Reclamation of ex-nickel mining soil using organic plus fertilizer to support corn cultivation in Southeast Sulawesi

S Leomo¹, M Tufaila¹, R Adawiyah², A A Anas¹, T C Rakian², Muhidin², L Mudi², E Aprianto², G A K Sutariati² and Y Lumoindong³

¹Department of Soil Science, Faculty of Agriculture, Halu Oleo University, Kampus Anduonohu JL. HEA Mokodompit, Kendari 93232, Indonesia
²Department of Agrotechnology, Faculty of Agriculture, Halu Oleo University, Kampus Anduonohu JL. HEA Mokodompit, Kendari 93232, Indonesia
³Agribusiness Study Program, Department of Social Economic of Agriculture, Faculty of Agriculture, Hasanuddin University

Email: sittileomo@yahoo.com

Abstract. In addition to providing incomes for the country, mining activities can also cause land damage resulting in a decrease in soil function as a medium for growing plants. The study aim to analyse the growth and production of corn on ex-nickel mining soils that had been remediated using cover crops and rhizobacteria for five years (2013-2018). The research has arranged in a randomized block design (RBD) with the treatment of organic fertilizer enriched with rhizobacteria of Bacillus sp and Pseudomonas sp (organic plus fertilizer), consisting of 6 levels, namely control without organic plus fertilizer (B₀), 1 ton ha⁻¹ (B₁), 2 tons ha⁻¹ (B₂), 3 tons ha⁻¹ (B₃), 4 tons ha⁻¹ (B₄), and 5 tons ha⁻¹ (B₅). Each treatment was repeated three times so that there were 18 experimental units. The observed variables were plant height, stem diameter, leaf area, the weight of corn kernels per fruit, and weight of dried kernels per hectare. The results show that the application of organic plus fertilizer on the ex-nickel mining soils effectively increased the growth and production of corn.

1. Introduction

Mining is one sector that can generate large income and that cannot be separated from the national economic system [1,2]. The mining industry, in addition to being a source of income, has also resulted in side effects in the form of environmental damage [3–5]. Nickel mining has physical and chemical problems [6,7].

Physical problems include changes in soil physical properties such as damaged soil profile, existing mining areas create steep slopes, soil compaction due to heavy equipment, increase the potential for erosion, reduce hydrological functions, and damage to a soil structure that decreases water retention capacity [8–10]. Moreover, the chemical problems include low organic matter content in ex-mining soil, very low macro-nutrients, and high amounts of metal elements that are toxic to plants because the elements have not yet mineralization [11,12].

A serious problem due to open mining is the exposure of rock layers composed of sulfide compounds, such as pyrite and chalcopyrite. This exposed rock layer will oxidize to release sulfate ions and hydrogen ions which can reduce the pH of water and soil [13]. This condition will directly affect plant growth and agriculture commodities due to the toxicity of heavy metals [10,14].
Reclamation of ex-nickel mining soil by using cover crops and rhizobacteria (phytoremediation) had been carried out from 2009 to 2018 and the results of the study showed improved soil physical properties such as soil permeability [8,11], where the values before and after planting Legume cover crops were 839 and 543.72 cm per hour, respectively [8]. In addition, soil water content also increases [11]. The chemical nature of the soil changes after phytoremediation includes the increase of the pH of the soil, the C-organic content, and the cation exchange capacity [12–16].

To accelerate the reclamation of ex-nickel mining soil to support the growth of food crops, it is necessary to provide organic materials as they can provide nutrients and regulate their release. Moreover, it plays a role in the formation of more stable aggregates so that water flow and air circulation can run well and the soil’s water retention ability will increase [14]. Organic plus fertilizer becomes one of the choices as sources of organic material for ex-nickel mining soil because organic plus fertilizer is an organic fertilizer product that enriched with local indigenous rhizobacteria agents from Southeast Sulawesi. The rhizobacteria would increase the growth of cover crops as sources of organic material. Rhizobacteria has benefit effect to plants [17–19] and produce growth hormones such as IAA and gibberellins [20]. The application of organic plus fertilizer is expected to improve the quality of ex-nickel mining soil.

2. Methods
The research was conducted in the Field Laboratory and Soil Science Laboratory of the Faculty of Agriculture, Halu Oleo University, from May to August 2018. The material used was the ex-nickel mining soil that had been used since 2009 from Sonai Village, Puriala District, Konawe Regency, Southeast Sulawesi, corn seeds, and organic plus fertilizer. The study used a randomized block design (RBD) with organic plus fertilizer treatment consisting of 6 levels, namely control without organic plus fertilizer (B₀), 1 ton ha⁻¹ (B₁), 2 tons ha⁻¹ (B₂), 3 tons ha⁻¹ (B₃), 4 tons ha⁻¹ (B₄), and 5 tons ha⁻¹ (B₅) of organic plus fertilizer. Each treatment was repeated 3 times; thus, there were 18 experimental units. Observation data were analysed using variance analysis. If there is a significant effect in the analysis of variance, further tests were carried out based on the Duncan's Multiple Range Test (DMRT) at a 95% confidence level. Variables observed included growth components (plant height, stem diameter, and leaf area) and components of corn production (the weight of corn kernels and weight of dried kernels).

