Opportunities of mine reclamation areas for food crops plantation: Case study of coffee plants in former limestone mining

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Introduction

Mining activities with open-pit methods can result in environmental damage, including landscape alteration, pit lake (void) formation, decreased biodiversity of flora and fauna, and changes in physical, chemical and biological properties of the soil. Soil coverage by mining dust resulting from mining and rock processing activities can affect the physical, chemical, and biological properties of the soil. Furthermore, the use of limestone powder can increase soil stability or expansive soil strength (physical properties). Changes to the physical properties of the soil will affect other soil properties, such as chemical and biological properties of the soil. The form of post-mining in the forest areas must include revegetation. The revegetation activity can be carried out using wood and/or non-wood product species, such as coffee. Changes in soil properties due to limestone dust from mining and processing will affect soil conditions and plant growth.

Changes in soil properties due to limestone dust coverage directly or indirectly will affect soil conditions so as to disrupt plant growth. The implementation of biological fertilizers such as mycorrhiza can increase plant growth, especially in degraded land conditions such as former limestone mines. The use of mycorrhizal fungi as biological fertilizers has the opportunity to save the cost of fertilization and can reduce environmental pollution due to excessive use of synthetic fertilizers. Furthermore, the inoculation of mycorrhizal fungi is able to improve the chemical properties of the soil by increasing the pH value of the soil through metabolic activity and the release of amino acids that are able to increase the Al element. The purpose of this study was to analyze the effect of the coverage of former mines by limestone dust and the effect of different doses of mycorrhizal biological fertilizers on coffee seedling growth.

Material and Method

- **Study Site**

The research was conducted at the limestone mining company located in West Bandung Regency, West Java Province, Indonesia. In addition to mining, the mining company carries out processing activities in the form of the comminution of limestone using crushers. The company is located in one of the forest areas owned by the state-owned forestry company, PT Perum Perhutani. Because it is located in a forest area, the form of reclamation carried out is revegetation of wood products and/or non-wood product species.

- **Study Design**

The study was conducted using the Randomized Complete Block Design (RCBD) method. The research area was divided into 3 groups, namely: without limestone dust (0 cm), covered with 0–2.5 cm, and covered with 0–5 cm . The dust for this research was taken from the residue of mining and processing (generally contain CaO and $CaCO_3$). Coffee seedlings were planted in each group with a spacing of 4 m x 4 m (plot size/group 8 m x 16 m). The group was randomly given the addition of commercial mycorrhizal biological fertilizers of 10 g, 15 g, and 20 g with 5 replications each (Figure 1). The commercial mycorrhizal biological fertilizers containing 5 species of endomycorrhizae, 33 spores per gram endomycorrhizae, and 300 live propagules per gram. Planting holes were made with a size of 40 cm x 40 cm x 40 cm and given poultry manure and humic acid 6 months prior to planting coffee crops (Figure 2). NPK inorganic fertilizer was given every 1 month to all treatments with an interval of addition of NPK fertilizer of 10 g/seedlings in the first month, 20 g/seedlings in the second month, 30 g/seedlings in the third month, 40 g/seedlings in the fourth month and 50 g/seedlings in the fifth month.

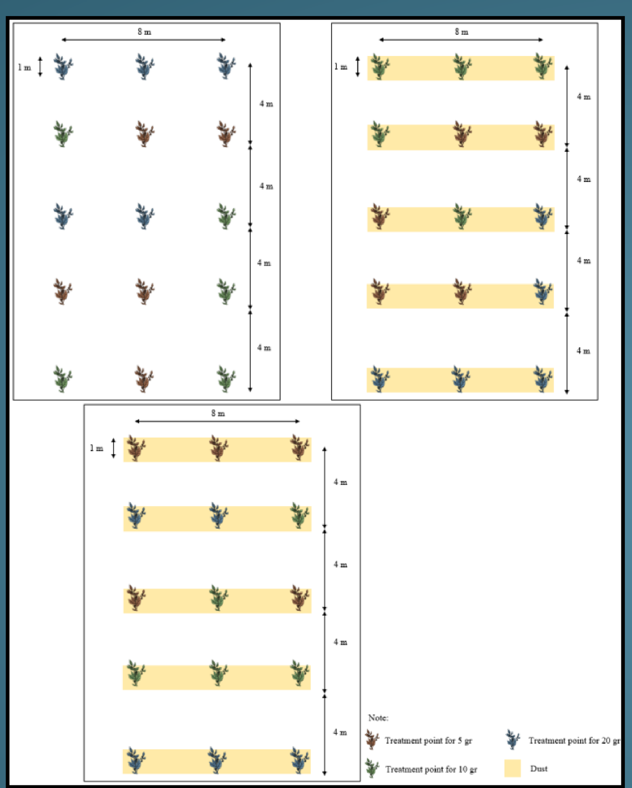

Figure 1. Randomized Complete Block Design: a) no dust; b) covered with 2.5 cm; c) covered with 5 cm

