The amelioration of tidal peatland to improve liberica coffee productivity in Jambi

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Abstract. Liberica coffee is a type of coffee that is adaptable to peatlands. The farmers in Jambi have been using peatland to grow Liberica coffee. However, after more than 15 years the productivity started to decline by 25%. This study aims to increase the productivity of Liberica coffee in tidal peat soils. The study used a randomized block design with soil ameliorants as treatments, namely (P0 as control) no ameliorants, (P1) dolomite, (P3) manure, (P4) biofertilizer, (P5) dolomite + manure, and (P6) manure + biofertilizer. Four replications were used with plot size 2 x 5 plants. The total samples of the study were 280 plants. Maintenance of the area and plants includes weeding, cleaning tertiary channels, cleaning the plant areas. Simultaneously, parameters observed, including the number of branches, number of bunches/branches, number of berries, berries production, number of berries /100 g. Vegetative parameters were the increase in plant height and number of branches. Another parameter was soil analysis. The results showed that amelioration of peatland increased nutrition in the Liberica coffee leaf. Dolomite application increased the P, Mg, and Fe levels. In contrast, manure increased N, K, and Fe, biofertilizers or dolomite combined with manure increased N, P, K, and Fe. In contrast, the combination of dolomite and biofertilizer increased P, K, and manure, and biofertilizer increased N, P, and Fe in Liberica coffee leaf. Dolomite increased plant height up to 0.76 cm and the number of branches up to 5.05 branches/plant of the Liberica coffee. Dolomite application also increased productivity up to 47.96%, manure 30.69%, while other soil ameliorants can increase productivity by 4.11% to 11.87%. Dolomite, manure, and biofertilizer application can improve berries quality by 5%.

1. Introduction

Coffee is an important export commodity for the national economy. Indonesia is known as one of the largest coffee producing and exporting countries in the world. The development of Indonesia’s coffee export volume in 1980-2018 fluctuates with a tendency to increase by an average of 2.77%/year [1]. The average coffee production of Indonesia is the fourth after Brazil, Vietnam, and Colombia. Robusta coffee dominates Indonesian coffee production. In 2018, Indonesia’s coffee production amounted to 722.46 thousand tons, of which 73.06% or 527.80 thousand tons was Robusta coffee, while the remaining 26.94% or 194.66 thousand tons was Arabica coffee [2].

Liberica coffee (Coffea liberica) has not been developed much. However, there has been a growing consumer in Southeast Asia countries such as Malaysia, Brunei, Thailand, and others, as indicated by the amount of Liberica coffee exported to those countries, which accounted for an average of 300 tons/year [3].
Aside from Arabica and Robusta coffee, Liberica coffee has a high potential to be developed. It is adaptable to peatlands and has low caffeine content (approximately 0.7%), much lower than Arabica and Robusta coffee, which each contains 1.4% and 4%, respectively. Its low caffeine makes Liberica coffee potential as a food additive for the flavor and consumable for everyone. The development of the Liberica coffee plant on peatland can support sustainable agricultural development by improving the cultivation of Liberica coffee [4].

The Liberica coffee productivity can reach up to 1,200 kg/ha/year, higher than Arabica and Robusta coffee (around 800 kg/ha/year and 900 kg/ha/year). Its price is also higher than Robusta coffee, although still lower than Arabica coffee. Liberica coffee is tolerant to pest and disease attacks and resistant to hot climates and high humidity [3]. Liberica coffee also does not require intensive maintenance and care. Liberica coffee is commonly known as peat coffee for its adaptability to peat soils, a unique character compared to Arabica and Robusta coffee [5]. Liberica coffee has been developed in peatlands in Tanjung Jabung, Jambi, Meranti, Riau, and South Sumatra. Therefore, Liberica coffee is highly potential to be designed to increase coffee production, improving coffee farmer income, and peatland use.

