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The Influence of Arbuscular Mycorrhizal Fungi (FMA) Dosage and Yomari Liquid Organic Fertilizer on the Growth of Seedlings of Agarwood-Producing Plants (Aquilaria malacensis Lamk.) on Former Gold Mining Soil"

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Abstract**—***Former gold mining land exhibits poor soil fertility, both biologically, chemically, and physically due to the damaging effects of the mining process on the land. Marginal land conditions, like former gold mining areas, necessitate high-viability seedlings. Efforts to acquire quality seeds and boost the productivity of this land involve planting adaptable and high-quality plant seeds, such as the agarwood-producing plant (Aquilaria malaccensis Lamk.). This plant is among the adaptive non-timber forest products that grow and naturally produce without inoculation (injection) on ex-mining lands—gold, nickel, rocky sand, tin, and coal—supplemented with liquid organic fertilizers like Yomari and Arbuscular Mycorrhizal Fungi (AMF) on Aquilaria malaccensis Lamk plants. Yomari liquid organic fertilizer, with its high organic and nutrient content, can enhance soil organisms, improve soil pH, while AMF can promote root growth and expansion, aiding roots in water and nutrient absorption through their external hyphae. Consequently, this facilitates the production of numerous and robust roots. This research aims to determine the optimal interaction between AMF doses and Yomari Liquid Organic Fertilizer for the growth of Aquilaria malaccensis Lamk seedlings in former gold mining land. Additionally, it seeks to ascertain the impact of administering the best Yomari organic fertilizer dosage and the best AMF dosage on the growth of Aquilaria malaccensis Lamk on ex-gold mining land. This research was conducted from June to November 2022 in the nursery of the Faculty of Agriculture, Andalas University. Employing a factorial experimental method in a Completely Randomized Design (CRD) with two factors—firstly, the AMF dose consisting of four levels: 10 grams (F1), 20 grams (F2), 30 grams (F3), and 40 grams (F4), and secondly, the Yomari organic fertilizer dosage comprising five levels: 0 ml (Y0), 0.75 ml/l (Y1), 1.5 ml/l (Y2), 2.25 ml/l (Y3), and 3.0 ml/l (Y4)—each treatment level comprised four replications. Qualitative and quantitative observation data were analyzed using the F-test at a 5% level of significance. Post-hoc analysis for differences among treatments was conducted using the BNT test at the 5% level. Observations included the percentage of live seeds, seed height increment, leaf number, widest leaf width, root weight, and percentage of roots infected by AMF in ex-gold mining soil media inoculated with Acaulospora sp. and Gigaspora sp. The administration of 40 grams of FMA with a dose of 3.00 ml/l of liquid organic fertilizer showed an increase in the percentage of survival, an increase in the number of leaves, an increase in the height of the plant seedlings, the widest leaf width, the percentage of root weight, and the seedlings of agarwood-producing plants infected with AMF.*

***Keywords*— Gold Mining Land, Aquilaria malaccensis Lamk, Liquid Organic Fertilizer, Arbuscular Mycorrhizal Fungi (AMF), Ex-Gold Mining Soil Media**

I. INTRODUCTION

The rehabilitation of former Gold mining areas generally requires high-quality seedlings. However, these seedlings often experience significant mortality after being planted in the field due to insufficient availability of nutrients and water for growth and development. This is a result of plants having few, shallow, weak, and damaged roots (Sari, 2018; Intan, Sutoyo, and Satria, 2019, and Kimi, Sutoyo, and Satria, 2021). The root issues can be addressed by using liquid organic fertilizers such as Yomari fertilizer and Arbuscular Mycorrhizal Fungi (AMF) at specific doses. Yomari organic liquid fertilizer functions to enhance the development of soil organisms, increase soil pH, stimulate vegetative plant growth, play a role in the formation of green leaf substances, and promote stronger and more numerous plant roots. Soaking coffee cuttings in 1 ml/l Yomari organic liquid fertilizer and spraying the cuttings three times at a dose of 1 ml/l within 10 days will result in numerous shoot cuttings with many strong roots (Satria et al., 2021). The presence of AMF can improve the availability of nutrients, especially phosphorus (P), which is usually low in former Gold mining soil. This improves soil structure, enhances water absorption, and protects plants from root pathogens and toxic elements. Inoculating 40 grams of AMF in ultisol and in planting media from former Gold mining soil can enhance the growth of seedlings of Aquilaria malacensis Lamk., especially those with high AMF infection and more extensive roots (Satria and Raesi, 2021; Kimi et al., 2021, and Satria, Fadli, Herawati, and Aprisal, 2021).