Figure 2. Coffee seedlings and the fertilization process using poultry manure and humic acid

Results and Discussion

Plant Height

Analysis of Variance (ANOVA) results show that parameters of time (July, August, September, October, and November), treatment (10 g, 15 g, and 20 g) and group (without dust, 2.5 cm dust, and 5 cm dust) have a significant effect ($p < 0.05$). Figure 3 shows the mean height of coffee seedlings based on the difference between treatment and block (dust). Further test results with the Tukey test (Figure 4) show that the treatment of mycorrhizal biological fertilizers with 15 g and 20 g did not result in a significant height difference in coffee seedlings even though the mean value at the 15-g treatment height was higher (26.37 cm) compared to the 20-g treatment (25.58 cm). Meanwhile, the treatment with 10 g of mycorrhizal biological fertilizer showed a significant difference from the 15 g and 20 g treatments (lower mean value of height; 23.09 cm).

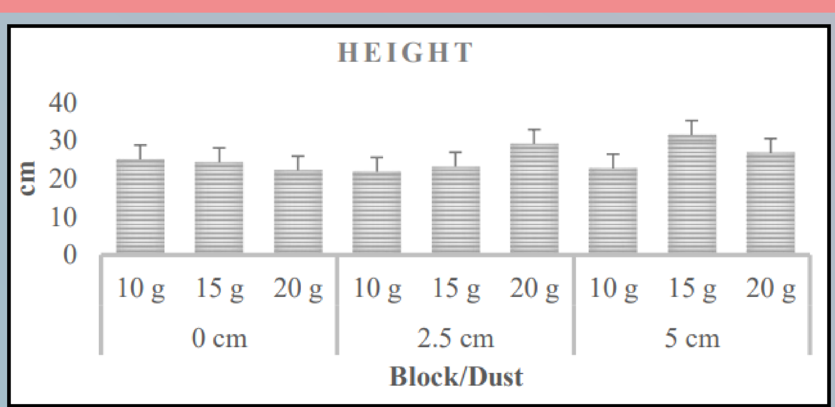

Figure 3. The height of coffee seedlings against different treatments and blocks

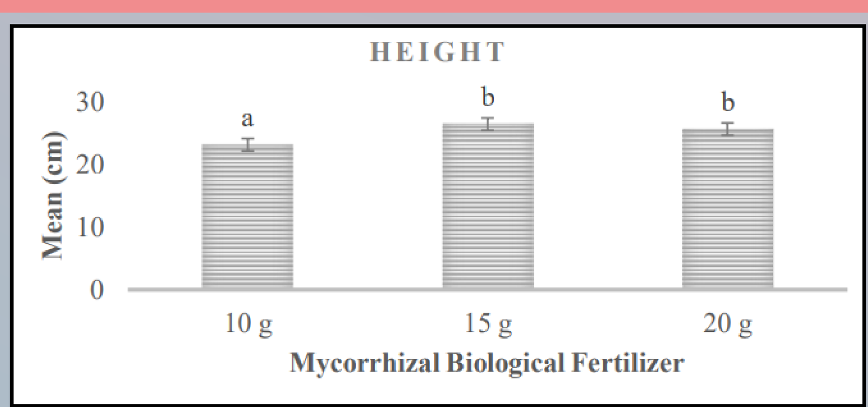

Figure 4. Tukey test of the height of coffee seedlings against different treatments (the same letters indicate results that are not significantly different)

Meanwhile, the Tukey test results (Figure 5) on the effect of the thickness of limestone dust (0 cm, 2.5 cm, and 5 cm) on coffee seedling height showed that the thickness of limestone dust (0 cm, 2.5 cm, and 5 cm) did not result in a significant difference in coffee seedling height even though the mean height of 2.5 cm thick limestone dust was higher (24.08 cm) compared to the block without limestone dust (23.79 cm). Meanwhile, blocks with a 5 cm thickness of limestone dust were significantly different from 0 cm and 2.5 cm, and showed a higher height mean value, namely 27.03 cm.