Whilst the agricultural land has been declining up to 130,000 ha/year, peatlands offer an alternative for agricultural land. The area of peatland with a thickness of <300 cm that has not been used optimally is reaching 9.3 million ha, and shallow peat (<100 cm) reaching 5,241,473 ha (35.17% of the total peatland) spread across the island of Papua covering an area of 2,425.523 ha, 1,767,303 ha in Sumatra, and 1,048,011 ha in Kalimantan [6].

In Tanjung Jabung, the development of Liberica coffee on peatland has reached an area of 3,000 ha. At the beginning of its development, the growth and production of Liberica coffee were relatively good and high, reaching 1,200 kg/ha/year. Still, after more than 15 years, the production decreased to 400-800 kg/ha/year, and many plants were damaged instead of reaching its peak productivity [7]. The decline in growth and production occurred due to changes in both the physical and chemical composition in the peat soil. Physically, the peat soil experiences subsidence (surface subsidence) which causes the plants uprooted. The chemical compounds in the soil may be toxic for the plants; for example, the phenolic acid inhibits the root development. In a certain period, peatlands productivity decreases and adversely affected the environment [8].

As part of Liberica coffee development, two varieties of Liberica coffee have been released, namely Lim 1 and Lim 2 varieties, and two Geographical Indications (GI), Kuala Tungkal and Meranti. In international trade, GI brings economic benefits such as increases the reputation of products in international trade and protection against unhealthy competition [9]. It also provides product marketing strategy for domestic and global trade. GI also gives legitimation on traditional knowledge [10] and providing added value to products hence increasing the farmers’ welfare [11].

Using chemical fertilizers to improve land productivity is often less effective and yet costly. The level of fertilizer use is influenced by the price of fertilizer [12]. Numerous studies have been conducted to produce environmentally friendly technologies to upgrade soil fertility [13]. One of the technologies currently being developed is integrated nutrient management that supports organic fertilization and the use of biofertilizers [14] [15]. Utilization of soil ameliorants, such as dolomite, manure, biofertilizers and so on [16]. Ameliorants are needed to counter the acidic soil and toxic organic acids, so that the plant rooting medium improved. Dolomite, manure, and ash can be applied to increase soil pH and soil bases. This study aims to determine the effect of dolomite and manure in increasing productivity of Liberica coffee aged more than 15 years in tidal peat soils.

2. Research Methods

2.1 Location and time

This research was conducted in a smallholders farm in Mekar Sari Village, Batara District, Tanjung Jabung Barat Regency, Jambi, located 250 km from Jambi. The primary, secondary and tertiary canals are well established, though poorly maintained, peat thickness is less than 75 cm. Research starts from January 2019 to March 2020.
2.2 Materials and tools
The material used in this study was Liberica coffee plants in smallholder farms aged more than 15 years, in tidal peatlands. Other materials include dolomite, goat manure, herbicide, wood, nails, etc.; for sluices, while the tools are; hoe, machete, cuttings, cod box, raffia rope, plastic bag, pH meter, hand sprayer, and basin.

2.3 Research design
The experiment used a randomized block design with the treatment of soil ameliorants, namely (P0) without soil ameliorants, (P1) Dolomite application at 2.5 tons/ha, (P2) Manure application at 20 tons/ha, (P3) Biofertilizer 1 litre/plant, (P4) Dolomite application at 1.25 tons/ha + manure at 10 tons/ha, (P5) Dolomite at 1.25 tons/ha + biofertilizer at 0.5 litre/plant, (P6) manure at 1.25 tons/ha + biofertilizer 0.5 litre/plant. The treatments were replicated four times, and the plot size was 2 x 5 plants (10 plants). Total samples were 280 plants.

2.4 Research implementation
Plotting. Plotting is 2 x 5 plants (10 plants) in two adjacent rows. The replication direction is determined based on the thickness of the peat.

Dolomite application. Dolomite was applied by spreading it evenly over the area, with a dose of 2.5 tonnes/ha or 0.25 kg / m², then mixed to a depth of 20 cm, with a hoe.

