Journal of Tropical Mycorrhiza
https://journal.ami-ri.org/index.php/JTM
E-ISSN 2829-467X
Vol. 2 No. 1 April 2023

Effect of Arbuscular Mycorrhizal Fungi Inoculation on content and nutrient uptake of four-month-old Angsana (Pterocarpus indicus Willd.) plants in post-gold mining land in Bombana, Southeast Sulawesi

Asrianti Arif[1], Husna[1*], Faisal Danu Tuheteru[1], Indrawati Saleh[1], Albasri[1], Wiwin Rahmawati Nurdin[1], Parwito[2] and Miranda Hadiyanti Hadijah[3]

[1]Department of Forestry, Faculty of Forestry and Environmental Sciences, Halu Oleo University, Kendari, Southeast Sulawesi. 93121, Indonesia
[2]Department of Agrotechnology, Faculty of Agriculture, Universitas Ratu Samban, Bengkulu, Indonesia
[3]Department of Forestry, Faculty of Agriculture, Universitas Pattimura, Jl. Ir. Putuhena, Poka, Ambon 97233, Indonesia
*Corresponding author : husna@uho.ac.id

ABSTRACT. Mining activities are the main cause of nutrient-poor land and damage to soil physical properties. This condition also occurs in the post-Bombana gold mining area. thus negatively impacting plant growth response. Therefore, post-mining land remediation is carried out using environmentally friendly approaches such as Arbuscular Mycorrhizal Fungi and the use of adaptive local plant species such as Angsana (Pterocarpus indicus Willd.). This study aims to determine the levels and uptake of nutrients in the mycorrhizal P. indicus plant in post-gold mining field scale. Sampling was carried out in the laboratory of the Faculty of Forestry and Environmental Sciences, Halu Oleo University and observations of nutrient levels were carried out in the soil and plant laboratory of SEAMEO BIOTROP Bogor, this research was carried out for 3 months (May 2021). This research method used a Randomized Block Design (RAK) with 4 treatments, namely control, Glomus coronatum, G. claroideum and mixed AMF. The results showed that mixed AMF was effective in increasing N, Mn and Fe nutrient levels and G. claroideum increased P and K levels. Mixed AMF increased N, Mn and Fe nutrient levels and nutrient uptake in P. indicus plants four months old on the Bombana Gold Post Mining Land, Southeast Sulawesi.

Keywords : *AMF, angsana, nutrient content and nutrient uptake, post-gold mine*

INTRODUCTION

Indonesia is known as a country with a large wealth of minerals and is the world's leading exporter of minerals (Nugroho, 2020). Mining activities cause environmental damage (Baowei et al., 2015), loss of top soil (Borisovna et al., 2013). One of them is a decrease in soil productivity and plant growth, the chemical, physical and biological properties of the soil will be damaged and become a problem in the ecosystem (Fachlevi et al., 2015). So that it will have a negative impact on the physiological response of plants. This condition also occurs in the Bombana post-gold mining area (Husna, et al., 2019a; 2020a). The characteristics of post-mining land are characterized by the appearance of sandy soil, almost no top soil layer, minimal vegetation and nutrients, high soil acidity (Neneng et al., 2012). Therefore, remediation of post-mining land contaminated with heavy metals is carried out by means of an environmentally friendly approach such as the use of beneficial microorganisms such as arbuscular mycorrhizal fungi (Wang, 2017a).

Arbuscular mycorrhizal fungi (AMF) are root symbionts which share a symbiosis with the majority of higher plants (Smith and Read, 2008). AMF has various functions, one of which is increasing the absorption of nutrients, especially P elements in the soil (Musfal, 2010). Studies on the effectiveness of AMF have been carried out in increasing plant growth and nutrient uptake (Husna et al., 2015), improving soil structure and playing a role in carbon transport from plant roots (Rosita et al., 2017). AMF is a potential biological fertilizer that exists in nature and is associated with approximately 80% of plant species (Husna, 2020). Arbuscular mycorrhizal fungi are reported to be able to symbiosis with three species of local Southeast Sulawesi legume plants that are threatened with extinction and one of them is the Angsana plant (Husna et al., 2018).

Angsana (Pterocarpus indicus Willd) is also a tropical legume species that produces high-value commercial timber (Husna et al., 2020b). Angsana plants grow naturally in tropical rain forests in lowland areas and are included in the endangered species category (IUCN, 2018). According to Husna et al. (2010) that the application of mycorrhiza to *Pterocarpus indicus* Willd and *Pericopsis mooniana* Thw. plants can increase plant nutrient levels and uptake at the greenhouse scale. While the application of AMF on a field scale has been carried out on nickel post-mining media (Husna et al., 2016), gold (Husna et al., 2019a; 2020a) and coal (Husna et al., 2019b). The results of research on the greenhouse scale and the field scale show that AMF consistently increases growth and nutrient uptake (Husna, 2015a; Husna et al., 2020a; Lumba, 2020).

