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The Effects of Arbuscular Mycorrhiza Fungi (AMF) and Organic Fertilizer on Chemical Features of Soil Planted by Sunflower (*Helianthus Annuus* L.) on Critical Land of Iron Ore Mining

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Abstract. The rate of land degradation is increasingly widespread and alarming, where the land becomes critical land. The transfer of forest into the iron ore mining area in Lhoong Subdistrict causes drying of river water. For that, it is needed a solution for the conservation of the land with the right and useful plants. This study aims to determine the effect of Arbuscular Mycorrhiza Fungi (AMF) and organic fertilizer on soil chemical properties planted with sunflower (*Helianthus annuus* L.) on critical land of iron ore mine in Lhoong, Aceh Besar. The soil sample was taken from Lhoong area, Aceh Besar District with a depth of 0-20 cm. The study was arranged according to a randomized block design of 2x3 factorial patterns with 4 replications. The first factor, AMF with 2 types, those are without Mycorrhiza and Mixed Mycorrhiza as much as 10 g each polybag. The second factor is organic fertilizer with 3 types those are Without Fertilizer, Manure, and Guano respectively as many as 30 tons each hectare area equivalent to 150 g/polybag. The results of the observations were tested by the variance analysis at $\alpha = 5\%$. The results of soil chemistry research showed that the provision of AMF had no significant effect on pH of H_2O, C-organic, N-total, P-available and CEC of soil. Organic fertilizer has a very significant effect on pH of H_2O, C-organic and N-total soil.

Keywords: Arbuscular Mycorrhiza Fungi (AMF), Organic fertilizers, Iron ore mining

1. Introduction

Aceh Government, particularly Aceh Besar District in 2006, granted mining concession rights to a mining company. The company was exploiting 500 hectares of land, while the exploration rights was 6000 hectares. The 500-hectare area is in the two settlements of Mukim Cot Jeumpa and Mukim Blang Me, located in four villages area; Jantang, Baroh Blang Me, Baroh Geunteut, and Gampông Teungoh Geunteut. [1]. Those villages will receive direct impact from the exploitation process up to seven other villages around. It wwould increase the amount of critical land and environmental degradation [2].

The Ministry of Forestry stated that approximately 1.2 million hectares of Indonesia's forests was damaged every year [3]. Critical land defined as land that is subjected to physical, chemical and biological damage due to their inadequate use and capability, which endanger the hydrological, orological, agricultural, socioeconomic and environmental functions [4]. Such soil has a low fertility

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due to low pH, nutrient deficiency especially P and N, low cation exchange capacity and poor organic material.

Critical land use can be renewed by planting sunflowers. These plants can be found in disturbed habitats, newly opened environments and various pastures [5]. It was able to grow in the presence of granulated slags and accumulated metals preferentially in above-ground tissues [6]. Sunflower can grow along the year in all places around the world and one source of biodiversity that acts as phytoremediation and biofuel producer. Phytoremediation use plants and microbes which is related more used as green technology to clean up the contaminated soil of mine [7], especially in an iron-mining sites [8, 9]. The ability of metal uptake differs depending on the type of AMF in remediating the soil [10].

Provision of AMF in host plants (sunflower plants) is able to reduce toxicity of contaminated mining land. Inoculation of AMF (R. *irregularis*) may be for phytoextraction Cd whereas F. mosseae can be useful for Cd and Zn fitostabilization [11]. In addition, , P-used of total organic fertilizers in the long term can increase the productivity of land and prevent land degradation and contribute substantially to the improvement of physical, chemical and biological soil [12]. Provision of organic fertilizer into ex-mining land can increase the pH value, organic C-total, CN available, P available, K, Ca, Mg, Na, K, and CEC [13].

Based on the study of the potential of AMF, organic fertilizer and sunflower benefits are quite promising. The researchers tried to use mycorrhizal and organic fertilizer to see how the influence of the AMF can and growing organic fertilizer plant sunflowers to changes in soil chemical properties. Futhermore, hopefully this study may be one of the solutions to improve the properties of the chemical on critical land of the former iron ore mine, spesically in Lhoong - Aceh Besar District.