Manure application. Manure is applied evenly on the surface of the area at a dose of 20 tons/ha or 2 kg / m², then stirring evenly with a hoe to a depth of 20 cm.

Biofertilizer application. It was applied by pouring the biofertilizer around the plant area with a dose of 1 litre/plant and the active substance in a concentration at 10⁸.

Dolomite + manure application. Dolomite + manure similarly applied in 2 months interval and the subsequent applications were dolomite at 1.25 tons/ha and manure at 10 tons/ha.

Dolomite + biofertilizer application. It was applied half the dose of dolomite (1.25 tons/ha) and half the dose of biofertilizer (0.5 l/plant)

Manure + biofertilizer application. It was applied half the dose of manure (10 tons/ha) and half the dose of biofertilizer (0.5 l/plant)

Maintenance. Use of herbicide for weeding, cleaning the planting area and tertiary canals, repairing sluices. Pest and disease control is carried out by spraying insecticides and fungicides at least every three months.

2.5 Observation
Observations on the increase in the number of branches, counting new branches that grew during the study. The number of bunch/branches was counted from all the bunch found in one branch in all directions, then taken the average number. The number of fruit/bunch is calculated by counting the number of berries on the branches as mentioned above, then averaged into the number of fruit/branches of the plant. Berry production was calculated by multiplying the number of branches/plants, the number of bunch/branches and the number of berries/bunch. The number of seeds/100 g, is done by counting the number of seeds of 100 g. Vegetative observations such as the increase of plant height, increase in the number of branches, and the length of the longest canopy. Other observations were on soil analysis, leaf analysis, peat soil maturity, peat water content, bulk density, subsidence, and bearing capacity.

3. Result and Discussions
Amelioration of peatland increased nutrition in the Liberica coffee leaf. Dolomite application increased the P, Mg, and Fe level, whereas manure increased N, K, Fe, biofertilizers or dolomite combined with manure increased N, P, K, and Fe. In contrast, the combination of dolomite and biofertilizer increased P, K, and manure and biofertilizer increased N, P, and Fe in Liberica coffee leaf (Table 1). The increased nutrient in leaves indicated that soil ameliorants increase the nutrients in the soil, and plants can absorb them. This also demonstrated that in improving peat soils, higher pH level, and microorganisms activity are vital to providing nutrients. Increasing the pH will accelerate
decomposition as microorganisms are more active, and this decomposition process will break down nutrients so that they become available to plants [17].

Table 1. Effect of treatments on leaf nutrient

| Treatments            | N    | P     | K     | Mg   | Fe    |
|-----------------------|------|-------|-------|------|-------|
| P0 (no ameliorants)   | 2.48 b | 0.13 b | 0.17 b | 1.3 a | 178.5 b |
| P1 (Dolomite)         | 3.22 b | 0.17 a | 0.25 b | 1.46 a | 196.25 a |
| P2 (manure)           | 3.81 a | 0.13 b | 0.52 a | 1.02 b | 192 a |
| P3 (biofertilizer)    | 3.86 a | 0.17 a | 0.53 a | 1.21 a | 225 a |
| P4 (Dolomite + manure)| 4.18 a | 0.15 a | 0.43 a | 1.24 a | 195.25 a |
| P5 (Dolomite + biofertilizer)| 3.12 b | 0.15 a | 0.59 a | 1.17 b | 163.75 b |
| P6 (manure + biofertilizer)| 3.99 a | 0.15 a | 0.3 b | 1.29 a | 184 a |

Note: Numbers followed by letter are not significantly different at 5%.

Manure not only increases N, K, and Fe but also improves soil pH, increases the number and activity of soil microorganisms to decompose peat matter. Similarly, biofertilizers which are cellulolytic microbiology can break down peat organic matter which will provide nutrients for plants, and this decomposition increases the content of all nutrients in the leaves.