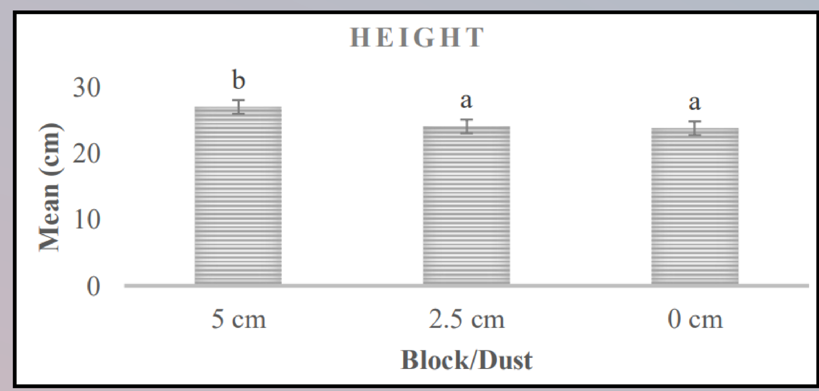

Figure 5. Tukey test of the height of coffee seedlings against different blocks (the same letters indicate results that are not significantly different)

Adding limestone can increase the height of coffee seedlings (Riyani et al., 2020). In addition, Kosanova et al. (2012) stated that the use of limestone has a positive influence on the increase in the height of Norwegian spruce. Limestone contains calcium that is able to neutralize the adverse effects of aluminum and soil acidity. Ca affects the availability of nutrients such as N and P. Calcinations increase the availability of N and K elements, which are urgently needed by plants' apical growth (Wijanarko et al., 2016). It indicates that height is strongly influenced by nutrient content that plays a role during the division of plant shoot cells.

Plant Diameter

ANOVA analysis showed that there was no interaction between time (July, August, September, October, and November), treatment (20 g, 15 g, and 10 g) and block (without dust, 2.5 cm dust, and 5 cm dust) at a 5% rate of level confidence. ANOVA's results showed that time (July, August, September, October, and November) and treatment (20 g, 15 g, and 10 g) had a significant effect ($p < 0.05$), while blocks (without dust, 2.5 cm of dust, and 5 cm of dust) had no significant effect. Figure 6 shows the mean height of coffee seedlings based on the difference between treatment and block (dust). Treatments had a significant effect; therefore, a further test was performed with the Tukey Test (Figure 7). The Tukey test results showed that the treatment with 10 g and 15 g of mycorrhiza biological fertilizer showed no significant difference in the diameter of coffee seedlings even though the 15 g treatment was greater (3.94 mm) compared to the 10 g treatment (3.78 mm), while the treatment with 20 g of mycorrhiza biological fertilizer was significantly different from the 10 g and 15 g treatments (higher diameter mean value; 4.53 mm).

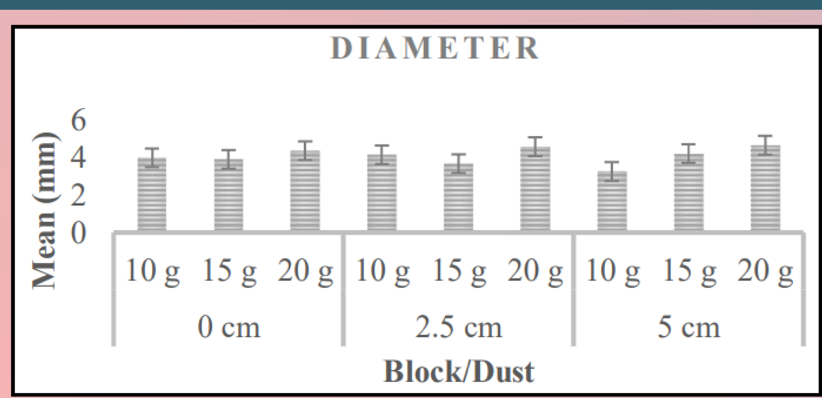

Figure 6. The stem diameter of coffee seedling against different treatment and blocks

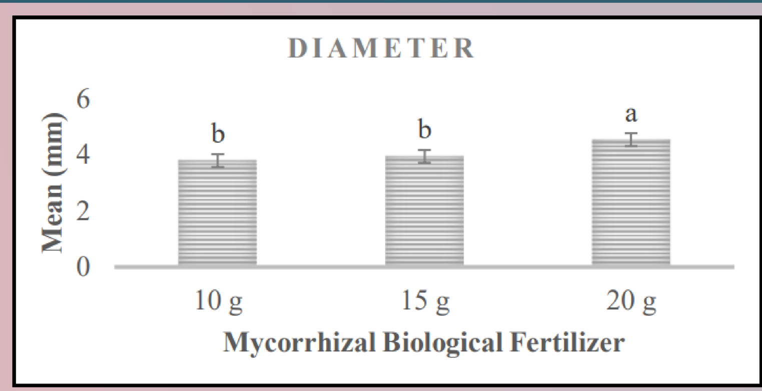

Figure 7. Tukey test of the stem diameter of coffee seedling against different treatment (the same letters indicate results that are not significantly different)

The results of the field evaluation conducted by Posada and Sieverding (2014) showed that mycorrhizal fungi can increase the growth and productivity of coffee plants by up to 62% by increasing the absorption of K and P. Several studies showed a positive effect of the addition of mycorrhizal biological fertilizers, including increased diameter growth in limestone post-mining land for Leucaena leucocephala seedlings (Ghaida et al., 2020).