2. Research Methods

The research was conducted in Meunasah Papeun Village, Krueng Barona Jaya Sub-district, Aceh Besar District. Initial soil chemical analysis of animal manure and Guano were conducted at the Laboratory Soil and Plants, Faculty of Agriculture, University Syiah Kuala. While soil chemical analysis was conducted at BPTP Aceh. The research activities started from January to December 2017.

The materials used were the critical soil taken from the former mining ore in Lhoong, Aceh Besar. Inoculum AMF used were Mixed Glomus (*Glomus*, *Gigaspora* and *Acaulospora*) with 100 spore density of each 10 g, obtained from the Soil Biology Laboratory of Soil Sciences, University Syiah Kuala. Local sunflower varieties obtained from Gampong Lhong Raya, Banda Raya District, Banda Aceh. Organic fertilizers consist of farm manures obtained from Area Usaha Shop, Diponegoro Street, Banda Aceh and guano from Gampong Lamdom, Sub-district Lampuuk, Aceh Besar. The basic fertilizer consists of KCl, TSP and Urea. Tools used are knives, weights and polybags (40 x 50 cm), hoes and buckets.

There are two factors studied. The first factor is the use of the AMF as much as 10 g each polybag which consists of 2 types AMF that is Without Mycorrhiza (Mo) and Mixed Mycorrhiza (M1). The second factor is an organic fertilizer with a dose of 30 tons each hectare area or equivalent to 150 g each polybag, consisting of 3 types of soil, that is Soil only (Po), soil with Manure (P1), and soil with Guano (P2). From those two factors, there were 6 treatment combinations and each treatment combination was repeated 4 times to 24 units of experiment. Randomized Block Design (RBD) 2x3 factorials pattern with 4 replications were applied. The treatment combination can be seen on the table 1 as follows.

Table 1. Combination arrangement of AMFs and Organic Fertilizers Treatment.

No	Treatment	Type of Mycorrhiza	Type of organic fertilizer
1	M0P0	Without Mycorrhiza	Without fertilizer
2	M0P1	Without Mycorrhiza	Manure
3	M0P2	Without Mycorrhiza	Guano
4	M1P0	Mixed Mycorrhiza	Without fertilizer
5	M1P1	Mixed Mycorrhiza	Manure
6	M1P2	Mixed Mycorrhiza	Guano

The mathematical math of Randomized Block Design The factorial group is as equation 1 follows.

$$Y_{ijk} = \mu + \beta_i + M_j + P_k + (MP)_{ijk} + \varepsilon_{ijk} \quad (1)$$

Where Y_{ijk} is the observations of the influence of mycorrhiza *to-j* and type of organic fertilizer *to-k* in a *to-i.,* μ is the average value, β_i is the effect of *i*- block (i = 1,2, and 3), M_j is the Effects of mycorrhizal species k e *j (j* = 1, and 2), P_k is the influence of the type of organic fertilizer *k (k* = 1,2, and 3), $(MP)_{ijk}$ is the effect of interaction of mycorrhiza *to-j* and type of organic fertilizer *to-k* d l m block *to-i. and* έ error $_{ijk}$ is the effect of treatment of mycorrhiza *to-j* and type of organic fertilizer *to-k* in the *i*- block .

Statgraphics for Windows software was used to analyze diversity of each observation with variance analysis (F test) at α = 5%. If there is a significant different effect on the parameters, the depth analysis will be done by using Least Significant Difference (LSD) 5% approach.

The research starts with initial soil analysis, analysis of organic fertilizers and preparation of soil for treatment. The soil properties analyzed were pH of H_2O, C-organic (Walkley & Black method), N-total (Kjeldhal method), P-available (Bray II method), K-dd, Ca-dd, Mg-dd, Na- dd (extraction method of 1 N NH4OAc pH7), CEC, alkaline saturation (NH4OAc pH7 extraction method), and EC (Electricity Conductivity). While the analysis of organic fertilizer includes C-organic content (Walkley & Black method), N-total (Kjeldhal method), total P-and total K (25% HCl destruction method). Determination of P and K in the extract solution was carried out each with a spectrophotometer and flame photometer. The soil material was taken at a depth of 0-20 cm, then cleaned and after it is dried and mashed and sifted with a hole diameter of 2 mm, then the soil is filled into a polybag of 10 kg each and watered to taste.

