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Effects of Arbuscular Mycorrhizal Fungi on Nutrient Uptake by *Pericopsis mooniana* in Media Post Gold Mining Land

Faisal Danu Tuheteru[1], Husna[1], Nuranisa[1], Basrudin[1], Asrianti Arif[1], Albasri[1], Ikraeni Safitri[2], Sedek Karepesina[3] and Wiwin Rahmawati Nurdin[1]
[1]Department of Forestry, Faculty of Forestry and Environmental Sciences, Universitas Halu Oleo, Kendari, Southeast Sulawesi. 93121, Indonesia.
[2]Departement of Forest Conservation, Universitas Nahdatul Ulama Gorontalo, Gorontalo. 96135, Indonesia.
[3]Departement of Forest, Universitas Darussalam Ambon, Maluku. 97128, Indonesia.
*Corresponding author : fdtuheteru1978@gmail.com

ABSTRACT. This study aims to determine the levels and nutrient uptake of kayu kuku (*Pericopsis mooniana* Thwaites) mycorrhizal plants aged four months in post-gold mining field scale. Sampling was carried out in the post-Bombana gold mining area. Leaf drying and weighing wass carried out at the Laboratory of the Faculty of Forestry and Environmental Sciences, Halu Oleo University and measurement of nutrient content and uptake at the *SEAMEO BIOTROP* Soil and Plants Laboratory Bogor, this study started from May to Jully 2021. This research method used a Randomized Block Design (RBD) with 4 treatments, namely control (A), *G. coronatum* (B), *G. claroideum* (C) and mixed AMF (B+C). This study was divided into 3 groups where each group contained 1 plant so that the total plants used are 12 kayu kuku plants. The results showed that AMF *G. coronatum* significantly increased N, P and Mn nutrient levels. Mixed AMF (*G. coronatum* + *G. claroideum*) was effective in increasing nutrient uptake of N, P, Mn and Fe. AMF was effective in increasing the levels and nutrient uptake of the four month old *P. mooniana* on post-Gold Mining.

Keywords: *Glomus coronatum, P. mooniana, Nutrient content and uptake, Post gold mining land*

INTRODUCTION

Mining is a common and well-known activity in Indonesia and is one of the most important parts of the national economy and a contributor to foreign exchange sources (Mustafa and Wahyuni, 2018). Mining includes natural resource utilization activities from the search (exploration), excavation (exploitation) stage, and the marketing stage of the results of mining and post-mining exploitation (Surachman et al., 2017), the final result of mining activities is post-mining land. Post-mining land is land that has less fertile soil, dense and poor in nutrients (Mansur, 2010), such as nitrogen, phosphorus, potassium, and nutrient levels of Mg>Ca and potassium which is quite high (Protocor, 2003) and high content of heavy metals, so that make it difficult for plants or vegetation to grow.

The condition of post-mining land that is poor in nutrients and high in metal content also occurs in post-gold mines in the Bombana region (Husna et al., 2019a: 2020b). Based on these conditions, it is necessary to improve land and nutrients such as the provision of organic and inorganic fertilizers, humic acid, and liming, which requires a large amount of money (Mansur, 2010) and input of biological fertilizer technology in the form of Arbuscular Mycorrhizal Fungi (AMF) which can support plant growth. And improvement of nutrients (Husna, 2010).

Arbuscular mycorrhizal fungi (AMF) are soil microbial fungi from the phylum Glomeromycota (Schubler and Walker, 2010). Arbuscular mycorrhizal fungi (AMF) can symbiotically with plant roots that grow in various ecosystems (Husna, 2015). AMF is

indispensable as a biological fertilizer because one of the basic functions of AMF is improving nutrient exchange (Yu et al., 2010). AMF can improve soil nutrient uptake, especially in soils lacking P, and AMF can also improve other nutrients such as Fe, Mn, Mg, and other nutrients needed by plants (Huang et al., 2017). AMF can help increase nitrogen nutrient uptake, promote plant growth, and reduce heavy metals in post-mining land (Husna, 2010, 2015; Bertolazi et al., 2018). AMF is reported to affect four species of local legumes in Southeast Sulawesi symbiotically and is threatened with extinction. One of them is the nail wood plant (Husna et al., 2018). Kayu Kuku is a plant from the Fabaceae family, a local tropical species of Southeast Sulawesi, widely spread in Kolaka Regency's plains (Husna, 2015a).