This plant has great potential for development in former mining areas, considering it is an adaptive non-wood forest product that naturally grows and produces on former mining lands such as nickel, sandy gravel, tin, and coal (Sari, 2018; Intan et al., 2019, and Kimi et al., 2021). In connection with the above explanation, the researcher is interested in conducting a study with the title "The Influence of Yomari Liquid Organic Fertilizer and AMF (Arbuscular Mycorrhizal Fungi) Doses on the Growth of Agarwood-Producing Plant Seedlings (Aquilaria malacensis Lamk.) in Former Gold Mining Soil."This research is conducted to address several formulated problems in the following questions: 1. Is there an interaction between AMF dose and Yomari organic fertilizer on the growth of agarwood-producing plant seedlings (Aquilaria malacensis Lamk.) in former Gold mining soil? 2. What is the effect of Yomari organic fertilizer dose on the growth of these seedlings in former Gold mining soil? 3. What is the effect of AMF dose on the growth of these seedlings in former Gold mining soil?

The long-term goal of this research is to obtain naturally produced Aquilaria malacensis Lamk. (without inoculation) and improve the productivity of former Gold mining soil. The specific objectives of this research are: 1. To determine the best interaction between Yomari organic fertilizer dose and AMF dose for the growth of agarwood-producing plant seedlings (Aquilaria malacensis Lamk.) in former Gold mining soil. 2. To determine the effect of the best Yomari organic fertilizer dose on the growth of these seedlings in former Gold mining soil. 3. To determine the effect of the best AMF dose on the growth of these seedlings in former Gold mining soil.

This research is expected to provide information about agarwood-producing plant seedlings (Aquilaria malacensis Lamk.) that can associate well with Yomari organic fertilizer and AMF doses and are compatible for planting in former Gold mining areas. The results of this research are expected to contribute to the development of plant science, especially plant breeding. Contributions include: 1. Providing information on the standard method of AMF Doses and Yomari Liquid Organic Fertilizer on the Growth of Agarwood-Producing Plant Seedlings (Aquilaria malacensis Lamk.) in Former Gold Mining Soil. 2. Making a positive contribution to the development of science and technology in agarwood cultivation (Aquilaria malacensis) and serving as a reference for adaptation and preservation of its germplasm.

II. METHODS

The research will be conducted in the experimental farm of the Faculty of Agriculture, Andalas University. The planned duration of the study is 6 months, starting from May 2023 to November 2023.

The tools utilized in this research include a hoe, bucket, polybags, scissors, hotplate, ruler, digital scale, meter, writing tools, tweezers, scissors, cover glass, hose, tea strainer, object glass, camera, and microscope. The materials employed consist of seedlings of agarwood-producing plants, Aquilaria malaccensis Lamk species, former Gold mining soil, ultisol, compost, Yomari liquid organic fertilizer, Arbuscular Mycorrhizal Fungi (including Acaulospora sp., Gigaspora sp., and a combination of Acaulospora sp. with Gigaspora sp.), NPK fertilizer, Curater 3 G, Aquadest, KOH 10%, HCl 2%, Trypan blue for root staining, and clean water.

This study adopts a factorial experiment method within a Completely Randomized Design (CRD) with two factors. The first factor involves the dosage of AMF with 4 levels: 10 grams (F1), 20 grams (F2), 30 grams (F3), and 40 grams (F4). The second factor includes the dosage of Yomari organic fertilizer with 5 levels: 0 ml (Y0), 0.75 ml/l (Y1), 1.5 ml/l (Y2), 2.25 ml/l (Y3), and 3.0 ml/l (Y4). Each treatment level consists of 4 replications. The observational data, both qualitative and quantitative, will be analyzed using an F-test at a significance level of 5%. Differential effects on treatments will be further analyzed using the Tukey's Honestly Significant Difference (HSD) test at a 5% significance level

