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Improving quality of nickel post-mining soil using mycorrhiza and biochar made from oil palm empty fruit bunch

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Abstract. The physics and chemistry properties of post-mining soil needs to be improved. It is not suitable for agriculture, so alternative technology is required such us using biochar made from oil palm empty fruit bunch and mycorrhiza. This study aims to examine the effect of biochar made from oil palm empty fruit bunch and mycorrhiza to improve the nickel post-mining soil quality. This study randomized group design with 4 levels; B0 (0 t/ha), B1 (10 t/ha), B2 (20 t/ha), and B3 (30 t/ha) with 4 levels; M0 (0 t/ha), M1 (0.8 t/ha), M2 (1.6 t/ha), each treatment was repeated 3 treatments so that the total experiment was 36 units. The results showed that the use of bio-ameliorant waste from oil palm empty fruit bunch with dosage of 30 t/ha, significantly improved the chemical properties of nickel post-mining soil regarding the parameter of C-organic, pH, available phosphorus, cation exchange capacity, exchangeable aluminium, Ca-dd and Mg -dd. The treatment of mycorrhiza 4 g significantly affected the soil properties regarding improvement of soil chemical properties in available phosphorus to plants and exchangeable aluminium parameters. The treatment of biochar with dosage of 30t/ha of soil and mycorrhiza 1.6 t/ha (B3M2) of soil is the best interaction of mycorrhiza and biochar made from oil palm empty fruit bunch as amelioration material of post-mining soil which is characterized by the decrease of exchangeable aluminium. The application of biochar made from oil palm empty fruit bunch and mycorrhiza can improve the nickel post-mining soil quality.

Keywords: nickel post-mining soil, biochar, oil palm empty fruit bunch, mycorrhiza, exchangeable aluminium, phosphorus available

1. Introduction

The land resource potential in Indonesia are very supportive of the mining industry. Most of Indonesia consists of old soil that has ultimate weathering from the parent material. Exposure to climate that alternates between the rainy season and the dry season accelerates the process of parent material mineralization so that it has the potential to be further exploited. This area of advanced weathering is about 67% of the total land area in Indonesia. The nickel mine in Sorowako, East Luwu Regency, is one of the largest nickel mining locations in Indonesia and has been managed since the 1980s by several foreign companies until now under the management of PT. Vale Indonesia [1]. In the area of soil distribution in Sorowako, there is a Ni (II) content with a Ni (II) concentration between 3-5%. A concentration value which is an internationally recognized standard for Ni concentration. Nickel parent rock containing nickel according to international standards is found at a depth of 20-40 m below ground

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level. PT Vale Indonesia uses an open cast mining system. In general, the stages of mining activities carried out include land clearing, stripping of top soil where mining is carried out by cutting the side of the hill from the top to the bottom in accordance with its contour lines, so it can be called contour mining and overburden, the removal of soil and rock material to obtain a nickel-rich layer called saprolite. The top soil of excavation is dumped on the area around the mining area and will be backfilled after mining activities are completed [2]. However, in its mining activities PT Vale has started to carry out land rehabilitation starting from land clearing. The reclamation area in the post-mining land rehabilitation process is intended for revegetation and reforestation processes [3]. Mining activities cause changes in characteristics as a result of the dredging process so that the soil conditions become unstable, the soil texture and structure are poor in composition for growth. Allo (1] states that the condition of the soil after being mined makes it clear that the characteristics of the tailings soil (waste/residue) are macro-porous, the texture of sand or gravel, low nutrient content, dense when dry and poor consistency.

The use of biochar and compost can be used as materials for improving the soil post-mining. According to [4] biochar is black charcoal resulting from the heating process of biomass in a state of limited oxygen or without oxygen. Biochar can be produced from a variety of materials containing ligni-cellulose, such as wood, crop residues (rice straw, rice husks, oil palm empty bunches and sago waste) and manure. Unlike organic matter, biochar is composed of aromatic carbon rings so it is more stable and durable in the soil. Biochar maintains soil moisture so that the water holding capacity is high [5] and remediates soil contaminated with heavy metals such as (Pb, Cu, Cd and Ni). In addition, giving biochar to the soil can also increase growth and nutrient uptake in plants [6].

High rainfall is one of the factors influencing the soil formation process in Sorowako, which allows the alkaline breakdown intensively and leaves leaching-resistant minerals that usually accumulate in the soil surface layer. This affects soil chemical properties, including acidic soil, low organic matter content, low C/N ratio, very low available phosphorus, low CEC and very low calcium content. Neswati et al. [7] states that there is an increase in the degree of soil acidity which affects the availability of macro nutrients P. The use of biochar can also increase available P in alkaline soils because P reactivity with soil increases and forms insoluble compounds with Ca [8]. In contrast to other organic matter in the soil, biochar absorbs P nutrient more strongly.