Many plant types of research using AMF have been carried out but are still limited to the greenhouse scale. Application of AMF at the greenhouse scale in post-mining soil media for nickel (Husna et al., 2016), gold (Husna et al., 2019a; 2020a), coal (Husna et al., 2019b), and nutrient uptake of mycorrhizal nails in drought stress (Husna et al., 2020). AMF has been proven to improve plant growth, soil, biomass, and plant nutrient uptake. Research on mycorrhizal nails in the field has been carried out on post-mining nickel and gold media (Husna, 2015b; Husna et al., 2017b; 2019a; 2020a). This study shows that AMF consistently increases growth and nutrient uptake at the field scale (Husna, 2015a; Wulandari et al., 2016). However, the field scale is still minimal. It is important to conduct research on the levels and nutrient uptake of mycorrhizal nails in post-gold mining land. This research was carried out to know the levels and nutrient uptake of four-month-old mycorrhizal nails (*Pericopsis mooniana* Thw.) on post-gold mining fields. Meanwhile, the benefit of this research is to obtain information on nutrient levels and uptake in nail wood plants on post-gold mining soil. Therefore, it can be used as a reference in supporting post-mining land reclamation efforts, especially post-gold mining in Southeast Sulawesi.

MATERIAL AND METHODS

Location and Time of Research. This research was carried out for three months from May to July 2021 with the location of sampling plant leaves in the Bombana Gold Post Mining Land with coordinates 4°39'27.7"LS 121°54'18.7" E. This research was conducted at the Laboratory of the Faculty of Forestry and Environmental Sciences, Halu Oleo University, and the Laboratory of Soil and Plants at SEAMEO BIOTROP Bogor.

Research Design. This study was designed using a Randomized Block Design (RBD), consisting of 4 types of treatment, namely: without AMF (control) (A), *Glomus claroideum* (B), *Glomus coronatum* (C), and Mixed AMF *Glomus claroideum* + *Glomus coronatum* (D). This study was divided into three groups where each group contained one plant so that the whole plants used were 12 nail wood plants.

Research Procedure. The research starts from preparing the tools and materials needed to carry out research. The stages of the research are as follows: 1) This research is a follow-up study from previous research on a greenhouse scale related to the application of AMF for nail wood plants (Nurdayanti, 2020) and continued with field-scale research on a four-month-old post-gold mine (Nasrullah, 2020). At the age of four months in the field, 15 leaves were harvested from each plant (randomly selected leaves that were old and green) in each treatment to keep the plant intact in the field (Giri et al., 2005), 2) The harvested leaves

are then dried in an oven at 70°C for 2x24 hours. After that, the dry weight of the leaves was weighed using an analytical balance, and 3) Samples of oven-dried leaves were then sent to the Laboratory of Soil and Plants at SEAMEO BIOTROP Bogor for analysis nutrient levels and uptake.

Parameters. Leaf dry weight, measured using an analytical balance. Phosphorus (P) concentration of the plant was analyzed using SL-MU-TT-05 (Bray I/II) method, while nitrogen (N) concentration of the plant was analyzed using SN 13-4721-1998 (Kjeldahl) method. The K, Mn, and Fe concentrations were analyzed using HNO3-HClO4 method (Carter 1993). The N, P, K, Mn, and Fe content were calculated by multiplying plant nutrients content with plant dry weight.

Data Analysis. The data analysis used was the analysis of variance (F test) and continued with the different treatment tests according to Duncan Multiple Range Test (DMRT) at a 95% confidence level using the SAS version 9.1.3.