Giving organic fertilizer is done according to the treatment a week before planting. The method of administration is by mixing 150 grams of organic fertilizer with soil in each polybag. Then the uniform size and normal growth of seedlings are prepared. Furthermore, planting with in a hole made as deep as 5 cm on the surface of the ground. After that, 10 g of polybag-1 mycorrhiza was given (except the treatment without mycorrhiza) into the hole. The application of basic fertilizer was also carried out on each soil polybag, namely KCl as much as 50 kg ha-1 or 0.25 g polybag-1, TSP 100 kg ha-1 or 0.5 g polybag-1 and Urea 50 kg ha-1 or 0, 25 g polybag

Maintenance needs to be done with watering twice a day morning and evening except rain. Weeding is done every two weeks depending on weed growth. Cleared weeds are immersed back into the soil. At the end of the experiment several soil properties were analyzed, those are pH of H_2O, C-organic (Walkley & Black method), N-total (Kjeldhal method), P-available (Olsen P method) and CEC (NH4OAc pH7 extraction method).

3. Results And Discussion

3.1 pH of H_2O

The result of variance analysis (F test) showed that AMF did not have significant effect on pH of H_2O while organic fertilizer showed very significant effect on pH of H_2O. The combination of these two factors does not show interactivity. The mean value of pH of H_2O soil based on treatment of AMF and organic fertilizer can be seen in table 2.

Table 2. Average pH of H_2O land due to treatment of AMF and organic fertilizer.

Treatment	PH (H_2O)			Average
	Without Fertilizer	Manure	Guano	
Without Mycorrhiza	7.24	7.85	7.13	7.41 A
Mixed Mycorrhiza	7.30	7.89	7.22	7.47 A
Average	7.27 a	7.87 b	7.17 a	

BNT of fertilizer = 0.275. Description: P level ≤ 5%. The lower case is read horizontally and the uppercase is read vertically. "A" means statistical group between Mycorrhiza, meanwhile "a" and "b" are statistical group between fertilizers.

Table 2 shows that there is no significant different between Mixed Mycorrhiza and Without Mycorrhiza on pH of H_2O of soil. Nevertheless when compared to pH of H_2O before the treatment, there is an increase before and after the treatment, from 6.11 to 7, 41, means changing from little acid to be neutral. In the treatment, organic fertilizer highly significant increases pH of H_2O [13], where the manure has the highest influence on increasing pH of H_2O. The manure can increase pH, C-organic and availability of nitrogen, fosfor, kalium and other micro substances [14], followed by Without Fertilizer and Guano.

When compared to pH of H_2O soil before the treatment, there was an increase in pH of H_20 after the experiment, from more acid to be neutral in the treatment of Without Fertilizer and Guano and became slightly alkaline in the treatment of Manure. Organic substances in the soil have a rich *buffer capacity* in order to keep pH of soil relative stabile [15]. This pH increase is influenced by organic fertilizer decomposition assisted by AMF, resulting in the release of alkaline cations as a contributor of OH-ions into the soil. The more OH-ions increase, the more pH ofH_2O increase.

C-organic Furthermore in C-organic , the result of variance analysis (F test) showed that giving of AMF did not significant changing C-organic content in soil, but giving organic fertilizer showed it has significant effect in changing C-organic content in soil, even though no interaction effect. The average value of C-organic percentage in soil due to the treatment of AMF and organic fertilizer can be seen in table 3.

Table 3. The average content of -C-organic soil due to the treatment of AMF and organic fertilizer.

Treatment	C-organic (%)			Average
	Without Fertilizer	Manure	Guano	
Without Mycorrizha	0.21	0.43	0.79	0.47 A
Mixed Mycorrizha	0.30	0.43	0.82	0.51 A
Average	0.25 a	0.43 b	0.80 c	

BNT fertilizer = 0, 156.