Table 2. Height increase, increase in the number of branches, girth and length of a canopy of Liberica coffee in 12 months after treatment

| Treatments               | Increase of plant height (m) | Increase in the number of branch/plant | Girth (mm) | The diameter of the canopy (m) |
|--------------------------|------------------------------|---------------------------------------|------------|-------------------------------|
| P0 (no ameliorants)      | 0.52 b                       | 3.06 b                                | 28.50 a    | 2.12 a                        |
| P1 (Dolomite)            | 0.76 a                       | 5.05 a                                | 30.69 a    | 2.13 a                        |
| P2 (manure)              | 0.58 b                       | 3.63 b                                | 25.19 a    | 2.09 a                        |
| P3 (biofertilizer)       | 0.57 b                       | 3.47 b                                | 27.81 a    | 2.44 a                        |
| P4 (Dolomite + manure)   | 0.57 b                       | 3.31 b                                | 27.50 a    | 2.19 a                        |
| P5 (Dolomite + biofertilizer) | 0.53 b                     | 3.06 b                                | 25.94 a    | 2.08 a                        |
| P6 (manure + biofertilizer) | 0.54 b                  | 3.08 b                                | 25.00 a    | 2.29 a                        |
| CV (%)                   | 15                           | 19                                    | 19         | 17                            |

Note: Numbers followed by letter are not significantly different at 5%.

Dolomite application increases plant height and a significantly higher number of branches compared to other treatments (Table 2). Other soil ameliorants enhance the vegetative growth of Liberica coffee plant but not significantly. This may be due to dolomite which can increase pH and nutrient uptake of P, Mg and Fe by the coffee plants. According to [16] dolomite application at 10 ton/ha is the optimum dose to improve chemical properties of the peatland by increasing the pH H2O up to 1.16 unit. Dolomite application in peatland significantly increases pH, base, and increases the pH up to 5.5 to 6.5% and provides Calcium (Ca) and Magnesium (Mg), which enables ideal growth of the plants. Dolomite also dissolves gradually, which helps to counter acidification of several fertilizers and/or irrigation water at medium pH [8] [18].

Apart from Mg, dolomite also contains Mn micronutrients. In specific amounts, these micronutrients can affect the vegetative growth of plants, i.e. plant height and the number of branches/plants. According to [8], micronutrients play a role in increasing vegetative growth. Plants that are deficient in microelements will experience dwarfism. The application of soil amendment (limestone, sea mud, and biofertilizers) significantly affect the pH level in soil and plant height.
Soil ameliorants from manure or biofertilizers do not affect improving vegetative growth. This can be because these materials require a longer time to process changes in soil chemical properties compared to dolomite so that their reaction to plant vegetative growth is not as immediate as dolomite. According to [19], manure affects the physical properties of the soil more than it affects the chemical properties of the soil. Decomposition process until the nutrients formed takes a longer, whereas biofertilizers decompose the organic matter present in peat soil.

Amelioration using dolomite or manure can increase the number of berries/bunch and the number of berries/plants. In contrast, ameliorants from a mixture of dolomite and manure only increase the number of berries/bunch (Table 3). The soil ameliorant does not affect the number of bunch/branches because the ameliorant is unable to improve the growth of the canopy length where the bunch is located. This can occur due to the maximum canopy growth so that the number of the bunch does not increase. An increase in the number of berry/bunch can occur due to the formation of berry until mature fruit takes up to 11-12 months, during which time the decomposition has occurred in decomposing nutrients in organic matter, and nutrients are available for coffee plants.