RESULT AND DISCUSSION

A recapitulation of the results of variance (F test) of the effect of AMF treatment on nutrient levels and uptake in four-month-old Kuku wood (*Pericopsis mooniana* Thwaites) is presented in Table 1. Table 1 shows that AMF treatment had a significant effect on the variables of K and Mn nutrient levels and very significant on the nutrient uptake variables N, P, K, and Mn. The AMF treatment had no significant effect on the variables of N, P, Fe, and Fe uptake.

Table 1. Recapitulation of results of analysis of variance of the effect of AMF treatment on levels and nutrient uptake of N, P, K, Mn and Fe in Kayu Kuku (*Pericopsis mooniana* Thwaites) plants.

Variety of Print Recapitulation	**Nutrient Content (mg/g)**				
	N	**P**	**K**	**Mn**	**Fe**
Treatment	tn	tn	*	*	tn
CV (%)	42,89	39,41	31,99	26,26	82,25
	Nutrient Absorption (mg/leaf)				
	N	**P**	**K**	**Mn**	**Fe**
Treatment	**	**	**	**	tn
CV (%)	20,96	21,14	16,11	28,00	70,23

Description: ** = Very significant effect.
ns = No significant effect.
* = Significantly effect.
CV = Coefficient of variant.

The AMF treatment of G. claroideum had the highest K levels compared to the control and was not significantly different from G. coronatum. On the Mn content variable, all AMF treatments were significantly different from the controls. There was no difference between treatments in nutrient levels of N, P and Fe.

Tabel 2. Leave N, P, K, Mn and Fe concentration of *P. mooniana* grown with or without mycorrhizal fungi under filed conditions for four months

Treatment	Nutrient Content (mg/g)				
	Nitrogen (N)	**Phosphorus (P)**	**Potassium (K)**	**Manganese (Mn)**	**Iron (Fe)**
Control	12,40±0,72	0,77±0,26	3,73±0,59[b]	0,03±0,06[b]	0,10±0,03
G. claroideum	26,77±0,69	2,03±0,09	15,93±0,65[a]	0,13±0,03[a]	0,17±0,04
G. coronatum	28,75±0,66	2,10±0,06	3,35±0,20[a]	0,14±0,01[a]	0,13±0,03
Mixed FMA	28,17±0,77	1,90±0,06	10,36 ±0,37[ab]	0,13±0,00[a]	0,10±0,02
Pr>F	0,2625	0,14	0,0227	0,0106	0,8344

Note: The average value followed by the same letter in the same column is not significantly different at the DMRT test level at the 95% confidence level. *Average±SE.

The results showed that AMF could increase nutrient levels in four-month-old nail wood plants. The AMF treatment significantly increased nutrient levels. Namely, AMF G. coronatum increased N, P, and Mn levels, and G. Claroideum increased K and Fe levels. The results of this study are in line with Husna et al. (2020a) AMF G. coronatum and G. claroideum significantly increased the nutrient content of Kallapia celebica in post-gold mining fields. The results of this study are in line with Karti et al. (2013), where AMF was able to increase the levels and uptake of P nutrients in post-gold mining and ex-silica sand mining soils (Aurum et al., 2020), AMF was able to increase the nutrient content (P, Ca, Mg and S) in post-coal mining areas. Furthermore, AMF can absorb nutrients such as N, P, K, Ca, Mg, Fe, Cu, Na, S, and Mn (Evitayani et al., 2015; Nurdin, 2001). The mechanism of nutrient absorption by AMF, directly and indirectly, is extradical hyphae which can absorb nutrients and translocate quickly into roots and transport nutrients by hyphae faster than roots (Wang, 2017). Furthermore, AMF has a long and fine hyphae structure that can penetrate the soil to absorb water and macro-micro nutrients that plant roots cannot reach (Goltapeh et al., 2008). The entry of nutrients into AMF hyphae reaches six times faster than plants not infected with AMF (Effendy and Wijayani, 2011).

The mixed AMF treatment and G. coronatum were significantly different from G. claroideum and controls on the uptake variables of N, P, K, and Mn. G. claroideum was significantly different from the control on the K uptake variable. There was no difference between treatments on the Fe variable (Table 3).