Research on nutrient content and uptake of angsana plants with the application of local AMF on post-gold mining land is an advanced research and is still very limited. Based on this, it is important to conduct research on the levels and nutrient uptake of mycorrhizal Angsana plants on post-gold mining land. This study aims to determine the levels and nutrient absorption of the mycorrhizal plant Angsana (*P. indicus*) on field-scale post-gold mining land. The benefit of this research is to obtain information on nutrient levels and nutrient uptake in Angsana plants. So that it can be used as a reference in supporting post-mining land reclamation efforts, especially post-mining gold land in Southeast Sulawesi.

MATERIALS AND METHODS

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

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 3 groups where each group contained 1 plant so that the total plants used were 12 Angsana plants

Research procedure. The research starts with preparing the tools and materials needed to carry out the research. The stages of the research are as follows:

1. This research is a continuation of previous research on the greenhouse scale regarding the application of AMF on the greenhouse scale (Sintalia, 2020) and continued with field-scale research at 4 months of age (Lumba, 2020). At the age of 4 months in the field the plants were harvested with 15 leaves each and randomly selected old green leaves in each treatment to keep the plants intact in the field (Giri et al., 2005).
2. The harvested plant leaves are then brought to the Laboratory of the Faculty of Forestry and Environmental Sciences to be dried in an oven to determine the leaf dry weight of each treatment at 70^{o}C for 2 x 24 hours. After that, the dry weight of the leaves was measured using an analytical balance.
3. Samples of leaves that have been roasted and weighed for dry weight are put in an envelope and sent to SEAMEO BIOTROP Bogor. For analysis of nutrient uptake levels.
4. Observation of nutrient levels in plants using the SL – MU – TT 05 (Bray I/II) method, N levels of plants were analyzed using the SN 13-4721 – 1998 (Kjeldah) method. Mn and Fe levels were analyzed using the HNO_3-$HC1O_4$ method (Carter, 1993). For observation of N, P, K, Fe and Mn

Journal of Tropical Mycorrhiza
https://journal.ami-ri.org/index.php/JTM
E-ISSN 2829-467X
Vol. 2 No. 1 April 2023

nutrient uptake is calculated by multiplying the plant nutrient content by the dry weight of plant leaves.

Variables. Variables measured in this study included plant dry weight and nutrient content and uptake. plant dry weight: The leaves were in the oven at 70oC for 2 times 24 hours and then weighed. Nutrient content : Phosphorus (P) and Potassium (K) levels were analyzed using the SL-MU-TT-05 (Bray I/II) method. Plant nitrogen (N) levels were analyzed using the SN 13-4721-1998 (Kjeldahl) method and plant manganese (Mn) and iron (Fe) levels were analyzed using the HNO3-HClO4 method (Carter, 1993). Nutrient uptake : N, P, K, Mn and Fe uptake was calculated by multiplying the plant nutrient content by the leaf 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 MultipleRange Test (DMRT) at a 95% confidence level using the SAS version 9.1.3.

RESULTS AND DISCUSSION

Recapitulation of the results of the variance (F test) of the effect of AMF treatment on nutrient content and absorption in four-month-old Angsana plants is presented in Table 1. Table 1 shows that AMF treatment had a very significant effect on the P and K nutrient levels. In the absorption of nutrients N, P, K and a significant effect on the Mn variable. The treatment had no significant effect on the variable levels of N, Mn, 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 *P. indicus* plants.

Variety of Print Recapitulation	**Nutrient content (mg/g)**				
	N	**P**	**K**	**Mn**	**Fe**
Treatment	ns	**	**	ns	ns
CV (%)	6,73	6,97	7,79	30,86	25,02
	Nutrient upatake (mg/plant)				
	N	**P**	**K**	**Mn**	**Fe**
Treatment	**	**	**	*	ns
CV (%)	6,18	15,13	13,72	34,62	68,99

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

Variable levels of P in the AMF treatment with G. clarodeum was the best compared to the control and other treatments. While the treatment of AMF type G. coronatum was significantly different from the control but not significantly different from mixed AMF. In table 3, the K nutrient content variables show that G. clarodeum was significantly different from control and mixed AMF, but not significantly different from G.coronatum AMF. Meanwhile, mixed AMF was significantly different from control and G. clarodeum, but not significantly different from G. coronatum. In the treatment of N, Mn and Fe nutrient levels it showed that AMF had no significant effect but the AMF treatment tended to increase nutrient levels higher compared to the control.