3. Results and discussion

3.1. The height of the corn plant
The height of corn plant was observed at 2-8 Weeks After Planting (WAP). The result showed that application of organic plus fertilizer has significant effect on the height of corn plant. But on the age of 6 and 8 WAP, it had no significant effect. The average height of a corn plant on the ex-nickel mines that were given organic plus fertilizer is presented in table 1.

| Dosage of organic plus fertilizer | 2     | 4     | 6     | 8     |
|---------------------------------|-------|-------|-------|-------|
| Control (B₀)                    | 15.10 c | 34.63 d | 107.56 | 114.81 |
| 1 ton ha⁻¹ (B₁)                  | 17.92 bc | 44.98 cd | 121.47 | 132.13 |
| 2 ton ha⁻¹ (B₂)                  | 19.89 abc | 49.53 bc | 126.00 | 133.25 |
| 3 ton ha⁻¹ (B₃)                  | 23.88 ab | 54.43 abc | 130.02 | 133.62 |
| 4 ton ha⁻¹ (B₄)                  | 24.34 a  | 60.09 ab | 131.79 | 133.99 |
| 5 ton ha⁻¹ (B₅)                  | 24.82 a  | 63.29 a  | 139.18 | 146.22 |
Table 1 shows that increasing in the dose of organic plus fertilizer on ex-nickel mine soils could increase the height of corn plants for all observations. The treatment of 5 tons ha$^{-1}$ of organic plus fertilizer (B5) showed the highest growth in plant height.

### Table 2. The average stem diameter of corn plant on ex-nickel mines soil that was given organic plus fertilizer in various observation times

| Treatment | Observation times (WAP) |
|-----------|-------------------------|
|           | 2          | 4          | 6          | 8          |
| ----------|------------|------------|------------|------------|
|           | Stem diameter (cm)       |
| Control (B$_0$) | 0.63 e     | 1.10 d     | 1.43 b     | 2.16a      |
| 1 ton ha$^{-1}$ (B$_1$) | 0.75 d     | 1.33 c     | 2.17 a     | 2.43a      |
| 2 ton ha$^{-1}$ (B$_2$) | 0.80 cd    | 1.44 bc    | 2.03 a     | 2.49a      |
| 3 ton ha$^{-1}$ (B$_3$) | 0.88 bc    | 1.53 bc    | 2.19 a     | 2.62a      |
| 4 ton ha$^{-1}$ (B$_4$) | 0.96 ab    | 1.65 ab    | 2.26 a     | 2.76a      |
| 5 ton ha$^{-1}$ (B$_5$) | 1.00 a     | 1.87 a     | 2.36 a     | 3.04a      |

Table 2 shows that each increase in the dose of organic plus fertilizer on ex-nickel mine soils can increase the stem diameter of corn plants for all observations. The treatment of 5 tons ha$^{-1}$ of organic plus fertilizer (B$_5$) showed the highest growth in stem diameter while the lowest value was obtained by B$_0$ (without fertilizer). This is caused by the improved condition of soil fertility due to the contribution of nutrient elements from organic plus fertilizer that was given.

### Table 3. The average corn production on ex-nickel mines soil that was given organic plus fertilizer

| Treatment | Corn production |
|-----------|-----------------|
|           | The weight of corn kernels per fruit (g) | The weight of dried kernels (kg ha$^{-1}$) |
| Control (B$_0$) | 17.21 b | 478.06b |
| 1 ton ha$^{-1}$ (B$_1$) | 25.37 a | 704.72a |
| 2 ton ha$^{-1}$ (B$_2$) | 28.69 a | 796.94a |
| 3 ton ha$^{-1}$ (B$_3$) | 29.79 a | 827.50a |
| 4 ton ha$^{-1}$ (B$_4$) | 32.24 a | 895.56a |
| 5 ton ha$^{-1}$ (B$_5$) | 33.11 a | 919.72a |
Table 3 shows that the corn planted on ex-nickel mines soil treated with organic plus fertilizer was able to provide production, although the production achieved was still low. This shows that the dose of organic plus fertilizer used was still low even though it is known that organic fertilizer plus is a source of nutrients for plants.

4. Conclusion
The results show that the reclamation of the land of the ex-nickel mine by providing organic plus fertilizer can increase the growth and production of corn plants. The application of organic plus fertilizer in a dose of 2 tons ha\(^{-1}\) has shown an influence on the growth and production of corn on ex-nickel mining soils.

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