Tabel 3. Leave N, P, K, Mn and Fe uptake of *P. mooniana* grown with or without mycorrhizal fungi under filed conditions for four months

Treatment	Nutrient Absorption (mg/leaf)				
	Nitrogen (N)	**Phosphorus (P)**	**Potassium (K)**	**Manganese (Mn)**	**Iron (Fe)**
Control	7,69±1,46[b]	0,48±0,08[b]	2,31±0,78[c]	0,02±0,02[b]	0,06±0,03
G. claroideum	17,21±0,78[b]	1,29±0,09[b]	10,12±0,43[b]	0,08±0,02[b]	0,11±0,03
G. coronatum	45,46±1,64[a]	3,32±0,19[a]	21,32±0,61[a]	0,023±0,03[a]	0,21±0,07
Mixed FMA	55,71±0,81[a]	3,79±0,15[a]	20,88±0,95[a]	0,27±0,02[a]	0,21±0,06
Pr>F	0,0003	0,0004	0,0001	0,0001	0.3217

Note: The average value followed by the same letter in the same column is not significantly different at the DMRT test level at the 95% confidence level. *Average±SE.

The results showed that the most significant AMF increased nutrient uptake, namely mixed AMF and G. coronatum, which increased N, P, Mn, and Fe uptake. The results of this study are in line with Hidayati et al. (2015) Mixed AMF (*Glomus* sp. + *Gigaspora* sp.) was able to increase the uptake of N, P, and K nutrients in plants. The results of this study are in line with previous studies on a field scale in post-gold mining areas where AMF increases the uptake of N, P, and K nutrients (Husna et al., 2021). This study is also in line with Husna (2010) AMF can increase the uptake of P, K, Ca, Mg, and Fe of nail wood on contaminated nickel soil. The high significance of mixed AMF is due to the large number of hyphae penetrating the root tissue, which causes the root cell network to increase and increase external hyphae, which function to increase the area of water and nutrient uptake (Vidyana, 2008). This study is in line with Husna (2015a; Husna et al., 2017b; 2019a; 2020a) that AMF is effective in increasing nutrient levels and uptake in plants consistently both at the field and greenhouse scale, and AMF can work synergistically so that water and nutrient absorption is more effective and reduce heavy metals (Muzakkir et al., 2010; Husna, 2010, 2015).

Soil conditions in post-gold mining areas contain high heavy metals such as Fe, Zn (Ambarsari and Qisthi, 2017), As, Cd (Setiabudi, 2005), Hg (Wawo et al., 2017) and Pb (Gurnita et al., 2017), and poor macro and micronutrients make plants difficult to grow. AMF plays a role in absorbing macro and micronutrients. According to Mansur et al. (2012), AMF can absorb nutrients N, P, K, Zn, Cu, and Fe in saline and post-mining soils for nickel (Husna et al., 2016), gold (Husna et al., 2019a; 2020a) and coal (Husna et al., 2012). and coal (Husna et al., 2019b). The results of research related to nutrient levels and uptake in mycorrhizal plants on post-mining AMF were reported to increase the uptake and nutrient levels of N, P, and K (Prayudaningsih et al., 2014). In addition, AMF was able to increase Fe and Mn (Husna et al., 2020a) and is also able to reduce the content of Fe and Mn elements if the concentrations are toxic or high in plants (Hego et al., 1990). Increase nutrient levels and uptake in *Eucalyptus deglupta* (Rosita et al., 2017) and *Kalappia celebica* (Husna et al., 2020a) plants and increase growth in *Pterocarpus indicus* and *Albizia saponaria* (Husna et al., 2020b; Tuheteru and Husna, 2011).

CONCLUSION

This study concluded that AMF inoculation treatment increased nutrient levels and uptake in Kuku wood (Pericopsis mooniana Thwaites) in post-gold mining land. The best treatment was AMF type G. coronatum which was effective in increasing N, P, and Mn nutrient levels, and the best treatment for nutrient uptake was mixed AMF (G. clorideum + G. coronatum) which was effective in increasing N, P, Mn, and Fe nutrients in plants four-month old Kuku wood.