Description: The numbers followed by the same letter in the same column and row means no significant statistical different at the P level ≤ 5%. Lower letters are read horizontally and uppercase letters are read vertically. Different letter means has different effect of the treatment between groups.

"A" means statistical group between Mycorrhiza, meanwhile "a" and "b" are statistical group between fertilizers

Table 3 shows that the treatment of Mixed Mycorrhizae has no significantly different from the Without Mycorrhiza on the soil C-organic content. However, when compared to C-organic soil before

and after the experiment, there was an increase of C-organic soil after the experiment from 0.24% to 0.47% with Without Mycorrhiza and 0.51% with Mixed Mycorrhiza. Moreover, organic fertilizer has very significant effect in increasing C-organic content of the soil [13]. It shows that Guano is the highest effect on C-organic before manure, and lowest effect is Without Fertilizer. The effect indirectly on the addition of C-organic soil due to the increase of soil nutrients such as N (0.5-0.8%), P (0.07-0.12%), K (1.2-1.7%), S (0.05-0.10%) and Si (4 -7%) [16].

The role of AMF one of which is to improve the soil structure where its hyphae binds one particle of soil to another particle. In addition to the extension of external hyphae, the secretion of the polysaccharide compounds, organic acids and mucus produced by it, will be able to bind the soil micro-aggregate / grain into a secondary grain / macro aggregate. This organic agent is very important in stabilizing micro aggregate through the strength of adhesives and binding by organic acids and hyphae. They will form a solid macro aggregate[17]. So that the provision of organic fertilizer and AMF can increase the number and activities of soil microbes as well as growth of plant roots.

C-organic content indicates that the content of organic matter in the soil where the C-organic content is approximately 58% of the soil organic matter[18,19]. Some elements of C can also be lost to the atmosphere, therefore the addition of organic matter is absolutely necessary every year to maintain and increase the C-organic -content in the soil. This is proven in the treatment of Mycorrhiza and without fertilizers C-organic content decrease from 0.24% to 0.21%.Iit is true that the decrease of C-organic is due to the decomposition process of organic material that is converted into in organic compounds so that the C- organic decreases [20].

3.2 N-total

The result of variance analysis (F test) showed that AMF did not significantly affect the N-total content of soil while organic fertilizer showed very significant effect on N-total of soil. The combination of these two factors does not show interaction. The average value of percentage of N-total soil content due to treatment of AMF and organic fertilizer can be seen in table 4.

Table 4. Average N-total of soil due to the application of AMF and organic fertilizer.

Treatment	N-Total (%)			Average
	Without Fertilizer	Manure	Guano	
Without Mycorrhiza	0.02	0.06	0.17	0.08 A
Mikoriza Mixed	0.04	0.04	0.17	0.08 A
Average	0.03 a	0.05 a	0.17 b	

BNT fertilizer = 0.042. Chart n The numbers followed by the same letters in the same columns and rows do not differ significantly at the level of $P \leq 5\%$. The lower case is read horizontally and the uppercase is read vertically. "A" means statistical group between Mycorrhiza, meanwhile "a" and "b" are statistical group between fertilizers

Table 4 shows that Mixed Mycorrhiza was not significantly different from the Without Mycorrhiza to the N-total soil content, but when compared with N-total soil before the experiment of 0.13%, there was a decrease in total N-total of soil after experiment to 0.8 %. Probably, this occur because of a low C / N ratio of organic fertilizers, which has not yet met the minimum N nutrient content for organic fertilizers and also because of the use by plants for growth. In the treatment of different organic fertilizer is very significant effect on the content of N-total soil. Organic matter contains much nitrogen nutrients and the rate of nitrogen liberation process through mineralization process from the remaining organic material needed by microorganisms [21].

The results show that Guano has the best effect on N-total improvement. This is because of the N content of Guano higher than that of manure. When compared to N-total before Guano experiments also were able to increase the total N-total of the soil to 0.17%. The increase in N-total content of the soil is still low allegedly due to the use of N by plants for growth and microorganisms including mycorrhiza for its development and activity in soil, due to the rapid

decomposition process and mineralization of organic fertilizers in soils in tropical climates. Other reasons can also occur because of the loss of N through washing. Nitrates are the result of mineralization processes that are mostly absorbed by most cultivated plants, but these nitrates are easily washed through water and evaporate into the inner atmosphere form of gas [17].