Indonesia is known as a country with high metal mineral potential where most of the mining activities in Indonesia apply the open pit mining method. This method has caused land degradation, such as changes in topography, opening of forest areas, erosion, contamination of mining waste, and a decrease in the physical, chemical and biological qualities of the soil [1]. According to [2], ex-mining soil clearly shows that the soil is experiencing structural damage and compaction so that it has a negative effect on the soil system. The biological condition of the ex-mining soil is that it has decreased the number of soil microorganisms that occur due to physical changes in the soil (soil compaction) due to mining activities. Meanwhile, [9] states that the total number of microorganisms found in the soil is used as the fertility index, without considering other things. Fertile soil contains a number of microorganisms, this high population indicates a sufficient supply of food or energy plus a suitable temperature, sufficient water availability, other ecological conditions that support the development of microorganisms in the soil. Provision of biological agents in the form of mycorrhizae can overcome these problems. Therefore, mycorrhizae can be a source of microorganisms. According to Anne [10], this biological agent is able to increase nutrient and water uptake for plants and increase soil aggregate stability through the hyphal structure it forms. The use of biochar will also affect mycorrhizal growth in the soil. Because, biochar application can provide a good habitat for soil microbes that help in promoting nutrients so that these nutrients can be absorbed by plants. Based on this description, it is hoped that the provision of biochar and mycorrhizae can be an alternative for the improvement of ex-mining land. This study aims to explore the potential use of oil palm waste bio-ameliorant for the improvement of ex-mining soils, examine the use of mycorrhizae together with oil palm empty bunches biochar and its interaction as amelioration material for ex-mining soil and examine the effect of mycorrhizal and biochar interactions of oil palm empty bunches on soil quality improvement post nickel mining. Meanwhile, the use of this research is

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as a technological input for the improvement of land after nickel mining, utilizing palm oil waste as ameliorant and increasing the potential for using ex-mining land for agricultural production.

This study aims to explore the potential use of waste bio-ameliorant oil palm for ex-mining soil improvement, assessing shared mycorrhizal uses oil palm empty bunches biochar and its interaction as used soil amelioration material mining and studying the influence of mycorrhizal and biochar interactions of oil palm empty bunches on improving the quality of soil after nickel mining. Meanwhile, the usefulness of this research namely as a technological input for land improvement after nickel mining, utilizing palm oil waste becomes ameliorant material and increases the potential use of used land mine for agricultural production land.

2. Methodology

This research was conducted from April to August 2020 at the Green House Experimental Farm, Faculty of Agriculture, Hasanuddin University. Soil sample analysis was carried out at the Laboratory of Soil Fertility Chemistry, Department of Soil Science, Faculty of Agriculture, Hasanuddin University. Soil sampling location post nickel mining is in Sorowako Village, Nuha District, East Luwu Regency at the longitude 121°21'11,838"W and latitude 2°33' 0.965"S. The materials used in the research were post-mining soil, oil palm empty bunches, mycorrhiza, and biochar. While the tools used consisted of sampling tools on the ground, global positioning system (GPS), 10 kg pots, several laboratory equipments This research was conducted using a randomized block design with two factors. A factorial experiment is an experiment whose treatment consists of all possible combinations of levels of several factors. This experiment consisted of biochar factor as F1 with 4 levels, namely B0 (0 t/ha), B1 (10 t/ha), B2 (20 t/ha), and B3 (30t/ha) and mycorrhizal factor as F2 with 3 levels namely M0 (0 t/ha), M1 (0.8 t/ha), and M2 (1.6 t/ha). The observational parameters in the study included the parameters for observing soil properties (pH, cation exchange capacity, C-organic, exchangeable aluminium, and available phosphorus).

3. Results

The results of the post-nickel mining soil analysis before treatment (Table 1) show that the pH value is classified as acidic. This is in accordance with the opinion of [1] which states that the loss of soil solum and the leaching of the soil after nickel mining results in the loss of some cations in soil colloids so that the soil pH is low. This acidic reaction (pH) of the soil after nickel mining causes the soil CEC value to be classified as very low and affects the availability of the macro nutrient P which also decreases its availability in the soil. This is due to the fixation of free Al and Al oxy-hydroxide and forming insoluble Al-P. The results of this study were reinforced by [10] which showed that soil pH had a negative correlation with the amount of Al that binds P (Al-P). Likewise, the level of availability of the nutrient Ca at the analysed soil pH level is very low. It is clear that there has been a decrease in the content values of each macro P nutrient due to mining activities. Soil pH that reacts acidic indicates an increase in Al ions in the soil and need to be improved for physics and fertility properties.