Tabel 2. Leave N, P, K, Mn and Fe content of P. indicus 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	33,43±1,42	2,30±0,10c	14,37±0,77c	0,28±0,03	0,20±0,02
G. claroideum	37,53±3,08	3,37±0,20a	26,63±1,14a	0,17±0,02	0,23±0,02
G. coronatum	36,87±0,62	2,77±0,12b	23,73±1,08ab	0,26±0,07	0,25±0,01
Mixed AMF	38,30±0,64	2,67±0,09bc	22,13±0,77b	0,28±0,045	0,28±0,06
Pr>F	0,2625	0,0030	0,0006	0,3600	0,4142

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 P nutrient uptake variable, the mixed AMF treatment was significantly different from the control and G. coronatum AMF and not significantly different from G. clarodeum AMF. Treatment of AMF G. coronatum was significantly different from control and mixed AMF but not significantly different from G. Clorodeum. The K nutrient uptake variables for all AMF treatments were significantly different from the control. The manganese uptake variable in table 5 shows that the mixed AMF was significantly different from the control and G. claroideum AMF and not significantly different from G. coronatum. AMF on the P and Fe nutrient absorption variables did not have a significant effect, but the AMF treatment tended to increase nutrient uptake higher than the control.

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

Treatment	**Uptake (mg/plant)**				
	Nitrogen (N)	**Phosphorus (P)**	**Potassium (K)**	**Manganese (Mn)**	**Iron (Fe)**
Control	60,51±5,06c	3,92±0,59	24,31±3,12b	0,44±0,15c	0,31±0,09
G. claroideum	252,89±5,17ab	22,68±1,28	183,93±4,56a	1,16±0,04bc	1,52±0,18
G. coronatum	255,53±6,27b	18,62±1,28	158,41±9,41a	1,56±0,32ab	1,70±0,45
Mixed AMF	278,36±11,39a	19,34±1,79	158,75±14,66a	2,13±0,31a	2,19±0,90
Pr>F	<0001	0,0003	0.0001	0.0204	0,2201

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 inoculation of AMF were effective in increasing nutrient levels and nutrient uptake in Angsana plants. Angsana plants that were inoculated with AMF and those that were not inoculated with AMF had significant differences in the uptake of nutrient levels and nutrient uptake in plants. The results showed that the AMF treatment had higher levels of nutrients and absorption of N, P, K, Mn and Fe than the control treatment. This is because AMF plays a role in assisting plants in absorbing both macro and micro nutrients (Indriani et al., 2011). In addition, AMF can increase the availability of host plant nutrients, especially nutrient P (Feng et al., 2003). Absorption of nutrients, especially P, occurs because AMF produces phosphatase enzymes which allow an increase in P elements in the soil so that plants are able to absorb nutrients in sufficient quantities and help plants from heavy metal stress (Miransari, 2017), and AMF has external hyphae which play a role in absorbing nutrients and water needed by plants (Smith and Read, 2008).

Journal of Tropical Mycorrhiza
https://journal.ami-ri.org/index.php/JTM
E-ISSN 2829-467X
Vol. 2 No. 1 April 2023

Gold mining generally produces a lot of tailings waste which can pollute the ecosystem (Purwantari, 2007). Tailings are the result of gold mining generally containing inert (inactive) minerals such as quartz, calcite and various types of alumino silicates, and usually still contain gold. In addition, gold tailings also contain several other metals such as Arsenic (As), Cadmium (Cd), Lead (Pb), Mercury (Hg) and Cyanide (Cn) (Riogilang and Masloman, 2009). Other heavy metal elements found in post-mining land are Fe, Mg, Ni, Cr and Co (Husna et al., 2016). In addition, the soil on post-gold mining land has a high heavy metal content and very low availability of macro nutrients such as phosphorus (Aryanti and Hera, 2019). It has been widely confirmed that arbuscular mycorrhizal fungi can increase the availability of plant nutrients (Wang, 2017b; Husna, 2015a). In addition, AMF species can increase the biomass and nutrient uptake of Eucalyptus cladacalyx plants in arsenical tailings of sulfidic gold mines (Orlowska et al., 2012) and can increase plant growth and nutrient uptake of N, P, K in Leucaena leucocephala plants and reduce Pb and Zn capacities. on Pb and Zn tailings (Ma et al., 2006).