3.3 P-available

The result of variance analysis (F test) showed that the giving of AMF and organic fertilizer had no significant effect on P-available in soil and combination of the two factors did not show interaction. The average value of P-available soil due to treatment of AMF and organic fertilizer in table 5.

Table 5. Average P-available soil due to treatment of AMF and organic fertilizer.

Mycorrhiza	P-available (ppm)			Average
	Without Fertilizer	Manure	Guano	
Without Mycorrhiza	0.67	0.69	0.78	0.71 A
Mixed Mycorrhizae	0.59	0.68	0.60	0.62 A
Average	0.63 a	0.68 a	0.69 a	

Description: The numbers followed by the same letter in the same column and row are not significantly different at the P level ≤ 5%. The lower case is read horizontally, uppercase vertically. "A" means statistical group between Mycorrhiza, meanwhile "a" and "b" are statistical group between fertilizers

Table 5 shows that the treatment of Mixed Mycorrhiza was not significantly different from the mycorrhiza on the P-available soil, as well as the organic fertilizer application did not show any significant difference. Although statistically not showing any significant difference but from the mean value of table 5, it is seen that Guano administration is better in the improvement of P-available.

This is possible because the highest nutrient content in Guano is the phosphorus associated with calcium. In the form of Ca-P, so that in the presence of high phosphorus content guano commonly called phosphorite [22]. Additionally, the pH content of the soil given Guano pH is neutral. Phosphorus availability is strongly influenced by soil acidity, generally available at very low to neutral soil acidity[23]. The decomposition of organic matter yields humic acid and fulvate so that the bound P can be released and become available in the soil [24].

3.4 Cation Exchange Capacity (CEC)

Result of analysis of variance (F test) showed that giving of AMF and organic fertilizer had no significant effect to CEC in the soil and combination of both factors did not show interaction. The average value of CEC content of soil due to treatment of AMF and organic fertilizer in table 6.

Table 6. Mean of CEC for the treatment of AMF and organic fertilizer.

Mycorrhiza	CEC (cmol / kg)			Average
	Without Fertilizer	Manure	Guano	
Without Mycorrhiza	3.00	3.00	2.50	2.83 A
Mixed Mycorrhiza	4.25	3.00	3.00	3.42 A
Average	3.63 a	3.00 a	2.75 a	

Description: The numbers followed by the same letter in the same column and row are not significantly different at the P level ≤ 5%. The lower case is read horizontally and the uppercase is read vertically. "A" means statistical group between Mycorrhiza, meanwhile "a" and "b" are statistical group between fertilizers

Based on the initial soil analysis results , it can be seen that the land taken from the location of the former Lhoong iron ore mine, Aceh Besar including the class of dusty clay soil. This soil has a slightly

acidic soil pH and low N, K, Na, Ca and CEC nutrients and C, P, Mg and H are very low. Likewise Electrical Power Supply and Base Saturation are also very low. This indicates that the soil is a critical soil where the soil fertility level is very low as well.

Based on the results of research and analysis of the soil after experiments showed that p emberian AMF and organic fertilizer well evident statistically or not, but on the value of the average showed an increase in the pH of H_2O soil increased to Neutral except for the provision of fertilizer K torch being bit alkalis, then against Corganic, N-total and P-available although small . This indicates a chemical soil improvement but takes a long time to land that has been degraded due to iron ore mining in Lhoong Aceh Besar.

4. Conclusions

Provision of AMF shows no statistical different effect on some soil chemical properties. But, organic fertilizer has significant effect on some chemical properties of soil. It has very significant effect on pH of H_2O, C-organic and N-total. Guano Fertilizer show the best results on the improvement of some soil chemical properties that are planted by the sunflower on the critical land of the former iron ore mine in Lhoong Aceh Besar. In the future it need an integrative research, such as phytoremedian, to find a proper method to rehab the area to recover from a damaged land to be a fertile land.

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