Table 3. Production components of 15-year-old liberica coffee on peatland

| Treatment                        | Number of bunch/branch | Number berries/bunch | Number of berry/plant |
|----------------------------------|------------------------|----------------------|-----------------------|
| P0 (no ameliorants)             | 7.94 a                 | 9.77 b               | 1,032.51 b            |
| P1 (dolomite)                   | 8.83 a                 | 12.26 a              | 1,454.96 a            |
| P2 (manure)                     | 8.64 a                 | 11.43 a              | 1,288.76 a            |
| P3 (biofertilizer)              | 7.29 a                 | 11.22 a              | 1,067.41 b            |
| P4 (dolomite+manure)            | 7.66 a                 | 9.75 b               | 1,155.10 b            |
| P5 (dolomite + biofertilizer)   | 7.35 a                 | 9.84 a               | 990.12 b              |
| P6 (manure + biofertilizer)     | 7.66 a                 | 9.84 a               | 1,008.51 b            |
| CV (%)                          | 22                     | 25                   | 25                    |

Note: Numbers followed by letter are not significantly different at 5%.

Dolomite application significantly increases production up to 47.96%, while manure increased the production significantly by 30.69%. Meanwhile, the application of biofertilizer and a mixture of dolomite with manure did not significantly increase coffee production (8.55% and 15.60%, respectively) (Table 4). Application of dolomite, manure, and biological fertilizers can improve berries quality by 5%.

The increase in berries production indicates that there has been an improvement in plant organs that were physically and chemically damaged. Applying manure around the plants cover the uprooted areas due to the lowering soil surface. Dolomite not only increases pH but also neutralizes organic acids [6] so that it is no longer toxic to plants.

Table 4. Estimated Production of 15-year-old Liberica Coffee on Peatlands

| Treatment                        | Number of berry/plant | Number of bean/100 gr | Population/ha | Production/ha (kg) |
|----------------------------------|-----------------------|-----------------------|---------------|--------------------|
| P0 (no ameliorants)             | 1,032.51 b            | 166 a                 | 880           | 545.17 b           |
| P1 (dolomite)                   | 1,454.96 a            | 158 a                 | 880           | 806.63 a           |
| P2 (manure)                     | 1,288.76 a            | 158 a                 | 880           | 712.49 a           |
| P3 (biofertilizer)              | 1,067.41 b            | 158 a                 | 880           | 591.77 b           |
| P4 (dolomite+manure)            | 1,155.10 b            | 161 a                 | 880           | 630.22 b           |
| P5 (dolomite + biofertilizer)   | 990.12 b              | 166 a                 | 880           | 522.78 b           |
| P6 (manure + biofertilizer)     | 1,008.51 b            | 166 a                 | 880           | 532.49 b           |
| CV (%)                          | 25                    |                       |               |                    |
Amelioration of peatland using dolomite only gave the highest result than other treatments, including the combination of the ameliorants. Dolomite application not only increases pH, Ca, and Mg which are vital for vegetative growth, but also the dose was higher than other treatments (dolomite + manure and dolomite + biofertilizer which only half the dose). As studied by [20] on tomato plants that NPK and dolomite in peatland affected the fresh and dry weight of the plant. However, excessive application of dolomite will increase the pH higher than necessary, which will lead to early decomposition too quickly. Due to the high subsidence, the decomposed nutrients will easily be washed away before being absorbed by plants. Therefore, dolomite is applicable until the pH reaches 5, likewise for biofertilizers which will trigger faster decomposition by the microorganisms.

4. Conclusion
Peat soil improvement can increase the nutrition of Liberika coffee leaves. Single dolomite increases the content of P, Mg, and Fe. Goat manure rises N, K, and Fe. Biofertilizer or a mixture of dolomite + manure increases N, P, K, and Fe. The combination of dolomite + biofertilizer increases P, K, and fertilizer combination manure + biological fertilizer increases the content of N, P, and Fe in Liberica coffee leaves. Dolomite increases plant height up to 0.76 cm and the number of branches up to 5.05 branches/plants of the Liberica coffee. Dolomite can also increase productivity up to 47.96%, manure 30.69%, while other soil ameliorants can increase productivity by 4.11% to 11.87%. Dolomite, manure, and biofertilizer application can improve berries quality by 5%.

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