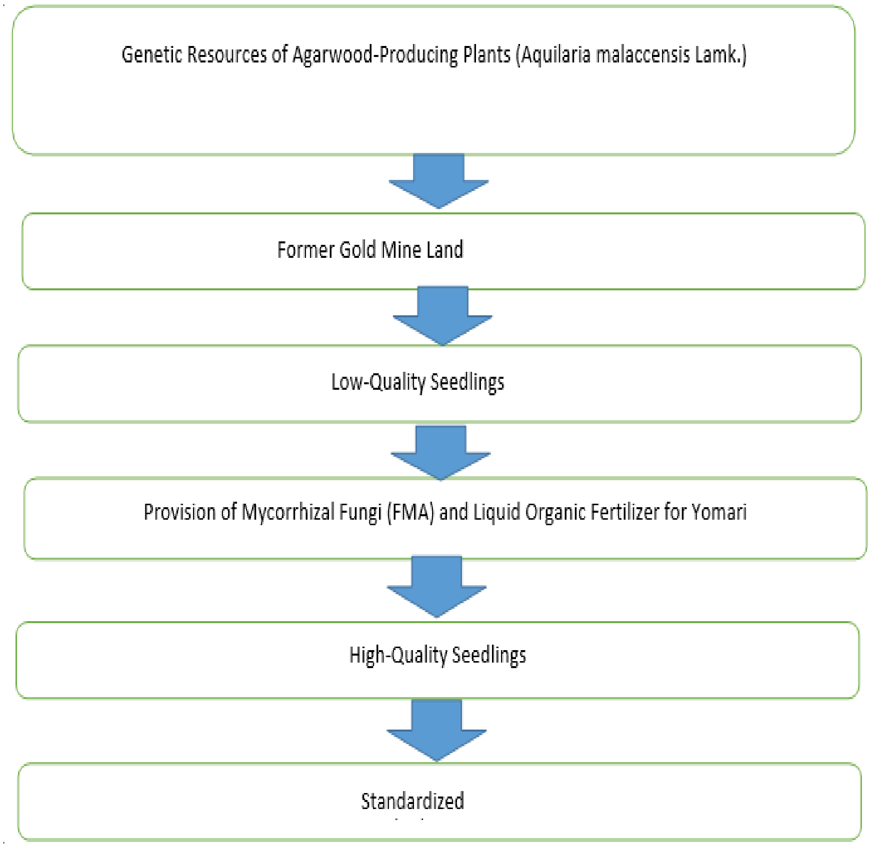

Fig.2. Flowchart of the Study: The Effect of the Application of FMA Doses and Yomari Liquid Organic Fertilizer on the Growth of Gaharu-Producing Plant Seedlings (Aquilaria malacensis Lamk.) on Former Gold Mining Soil

Seedlings of Aquilaria malaccensis Lamk, the agarwood-producing plant species, are sourced from the Gaharu farmer group in Kanagarian Muaro Linggae, Sijunjung Regency. These seedlings are initially prepared in polybags measuring 8 cm x 9 cm. When the research is set to begin, the plants are transplanted into larger polybags, sized 12 cm x 17 cm. The seedlings meet specific criteria, including being free from pests and diseases, having a height ranging from 5-15 cm, and possessing 2-5 leaves.

The soil used is a mixture of former Gold mining soil from Dharmasraya Regency and Ultisol obtained from the experimental farm of the Faculty of Agriculture, Andalas University. The soil is evenly processed, and the planting medium is filled into polybags measuring 12 cm x 17 cm. Seedlings are then transferred from the previously mentioned polybags, which already contain the planting medium (a mixture of former Gold mining soil and Ultisol). Before planting, the seedlings, which have been immersed for 15 minutes in Yomari liquid organic fertilizer solution (according to the treatment), are inserted into the planting hole where their roots come into contact with FMA (according to the treatment) in the planting medium. The hole is then covered with the soil within the polybag.

The FMA used is a combination of Acaulospora sp. and Gigaspora sp. The FMA is weighed according to the treatment doses (10, 20, 30, and 40 grams per polybag) using a digital scale, following the research by

Nurmasyitah *et al*., (2013), and Satria et al., (2021), which states that the application of 40 grams of FMA is the optimal dose. FMA treatment is applied by sprinkling it into the planting hole, then placing the pre-soaked seedlings into the hole and covering it again with the soil in the polybag. Starting two weeks after planting, the seedlings are sprayed with POC fertilizer according to the treatment doses (0, 0.75, 1.5, 2.25, and 3 ml/liter), with additional spraying at 8 weeks after planting.

