The effectiveness of cover crop and rhizobacteria as amelioration on ex-nickel mine soil southeast Sulawesi

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Abstract: The ex-nickel mining area in Southeast Sulawesi is planned to be developed as the center of the economic activities. Concerns regarding the negative effect of the past nickel mining activities must be considered. This study aimed to develop technical improvements and recovery of soil fertility mining through phytoremediation. The study used a randomized block design (RBD) consisted of two factors. The first factor was application of rhizobacteria, consisting of two levels, i.e., without rhizobacteria (R0) and with rhizobacteria (R1). The second factor was cover crop types, consisting of four types viz; Centrosema pubescens Benth, Calopogonium mucunoides (C2), Crotalaria sp. (C3) and Amaranthus spinosus (C4), with three replications. The results show that the cover crop of Centrosema pubescens Benth, Calopogonium mucunoides and Crotalaria sp were able to improve the soil fertility.

1. Introduction
Southeast Sulawesi is designated as a mining-specific economic zone based on the Master Plan for the Acceleration and Expansion of Indonesian Economic Development 2025. To accelerate the development of Sulawesi's Special Economic Zone, mining activities must be balanced with planned activities to deal with adverse impacts caused by mining [1-2]. The impact of externalities due to mining activities could be minimized to grow sustainable mining activities for mining business activities, agricultural development around the mining area, and the welfare of the community, both for the present and the future [3-4].

The rise of smallholder mining activities on agricultural lands in some areas of Southeast Sulawesi affects the sustainability of the agricultural sector. The decline in production rates of food crop such as rice, cassava, and corn can be contributed to the mining business that is done on agricultural lands, which result in the production decrease of the agricultural farm. Moreover, the water supply and discharge are also declined due to the smallholder gold mining business, resulting in the low availability of water for agriculture in some irrigated fields. Furthermore, the ex-mining land that has been exploited is left open without adequate efforts to improve and restore the fertility level of the land. The land cannot be used for agricultural business because the soil solum is also disturbed due to the accumulation of heavy metals from the subsoil to the surface.

The development of organic remediation is essential in the ex-mine soil. One of the popular methods is the use of cover crops as phyto remediant. Since the ex-mine soil cannot be directly used...
for agricultural purposes, the cover crops act as remediation on the soil. Many plants have been proven to have the ability as hyper accumulators for remediation. The cover crop such as *Thalpsi caerulescens* is capable of producing biomass and accumulates Zn [5-9]. *Alyssum bertolonii* can accumulate nickel [5,10]. *Reynourtria sachalinensis* and microalgae *Chlamydomonas* sp. have been used for the remediation of arsenic [11]. Considering the importance of cover crop and rhizobacteria, it is essential to use cover crop and rhizobacteria to increase the productivity of ex-nickel mining area. This study aimed to analyze the effectiveness of cover crop and application of rhizobacteria in improving chemical properties of ex-nickel mine soil.

2. Materials and Method
The study used a randomized block design (RCB) consisted of two factors. The first factor was application of rhizobacteria, consisting of two levels, i.e., without rhizobacteria (R0) and with rhizobacteria (R1). The second factor was the cover crop type, consisting of four types, namely *Centrosema pusbences* Benth. (C1), *Calopogonium mucunoides* (C2), *Crotalaria* sp. (C3), and *Amaranthus spinosus* (C4). There were eight treatment combinations and three replications; thus, there were 24 experimental units in this study.

3. Results and Discussion

3.1. Effect of cover crop and rhizobacteria on P and K

The results of P2O5 and K2O showed that there were differences in soil chemical properties analysis on P2O5 25% and K2O HCl 25% parameters before and after treatment (Figure 1). Before the treatment, the level of P2O5 HCl 25% was 39 mg 100g-1 while after the treatment, the number increased to the range of 54 – 64 mg 100g-1. Meanwhile, the level of K2O HCl 25% before treatment was 8 mg 100g-1 decrease and the K2O level also increased after the treatment. However, the decrease in K2O level occurred in the treatment of R0C1 and R0C3, to reach the level of 6 mg 100g-1. The levels of R1C1 and R1C2 also decreased to 4 mg 100g-1 and 3 mg 100 g-1, respectively. The highest increase of K2O level was in the treatment of R0C4 and the lowest treatment was in the R1C1 and R1C2 of 0.04 cmol.kg-1 (very low). The results of the analyzed exchangeable Na of the soil ranged from 0.03-0.07 cmol.kg-1.
3.2. Effect of cover crop and rhizobacteria on cation exchange capacity

The results of CEC show that there were different soil chemical properties on the parameters of exchangeable bases and CEC before and after treatment (Figure 2). Before the treatment of Ca, the conversion result was 1.25 cmol.kg\(^{-1}\) (very low). Moreover, there was a decrease in the treatment of R1C3 to 1.14 cmol.kg\(^{-1}\) and an increase in the treatment of R0C3 to 1.51 cmol.kg\(^{-1}\). In overall, the treatments were in a very low category. The result of interchanged Mg analysis before treatment was 6.89 cmol.kg\(^{-1}\) (high). The result of the analyzed Mg content on the cover crop treated with rhizobacteria ranged from 3.65 to 5.66 cmol.kg\(^{-1}\). The result of Mg analysis of R1C1 exchange treatment decreased to 3.65 cmol.kg\(^{-1}\) while it increased to 5.66 cmol.kg\(^{-1}\) in the R1C3 treatment.

![Figure 2](image)

**Figure 2.** Effect of cover crop and the application of rhizobacteria on the cation exchange capacity

The result of the analyzed K-level analysis before treatment was 0.15 cmol.kg\(^{-1}\). There was a decrease in R1C1 and R1C2 treatments after the cover crop and the application of rhizobacteria to 0.04 cmol.kg\(^{-1}\) (very low) and an increase in R0C4 treatment to 0.25 cmol.kg\(^{-1}\) (low). The result of exchanged Na analysis before treatment was 0.36 cmol.kg\(^{-1}\) (low). The result of soil cation exchange capacity (CEC) analysis before treatment was 8.50 cmol.kg\(^{-1}\) (low) while after the treatment, the soil CEC decreased in R1C1 treatment to 4.46 cmol.kg\(^{-1}\) (very low) and in R1C3 treatment to 6.99 cmol.kg\(^{-1}\) (low).

4. Conclusion

It can be concluded that the application of rhizobacteria could increase the availability of P\(_2\)O\(_5\) on ex-nickel mine land. Meanwhile, the application of cover crops on the ex-nickel mine could improve soil chemical properties of total C and N organic. The cover crop could fix nitrogen and when it decays, it can be used as a source of organic material.

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