The results showed that AMF was effective in increasing nutrient levels in mycorrhizal four-month-old Angsana (Pterocarpus indicus Willd.) plants. The effective AMF treatment increased nutrient levels, namely mixed AMF increased N, Mn, and Fe nutrient levels. FMA G. cloroideum increases levels of P and K nutrients. The results of this study are in line with Husna et al. (2021) AMF of the type G. claroideum which was inoculated with the gosana plant could increase K nutrient levels. This research is in line with Husna et al. (2017) AMF has an important role to support plant growth through improving plant nutrition (uptake of N and P elements as well as micro-nutrients and water) as well as plant resistance and tolerance to abiotic and biotic stresses, such as drought and soil pathogens. This result is in line with Zulfikar et al. (2019) FMA is also able to increase the absorption of phosphorus and other nutrients such as N, K, Mg and Zn.

The results showed that AMF was effective in increasing nutrient uptake in four months old mycorrhizal plants (Pterocarpus indicus Willd.). Treatment of FMA G. cloroideum was effective in increasing nutrient K uptake and mixed FMA was effective in increasing P and Mn nutrient uptake. The results of this study are in line with Husna et al. (2021) AMF inoculation can improve the uptake of N, P, K and metals Mn and Fe from plants in post-gold mining conditions. This result is in line with Rosita et al. (2017) in post-mining land, nitrogen, phosphate and potassium are deficient and absorption by plants can be increased by the role of AMF.

In addition, mycorrhiza can reduce stress in post-mining land conditions with high, acidic, and dry environmental temperatures. FMA inoculation can increase plant biomass, plant height, nutrient uptake and nodulation in Angsana plants (Husna et al., 2018) and FMA can increase plant tolerance to the heavy metal Pb, increase Pb accumulation in roots, and inhibit Pb accumulation in stems and leaves. (Istiqomah et al., 2017). The results of this study are in line with Husna et al. (2021) that the Angsana plant has the consistency of vitality and high growth on the plastic house scale and on post-gold mining land at PT. Panca Logam Makmur, Bombana, Southeast Sulawesi. Based on the results of the research, Angsana can have a positive impact on growth and nutrient uptake in Angsana plants on the field scale of post-gold mining land (Lumba, 2020; Husna et al., 2021; 2020b; 2015a).

CONCLUSION

Based on the results of the research that has been done, it can be concluded that mixed AMF is effective in increasing nutrient levels and nutrient uptake in four-month-old Angsana (Pterocarpus indicus Willd.) plants in post-gold mining land. The best treatment on nutrient content, namely FMA type G. clarodeum, was effective in increasing levels of P and K nutrients. Meanwhile, the best treatment for nutrient uptake, namely mixed AMF type (G. claroideum + G. coronatum) was effective in increasing N and Mn nutrients.

REFERENCES

Aryanti, E., & Hera, N. (2019). Sifat kimia tanah area pascatambang emas: (studi kasus pertambangan tanpa izin di Kenegerian Kari Kecamatan Kuantan Tengah, Kabupaten Kuantan Singingi. Jurnal Agroteknologi, 9 (2), 21-26.

Baowei, L., Yongsheng, D., Xuefeng, Z., Mingdan, Z., & Hua, C. (2015). Crystallization characteristics and properties of high-performance glass-ceramics derived from Baiyunebo East mine tailing. Environmental Progress and Sustainable Energy, 34 (2), 420-226.

Borisovna, N.O., Naumov, V.A., Osevetskiv, B.M., Lunev, B.S., & Kovin, O.N. (2013). Nanoforms of secondary gold in the tailings wastes: Placers of is River, Russia. Middle-East Journal of Scientific Research, 18 (3), 316-320.

Fachlevi, A. T., Putri , E. I. K., & Simanjuntak, S. M. H. (2015). Dampak dan evaluasi kebijakan pertambangan batubara di Kecamatan Mereubo. Risalah kebijakan pertanian dan lingkungan, 2 (2), 171-180.

Gasperz, V. (1995). Teknik analisis dalam penelitian percobaan. Bandung: Tarcito.

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.

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. (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. (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. (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, Tuheteru, F.D., Arif, A., & Solomon (2019). 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, 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. (2021). Linggau: Kayu merah dari Indonesia Timur. Bogor: IPB Press.

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, 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, 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, Budi, S.W., Mansur, I., Kusmana, C., & Kramadibrata, K. (2014). Fungi mikoriza arbuskula pada rizosfer Pericopsis mooniana (Thw.) Thw. di Sulawesi Tenggara. Jurnal Berita Biologi, 13(3), 263-273.