Gaharu seedlings are watered in the morning and evening to maintain soil moisture in the polybag, using a hose for watering. After the study, it was found that the percentage of surviving seedlings was 100%, indicating that replanting was unnecessary.

Weeding is done when weeds appear inside or around the polybag, with weeding performed every 2 weeks. Weeding involves manually pulling out the weeds. Root pruning is done to trim roots growing outside the polybag, preventing the roots from spreading beyond the polybag. Pruning is carried out using cutting tools such as scissors. According to Rusmana (2014), root pruning encourages lateral root growth within the polybag and reduces stress during transportation. The illustration of seedling root pruning can be seen in Figure 2. After the study, no weeds were found growing outside the polybag.

Observations on the survival of seedlings during the study can be calculated at the end of the observation period (16 weeks after FMA inoculation). The percentage of surviving seedlings is calculated as follows: Measurements of plant height increment were conducted starting from the inoculation of FMA to the seedlings. These measurements were performed once a week until the end of the observation period (16 weeks after FMA inoculation). Plant height was measured from the base of the lower stem to the tip of the upper stem using a measuring tape.

Observations on the number of leaves were initiated after FMA inoculation to the seedlings. These observations were conducted once a week until the end of the observation period (16 weeks after FMA inoculation). The observed leaves were those that had fully opened and remained on the plant during the observation. Measurements of the widest leaf width were conducted weekly starting from FMA inoculation to the seedlings until the end of the observation period (16 weeks after FMA inoculation). The leaves measured were those that had fully opened. The measurement of the widest leaf width was carried out by measuring all the leaves on the agarwood seedlings using a measuring tape, then marking the leaves with the widest width for further observation.

Observations on roots emerging from the polybag during the implementation of the agarwood seedling study were conducted from week 1 to week 16, and no roots were found outside the polybag. After the observations, it was confirmed that there were no roots emerging from the polybag. Observations on the weight of the roots of agarwood-producing plant seedlings in each treatment were conducted at the end of the experiment (16 weeks after FMA inoculation),

Using a scale, observations of root weight were conducted by tearing the polybag, then loosening the planting medium in a bucket containing water while rinsing until the roots were clean. After cleaning the root samples, the roots were dried, and then the weighing of the roots was carried out.

Observations of FMA infection on the roots of agarwood-producing plants were conducted at the end of the observation period (16 weeks after FMA inoculation) by taking root samples. The observation of the percentage of FMA-infected roots was conducted at the Plant Physiology Laboratory, Andalas University, after field observations were completed. The percentage of FMA-infected roots can be calculated as follows:

The roots were thoroughly cleaned using distilled water (aquadest). After cleaning, the roots were immersed in a 10% KOH solution. The KOH immersion aims to release oxygen from the cell walls for 2 days (48 hours). Once the immersion is complete, the roots were rinsed again using distilled water 3-5 times, with the assistance of a tea strainer as a container. Subsequently, the roots were soaked in a 2% HCl solution to soften the cell walls for 2 days (48 hours), followed by immersion in a trypan blue solution for another 2 days (48 hours). Trypan blue is utilized for root staining.

Next, the plant roots were cut using a knife to a length of 1 cm, with 5 pieces taken from each treatment and 3 replications. The glass slides were cleaned using 95% alcohol, and the cut roots were placed on the glass slides and covered with a cover glass. Each sample was labeled on the glass slide. Each prepared sample was observed under a microscope at a magnification of 400X. Root infection could be determined by the presence of hyphae, vesicles, and arbuscules

III. RESULT AND DISCUSSIONS

1. Percentage of Life of Agarwood-Producing Plant Seeds

Based on the analysis of variance, it is indicated that there is an interaction between the dosage of FMA and the dosage of POC concerning the percentage of live agarwood-producing plant seedlings. The average percentage of live agarwood-producing plant seedlings can be observed in Table 1.