REFERENCES

Ambarsari, H., & Qisthi, A. (2017). Remediasi merkuri (Hg) pada air limbah tambang emas rakyat dengan metode lahan basah buatan terpadu. *Jurnal Teknologi Lingkungan*, 18 (2), 148-156.

Aurum, P., Budi, S. W., & Pamoengkas, P. (2020). Ketergantungan tiga jenis tanaman kehutanan terhadap mikoriza pada media tanah bekas tambang pasir silika. *Jurnal Ilmu Pertanian Indonesia (JIPI), 25 (2)*, 307-315. doi:10.18343/jipi.25.2.309

Bertolazi, A.A., da Silva Folli Pereira, M., Gustavo, C., Lucas, Z.P., Carlos, M. C., S.B. de Souza., Alessandro C.R., Nazima, R., Getúlio de Freitas Seben Júnior., & Evandro, L.S. (2018). *Linking plant nutritional status to plant AMF interactions. Springer. Nature Singapore Pte Ltd*.

Effendy, M., & Wijayani, B. W. (2011). Estimation of available phosphorus in soil using the population of arbuscular mycorrhizal fungi spores. *Jurnal Tropical Soils, 16*, 225-232. doi:10.5400/jts.2011.v16i3.225-232

Evitayani, Khalil, Dirgantara, E., Lidra, M., & Yolanda. (2015). Pengaruh pemberian cendawan mikoriza arbuskula (CMA) dan pupuk N, P dan K pada lahan pascatambang batubara terhadap kandungan mineral makro rumpu gajah (Pennisetum purpureum) CV. Taiwan. *Jurnal Pastura, 5*(1), 15-19.

Giri, B., Kapoor, R., & Mukerji, K. (2005). Effect of the arbuscular mycorrhizae Glomus fasciculatum and G. macrocarpum on the growth and nutrient content of Cassia siamea in semi-arid Indian wasteland soil. *Jurnal New Forest, 29*, 63-73.

Goltapeh, E.M., Danesh,YZ., Prasad, R., & Varma, A. (2008). Mycorrhizal Fungi : what we know and what should we know ?. In : Varma. A, editor. *Mycorrhiza :State of the Art, Genetic and Molecular Biology, Eco-Function, Biotechnology, Eco Physiology, Structure and Systematics*. India (IN): Springer.

Gurnita., Sondari, N., & Budiasih, R. (2017). Pengaruh pengindus ammonium sulfat terhadap pertumbuhan dan kandungan logam berat timbal (pb) pada rumput akar wangi (*Vetiveria zizanoides* L.) yang di tanam pada tailing tambang emas. *Jurnal Biosfer*, 2(1), 26-35.

Heggo A., Angle, J.S., & Chaney, R.L. (1990). Effects of vesicular arbuscular mycorrhizal fungi on heavy-metal uptake by soybeans. *Jurnal Soil Biol Biochem*, 22(6), 865–869.

Hidayati, N., Faridah, E., & Sumardi. (2015). Peran mikoriza pada semai beberapa sumber benih mangium (*Acacia mangium* Willd.) yang tumbuh pada tanah kering. *Jurnal Pemuliaan Tanaman Hutan*, 9(1), 13-29.

Huang, Y.M., Zou, Y.N., & Wu, Q.S. (2017). Alleviation of draught stress by mycorrhizas is related to increased root H_2O_2 efflux in trifoliate orange. *Jurnal Scientific Reports*, 7(1), 1-9.

Husna. (2010). Pertumbuhan bibit kayu kuku (*Pericopsis mooniana* thw) melalui aplikasi fungi mikoriza arbuskula (fma) dan ampas sagu pada media tanah bekas tambang nikel. Thesis, Universitas Halu Oleo. Kendari.

Husna, Budi, S.W., Mansur, I., & Kusmana, C. (2015). Respon pertumbuhan bibit kayu kuku [*Pericopsis mooniana* (Thw.) Thw.] terhadap inokulasi fungi mikoriza arbuskula lokal. *Jurnal Pemuliaan Tanaman Hutan*, 9(3), 131-148.

Husna. (2015a). Budidaya dan konservasi kayu kuku. Bogor: IPB Press.