Indriani, P. N., Mansur, I., Susilawati., & Islami, R. J. (2011). Peningkatan produktivitas tanaman pakan melalui pemberian fungi mikoriza arbuskular (FMA). Jurnal ilmu tumbuhan pakan ternak, 1 (1), 27-30.

Istiqomah, F. N., Budi, S.W., & Wulandari, A. S. (2017). Peran Fungi Mikoriza Arbuskula (FMA) dan asam humat terhadap pertumbuhan balsa (ochroma bicolor rowlee.) Pada tanah terkontaminasi timbal (Pb). Jurnal pengelolaan sumberdaya alam dan lingkungan, 7 (1), 72-78.

IUCN International Union for Conservation of Nature and Natural Resources. (2018). IUCN Red List of Threatened Spesies. Version 2018. 2. 3.

Lumba. M. C. D. (2020). Aplikasi fungi mikoriza arbuskula terhadap pertumbuhan jenis terancam punah angsana (Pterocarpus indicus Willd.) pada Lahan Pascatambang Emas Bombana, Sulawesi Tenggara, Skripsi Universitas Haluoleo, Kendari.

Ma, Y., Dickinson, N., & Wong, M. (2006). Beneffical effects of earthworms and Arbuscular Mychorrhizal Fungi on establishment of leguminose trees on Pb/Zn mine tailings. Soil Biol Biochem, 38 (6), 1403-1412.

Miransari, M. 2017. Arbuscular mycorrhizal fungi and beavy metal tolerance inplants.In : QS Wu (eds.) Spinger. Nature Spinger Pte Ltd.

Musfal. (2010). Potensi fungi mikoriza arbuskula untuk meningkatkan hasil tanaman jagung. Jurnal Litbang Pertanian, 4,1-5.

Neneng, L., & Saraswati, D. (2019). Reklamasi Lahan Kritis Bekas Penambangan Emas Menggunakan Metode Bioremediasi Dan Fitoremediasi. Enviro Scienteae, 15 (2), 216-225.

Neneng, L., Yushintha, T., & Saraswati, D. (2012). Aplikasi metode reklmasi terpadu untuk memperbaiki kondisi fisik, kimiawi, dan biologis pada lahan pasca penambangan emas Di Kalimantan Tengah. Prosiding Inhas, 81- 86.

Nugroho, H. (2020). Pandemi covid-19: tinjau ulang kebijakan mengenai PETI (Pertambangan Tanpa Izin) di Indonesia. Jurnal of development planning, 4 (2), 117-125.

Orlowska, E., Orlowski, D., Przybylowicz, J. M., & Turnau, K. (2011). Role of mycorrhizal colonization in plant establishment on an alkaline gold mine tailing. International Journal of Phyto remediation, 13, 185-205.

Pertiwi, & Dharma, H. (2011). Dampak Keberadaan Perusahaan Pertambangan Batubara Terhadap Aspek Ekologi, Sosial dan Ekonomi Masyarakat di Era Otonomi Daerah (Kasus: Kelurahan Sempaja Utara, Kecamatan Samarinda Utara, Kota Samarinda). Skripsi. Bogor: IPB.

Purwantari, N. D. (2007). Reklamasi area tailing di pertambangan dengan tanaman pakan ternak; Mungkinkah?.Wartazoa, 17 (3), 101-108.

Rafikasera, G. (2017). Pertumbuhan Bibit Angsana (Pterocarpus indicus Wild) dengan Aplikasi Fungi Mikoriza Arbuskula Lokal, Skripsi Universitas Haluoleo, Kendari.

Ruhnayat, A. (2007). Penentuan kebutuhan pokok unsur hara N, P, K untuk pertumbuhan tanaman panili (Vanilla planifolia Andrews.). Jurnal buletin penelitian tanaman rempah dan obat, 18 (1), 49 – 59.

Smith, S. E., & Read, D. J. (2008). Mycorrhizal symbiosis. Third ed. New York (US): Academic Press.

Tinker, P. B. 1976. Soil requirements of the oil palm.In R. H. V. Corley, J. J. Hardon, B. J. Wood (Ed.). Oil palm Research. Elsevier Scientific Publishing Company, 165-181.

Wang, F. (2017a). Occurrence of arbuscular mycorrhizal fungi in mining-impacted sites and their contribution to ecological restoration: Mechanisms and applications. Critical Reviews In Environmental Science And Technology, 1, 1-57.

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

Zulfikar., Eliyani., & Nazari, A.P.D. (2019). Aplikasi mikoriza pada tanah lahan reklamasi tambang batu bara terhadap pertumbuhan dan hasil tanaman kedelai (Glycine max L.Merrill). Jurnal ilmu pertanian dan kehutanan, 18 (2), 1-10