). Ameliorant treatment which provides the highest P availability is indicated by A4 ameliorant (50% cow manure + 50% ash from weeds in situ). The ameliorant contained a lot of positively charged alkaline ions, so it could suppress phenolic acid [20]. Decreasing phenolic acids is caused by interactions between cations as bridges of cations and phenolic acids through the polymerization process. The addition of polyvalent cations such as Fe and Al would create a trapping site for phosphate ions so that it could reduce P nutrient loss through leaching. Provision of high-Fe mineral soils could increase rice growth and production in peatland.

![Figure 2. P-available fluctuations due to the treatment of the ameliorant type and the dose of N, P, K fertilizer in several observation periods](image)

Ameliorant A2 (50% cow manure + 50% biochar) is also able to increase P availability even though it is not as large as A4 treatment. Giving biochar could increase the availability of P, soil pH, K and Ca-dd [21]. Biochar was able to increase nutrient availability for plants and plant productivity (22). The effect of biochar addition on soil respiration and CO₂ emissions varied [23], depending on the type of biochar, soil type and soil organic C level [18]. Addition of ameliorates with alkaline cations was expected to reduce the amount P was leached, through formed a cation bridge (24). (25) reported that polyvalent cation could increase available P.
3.4. Red Chili Growth

The treatment of ameliorant type and fertilizer dosage affected the height of chili plants. Treatment without fertilization (D0) shows the lowest plant height in all types of ameliorants (Figure 3). While the treatment that gave the best effect on the height of chilli plants on 6 WAP was A4D2 treatment (50% cow manure + 50% ash from insitu weeds) which was combined with NPK doses according to the recommendations. Amelioran which gives the best influence on plant growth is A4 ameliorant. Ash contained bases, so it could increase soil pH and increase the availability of Ca, and Mg in peat soil [26].

![Figure 3. Effect of treatment on the growth of chili plants](image)

Improvement of growth in A4 ameliorant is due to A4 ameliorant being able to increase nutrient availability of P (Figure 2), thereby increasing root development and plant cell growth. According to [27], that P played a role in plant cell growth. The function of element P to stimulate root growth, fruit growth and ripening of seeds [28]. According to [29], peatland had the potential to be developed chili plants, if soil acidity and availability of K, Ca, and Mg were improved through the provision of dolomite lime, manure, Urea, SP36, and KCl.

3.5. Red Chili Yields

The treatment of the type of ameliorant and the dose of NPK fertilization affect the yield component and yield of chili plants. The effect of fertilizer dosage on A2 and A3 ameliorants is not different, namely, an increase in fertilizer dosage of 50% from the recommended dosage gives chili yield not different from the recommended dosage. Whereas in A4 ameliorant, increasing dose of N, P, K fertilizer up to 150% from the recommended dosage showed an increase in the size and weight of chili fruit.
Figure 4. The weight and number of chili due to the type of ameliorant treatment and NPK fertilizer dosage

Production of chili plants is influenced by nutrient content, especially nutrients, N, P, K on soil and plant growth. According to (30) fruit growth required nutrients, especially nitrogen, phosphorus and potassium. Nitrogen is needed for the formation of chlorophyll which is useful in photosynthesis, protein and fat formation. The phosphorus element is useful for stimulating root growth, helping assimilation and breathing while accelerating flowering, fruit formation and ripening of fruit and seeds. P could increase crop yields, improved yield quality and accelerated maturation while potassium (K) acted as a catalyst for various enzymatic reactions and other physiological processes so that the overall effected on growth and quality of results (27).

Figure 5. Results of chili due to the type of ameliorant treatment and NPK fertilizer dosage
Increasing of the fertilizer dosage of N, P, K will increase the yield of chili (Figure 5). The highest production of chili plants was shown by the treatment of ameliorous A4 at N, P, K dose 150% of the recommendations (D3) reached 19.01 t ha\(^{-1}\). Increased N, P, K fertilization doses from recommendations will improve chili yield. The research sites are degraded peatlands and have never been used for agriculture with very low nutrient content. In order to support plant growth and yield, nutrients in quantities are needed [31]. Chili plants require nutrients in sufficient quantities. The fertilizer needed of chili plants in general are 250 kg ha\(^{-1}\) Urea, 500 kg ha\(^{-1}\) TSP, 400 kg ha\(^{-1}\) KCl [32]. Elements of N, P, K played a role in photosynthesis so that they played a role in the preparation of carbohydrates, constituents of carbohydrates, fats, proteins, minerals and vitamins which would be translocated to fruit storage [33]. If the plant photosynthesis process taken place optimally, the photosynthate produced would be optimal, which would affect the size and weight of the fruit harvested [34].

4. Conclusion
Amelioration and fertilization affect the soil properties, growth and yield of chilli on peatland. The effectiveness of amelioration and fertilization varies depending on the type of ameliorant and the dose of NPK fertilizer. The highest soil pH was indicated by A4D1 treatment. However, the highest soil P indicated by the A4D3 treatment, as well as for the highest chilli yield indicated by A4D3 treatment reached 19 t ha\(^{-1}\) or increased 6% from the recommended dose (18 t ha\(^{-1}\)) on the same ameliorant treatment (A4), and increased up to 43% compared to the ameliorant A1 (100% cow manure) on the same dose of NPK fertilizer.

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