Husna. (2015b). Potensi fungi mikoriza arbuskula (FMA) lokal dalam konservasi ex-situ jenis terancam punah kayu kuku [*Pericopsis mooniana* (Thw.) Thw.] Disertasi, Institut Pertanian Bogor. Bogor.

Husna, Budi, S.W., Mansur, I., & Kusmana, C. (2016). Respon pertumbuhan bibit kayu kuku (*Pericopsis mooniana* Thw.) with mikoriza in soil media of nickel post mining. *Pakistan Journal of Biological Science*, 19, 158-170.

Husna., Tuheteru, F.D., & Wigati, E. (2017b). Short communication: Growth response and dependency of endangered nedun tree species (*Pericopsis mooniana*) affected by indigenous arbuscular mycorrhizal fungi inoculation. *Jurnal Nusantara Bioscience*, 9(1), 57-61.

Husna, Tuheteru, F.D., & Arif, A. (2018). Arbuscular mycorhizal fungi symbiosis and conservation of endangered tropical legume trees. *Springer International Publishing AG, Part Of Springer Nature*.

Husna, Tuheteru, F.D., Arif, A., & Solomon (2019a). Improvement of early growth of endemic Sulawesi trees species *Kalappia celebica* by arbuscular mycorrhizal fungi in gold mining tailings. *IOP Conf. Series: Earth and Environmental Science*, 394, 1-5.

Husna, Mansur, I., Wilarso, S., Budi, R., Tuheteru, F. D., Arif, A., Tuheteru, E.J., & Albasri. (2019b). Effects of Arbuscular mycorrhizal fungi and organic material on growth and nutrient uptake by *Pericopsis mooniana* in Coal Mine. *Asian Journal Plant Sci,* 18, 101-109.

Husna., Tuheteru, F.D., Albasri., Arif, A., Basruddin., & Umar, Y. (2020). Serapan hara tanaman kayu kuku (*Pericopsis mooniana* Thw.) bermikoriza pada interval penyiraman berbeda. *Jurnal Hutan Tropika*, 16(2), 88-101.

Husna, Tuheteru, F.D., & Arif, A. (2020a). The potential of arbuscular mycorrhizal fungi to conserve *Kalappia celebica*, an endangered endemic legume on gold mine tailings in Sulawesi, Indonesia. *Journal For Res. Springer*.

Husna, Tuheteru, F.D., Arif, A & Sintalia, P. (2020b). Pemanfaatan FMA untuk mendukung pertumbuhan jenis terancam punah angsana pada media Tailing Emas. *ANR Conference Series 03*.

Husna, Tuheteru, F.D., & Arif, A. (2021). *Linggau: Kayu merah dari Indonesia Timur*. Bogor: IPB Press.

Karti, P.D.M.H., Kumalasari, N.R., & Setyorini, D. (2013). Peran fungi mikoriza arbuskula, mikroorganisme pelarut fosfat, *Rhizobium* Sp. dan asam humik untuk meningkatkan pertumbuhan dan produktivitas legun *Calopogonium* pada tanah latosol dan tailing tambang emas di PT. Aneka Tambang. *Jurnal Pastura*, 3(1), 44-47.

Mansur I. 2010. *Teknik silvikultur untuk reklamasi lahan bekas tambang*. Bogor: Seamea Biotrop.

Mansur, I., Arif, A., Husna., & Tuheteru, F.D. (2012). *Pupuk hayati mikoriza untuk budidaya dan rehabilitasi wilayah pantai*. Bogor: Seameo Biotrop.

Mustafa, A.B., & Wahyuni, S. (2018). Fitoremediasi sebagai alternatif pemulihan lahan pascatambang. *Pusat Penelitian Bioteknologi dan Bioindustri Indonesia*, 6(1), 1-6.

Muzakkir, Husin, E.F., Agustian., & Syarif, A. (2010). Efektivitas berbagai fungi mikoriza arbuskular indigenus terhadap serapan hara p dan pertumbuhan tanaman jarak pagar (*Jatropha curcas* L.). *Jurnal Solum*, 7(2), 137-143.