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Table 1. Soil analysis result before treatments

Soil chemistry	Value	Criteria
C-Organic	0.93 %	*low
CEC	3.76 cmol/kg	*very low
Ca	1.95 cmol/kg	*very low
Mg	5.15 cmol/kg	*high
pH H_2O (1:2.5)	5.40	*acid
pH KCl (1:2.5)	5.20	*acid
P available	12.26 ppm	*medium
Al-dd	2.61cmol/kg	*very high

Source: *Balai Penelitian Tanah (2009) & Hill Laboratories (2018)

Table 2. Average of soil C-Organic with biochar treatment

Treatment	C-organic (%)
B0	0.90 c
B1	1.24 b
B2	1.19 b
B3	1.40a

Note: The numbers followed by the same letter (a, b, c, d) are not significantly different in the 5% BNJ level test

Table 2 shows that the treatment that had the highest C-Organic content was found in B3 of 1.40%. Treatment of B3 is significantly different from B0, B1 and B2. Based on the [12], the C-Organic content of 1% -2% is still low. When compared with the initial analysis of nickel post-mining soil before treatment (0.93%) there was an increase in C-organic. This is in accordance with the opinion of [13] which states that biochar is persistent in the soil because it contains high carbon (C), more than 50% and does not experience further weathering so that it is stable for decades in the soil. Biochar have a wide surface area and contains many pores so that it has a high density. This physical property allows biochar to have the ability to hold water and fertilizers which is quite high.

Table 3. Average of soil reaction (pH H_2O)

Treatment	C-organic (%)
B0	0.90 c
B1	1.24 b
B2	1.19 b
B3	1.40

Note: The numbers followed by the same letter (a, b, c, d) are not significantly different in the 5% BNJ level test

Table 3 shows that the highest soil pH was found in treatment B3 (5.86). Treatment of B3 is significantly different from B1 and B0, but not significantly different from B2. The pH value before treatment, which is 5.40 which is classified as acid, it indicates that the average pH of the treatment B1, B0, and B3 have increased so that the soil is classified into a slightly acidic. This is in accordance with the opinion of [14] that the 6 kg pyrolysis process produces 1.9 kg of biological charcoal where the pH value is 9. This is in line with the opinion of [15] which states that in general biochar is neutral to alkaline so it can be used for increase acid soil.

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As pH decreases, the solubility and toxicity of aluminium (Al) increases in the soil. Al-dd also correlate to the level of P available in the soil. The chemical process that occurs is Al and Fe oxides increase P retention. This reaction occurs depending on soil acidity, P is bound by strong absorption energies such as iron/aluminium oxides and Fe/Al hydroxides so that Al-P bonds occur (Ohno & Amirbahman, 2010).

Table 4. Average of available P

Treatments	P (ppm)
B0	6,71 ^{d}
B1	11,03 ^{c}
B2	14,34 ^{b}
B3	19,08 ^{a}

Note: The numbers followed by the same letter (a, b, c, d) are not significantly different in the 5% BNJ level test

Table 4 shows that the highest available P is in the M1 treatment with a value of 13.58 ppm. However, M1 treatment was not significantly different from M2. This is because these treatments differ only in dosage but give the same effect. However, M1 and M2 are significantly different from M0. This treatment was significantly different from treatment B0, B1 and B2. This is in line with decreasing Al-dd and increasing pH after treatment. This is in accordance with [1] opinion which states that a high soil pH indicates a decrease in Al ions in the soil so that the nutrient elements needed are in greater numbers. This is because these nutrients do not dissolve easily.

The interaction effect between biochar and mycorrhizae as shown in Table 5 shows that B3M2 treatment has the lowest exchangeable Al and was significantly different from other treatments. This is in line with the increase in pH after treatment which indicates a decrease in Al ions in the soil.

Table 5. Average exchangeable of Al (cmol kg^{-1}) from interaction biochar and mycorrhiza

Mycorrhiza (t ha^{-1})	Biochar (t ha^{-1})			
	B0	B1	B2	B3
M0	2.41^{bcd}	2.52^{ab}	2.39^{cd}	1.99^{g}
M1	2.54^{a}	2.50^{abc}	2.22^{e}	1.84^{h}
M2	2.38^{d}	2.36^{d}	2.10^{f}	1.58^{i}
NP BNJ $_{0.05}$	0.01			

Table 6. Average CEC (cmol kg^{-1}) from interaction biochar and mycorrhiza

Mycorrhiza (t ha^{-1})	Biochar (t ha^{-1})			
	B0	B1	B2	B3
M0	5.49^{f}	11.02^{c}	11.80^{c}	15.82^{a}
M1	7.95^{e}	11.51^{c}	13.13^{b}	16.24^{a}
M2	9.05^{d}	12.73^{b}	13.47^{b}	15.88^{a}
NP BNJ $_{0.05}$	0.83			

Furthermore, the results of this study also indicated that B3 treatment significantly increased soil CEC compared to other treatments (Table 6). The best interaction effect of the biochar and mycorrhizal treatment and significantly different from other interactions was found in B3M1 treatment that have 16.24 cmol kg^{-1}.

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4. Conclusion

- The use of oil palm empty fruit bunches bio-ameliorant at a dose of 30 t/ha soil significantly improves nickel post mining soil quality.
- Application of mycorrhizae 1.6 t/ha significantly improved soil chemical properties of available phosphorus parameters and decreased exchangeable aluminium.
- Interactions between biochar 30 t/ha and mycorrhizal 1.6 t/ha (B3M2) is the best interaction to decrease in the of exchangeable aluminium and increase availability of P in the nickel post-mining soil.

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