Number of leaves

Figure 8 shows the mean height of coffee seedlings based on the difference between treatment and block (dust).

The results of the Tukey test on the treatment of mycorrhizal biological fertilizers with 10 g and 15 g did not show a significant difference in the number of leaves of the coffee seedlings. A higher number of leaves in the 10 g treatment was observed (10) compared to the 15 g treatment (9.5). Treatment with 20 g (8) of mycorrhizal biological fertilizer showed a significantly different result from the 10 g (10) treatment but not significantly different from the 15 g (9.5) treatment (Figure 9).

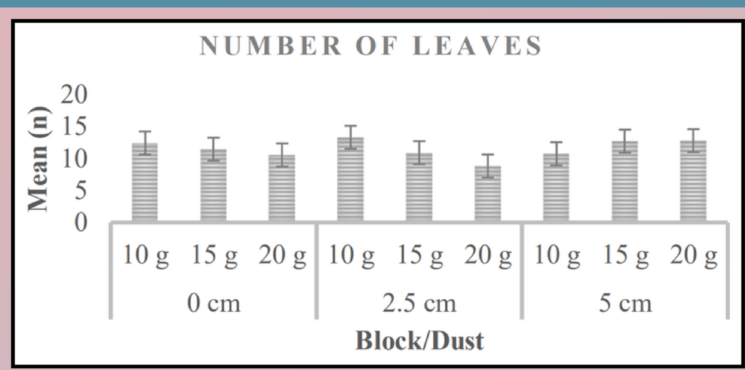

Figure 8. The leaf number of coffee seedling against different treatment and blocks

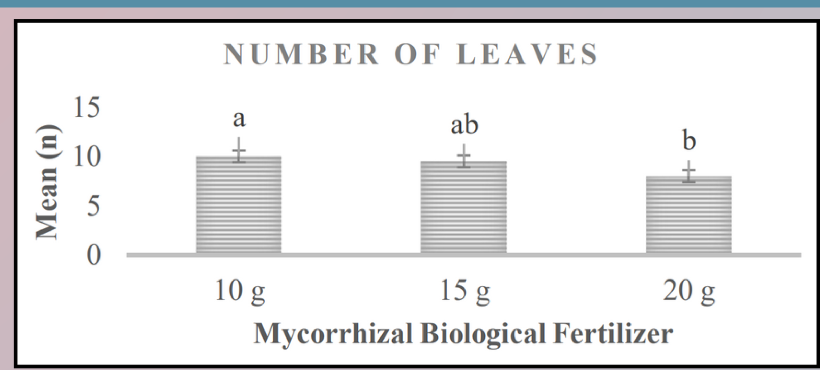

Figure 9. Tukey test of the number of leaves of coffee seedling against different treatment (the same letters indicate results that are not significantly different)

Meanwhile, the block without limestone dust (7.2) has a lower mean number of leaves and thus is significantly different from both the blocks with 5 cm and 2.5 cm of limestone dust (Figure 10).

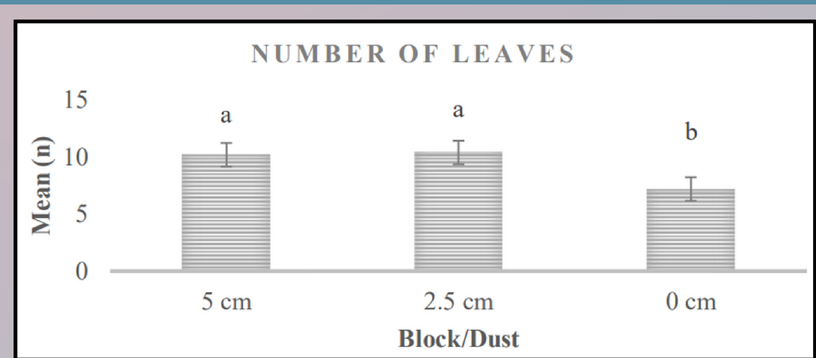

Figure 10. Tukey test of the number of leaves of coffee seedling against different block (the same letters indicate results that are not significantly different)

Conclusion

In a certain amount, limestone dust can be beneficial for plant growth. Limestone dust can raise soil pH, increasing the availability of nutrients required for plant growth. The implementation of biological fertilizers of mycorrhiza can increase the growth of coffee seeds both in height, diameter and number of leaves. Further research needs to be done by comparing mycorrhiza-added coffee seedlings with those without the addition of mycorrhizal biological fertilizers as well as the percentage of mycorrhizal fungal infections against coffee root seeds.