Nasrullah, M. M. (2020)**.** Uji efektivitas fungi mikoriza arbuskula terhadap pertumbuhan kayu kuku (*Pericopsis Mooniana* Thwaites) Di Lahan Pascatambang Emas Bombana Sulawesi Tenggara. Skripsi, Universitas Halu Oleo. Kendari.

Nurdin. (2001). Kontribusi mikoriza pada proses biogeokimia ditanah galian tambang emas dan serapan hara untuk pertumbuhan semai *Paraserianthes falcataria* (L) *nielson* dan *Acacia mangium* Wild. Skripsi, Institut Pertanian Bogor. Bogor.

Nurdayanti, S. (2020). Aplikasi Fungi Mikoriza Arbuskula (FMA) Lokal Terhadap Pertumbuhan Kayu Kuku (*Pericopsis mooniana* Thw.) Pada Media Tanah Tambang Emas. Skripsi, Universitas Halu Oleo. Kendari.

Prayudaningsih R., Rikupadang, H., Kurniawan, E., & Hajar. (2014). Laporan hasil: Pemanfaatan fungi mikoriza arbuskula (FMA) untuk reklamasi lahan bekas tambang Sulawesi. Balai Penelitian.

Protocor J. 2003. Vegetation and soil and plant chemistry on ultramic rocks in the tropical far east. *Jurnal Prespective in Plant Ecology, Evolution and Systematics*, 6(12), 105-124.

Rosita, Budi, I.R., Wulandari, S.W., & Sekar, A. (2017). Efektivitas FMA dan pupuk P terhadap pertumbuhan bibit leda (*Eucalyptus deglupta* Blume) dimedia pascatambang. *Junal Silvikultur Tropika*, 8(2), 96-102.

Schubler, A and Walker, C. (2010). *The Glomeromycota. A species list with new families and new genera*. Kew (GB): The Royal Botanic Garden Kew.

Surachman, A., Handayani, I.G.K.R., & Taruno, Y. (2017). Effects of globalization on estabilishment of water resource law: A Practice in Indonesia. *International Journal Of Economic Research*, 14(13), 93-103.

Setiabudi, B.T. (2005). Penyebaran merkuri akibat usaha pertambangan emas di daerah Sangon, Kabupaten Kulon Progo, D.I. Yogyakarta. *Kolokium Hasil Lapangan-DIM*, 61, 1-17.

Tuheteru, F.D. dan Husna. (2011). Respon pertumbuhan dan tingkat ketergantungan *Albizia saponaria* (lour.) miq terhadap fungi mikoriza arbuskula lokal Sulawesi Tenggara. *Jurnal Biota*, 16(2), 52-261.

Vidyana, P. (2008). Pengaruh dosis cendawan mikoriza arbuskular (CMA) dalam pupuk P terhadap pertumbuhan dan hasil cabai merah besar. *Jurnal Inovasi Pertanian*, 32(1), 1-10.

Wang, F. (2017). *Arbuscular Mycorrhizas and Ecosystem Restoration. In: QS Wu (eds.) Arbuscular Mycorrhizas and Stress Tolerance of Plants*. Singapore: Springer..

Wawo, R.H.A., Widodo, S.., Jafar, N., & Yusuf, N. (2017). Analisis pengaruh penambangan emas terhadap kondisi tanah pada pertambangan rakyat Poboya Palu, Provinsi Sulawesi Tengah. *Jurnal Geomine*, 5 (3), 116-119.

Wulandari, D., Saridi., Cheng, W., & Tawaraya, K. (2016). Arbuscular mycorrhizal fungal inoculation improves *Albizia saman* and *Paraserianthes falcataria* growth in post-opencast coal mine field in East Kalimantan, Indonesia. *Journal Forest Ecology and Management*, 376, 67-73.

Yu Y., Zhang, S., & Huang, H. (2010). Behavior of mercury in a soil–plant system as affected by inoculation with the arbuscular mycorrhizal fungus Glomus mosseae. *Jurnal Mycorrhiza* 20, 407-414.