Table 1. Percentage of Life of Agarwood-Producing Plant Seeds due to AMF and LOF treatment at 16 weeksay of age

Dosis FMA (g)	Dosis POC (ml/l)				
	0,00	**0,75**	**1,50**	**2,25**	**3,00**
10	32,50 B c	37,50 C c	55,00 B b	62,50 B b	80,00 B b
20	37,50 AB d	42,00 BC cd	50,00 B c	62,50 B b	75,50 B a
30	37,50 AB d	52,50 B c	55,00 B c	67,50 B b	85,00 B a
40	42,50 A d	62,00 A c	75,00 A b	90,00 A a	97,50 A a
KK = 9,13%					

Note: The numbers followed by the same uppercase letter in the same row and the numbers followed by the same lowercase letter in the same column are not significantly different ccording to the LSD 5%.

Based on Table 1, it can be observed that there is a significant interaction between the dosage of FMA and the dosage of POC regarding the percentage of live agarwood-producing plant seedlings. The application of 10 g of FMA has a similar effect on the percentage of live seedlings when combined with POC dosages of 0 ml, 1.50 ml, 2.25 ml, and 3 ml. Similarly, the application of 20 g of FMA has a consistent effect on the percentage of live seedlings with POC dosages of 1.50 ml, 2.25 ml, and 3 ml. The application of 30 g of FMA shows a similar effect on the percentage of live seedlings with POC dosages of 0.75 ml, 1.50 ml, 2.25 ml, and 3 ml. Lastly, the application of 40 g of FMA exhibits a uniform impact on the percentage of live seedlings across all POC dosage applications.

The results of the research depict the complexity of the interaction between FMA and POC in influencing the growth of agarwood plants in former gold mining areas. The use of liquid organic fertilizer and mycorrhiza can have a positive impact on the growth of agarwood plants in former gold mining areas. Liquid organic fertilizer provides the necessary nutrients for plants, while mycorrhiza helps enhance nutrient absorption and improve soil structure. The combination of both can increase plant resilience to less fertile conditions, such as former gold mining areas, and enhance agarwood plant productivity. Perez and Urcelay (2009) stated that FMA can improve the height growth of specific host plants that are compatible with FMA. Different FMA types can have different effects on different host plants. FMA is a biological fertilizer that only needs to be infected into its host plants once because it is a living organism that can continue to grow and develop (Setiadi and Setiawan, 2011).

Table 1 also indicates that the application of 0 ml POC has a similar effect on the percentage of live seedlings with the application of 20 g, 30 g, and 40 g FMA. The application of 0.75 ml POC has a consistent effect on the percentage of live seedlings with the application of 10 g, 30 g, and 40 g FMA. The application of 1.5 ml POC has a similar effect on the percentage of live seedlings with the application of 10 g and 40 g FMA. The application of 2.25 ml POC yields the highest percentage of live seedlings with the application of 40 g FMA. Lastly, the application of 3 ml POC has a similar effect on the percentage of live seedlings with the application of 20 g, 30 g, and 40 g FMA.

POC can help improve soil structure in former gold mining areas, which may have less than ideal soil textures. Well-structured soil can facilitate the movement of water and air, as well as improve plant access to nutrients. Liquid organic fertilizer can also help increase the soil's capacity to retain water, which is crucial, especially in former gold mining areas that may have water retention issues. Soil that can retain water effectively can help agarwood plants thrive in unstable environmental conditions.

POC can provide essential nutrients for agarwood plants in former gold mining areas through organic substances. POC contains organic substances such as humic acid and fulvic acid. These substances can help increase the availability of nutrients in the soil by enhancing ion exchange and binding available nutrients. Additionally, liquid organic fertilizer also contains microorganisms such as bacteria and fungi that are beneficial to plants. These microorganisms help break down organic matter in the soil into forms that are more easily absorbed by plant roots. Liquid organic fertilizer can also stimulate the growth of soil microbes, which play a role in breaking down organic matter and releasing trapped nutrients. This can enhance nutrient availability for plants.

2. Increase in the number of leaves of agarwood producing plant seeds

Based on the analysis of variance, there is an interaction between the application of FMA dosage and POC dosage concerning the increase in the number of leaves on agarwood plant seedlings. The increase in the number of leaves on agarwood plant seedlings can be observed in Table 2.

Table 2. Increase in the number of leaves of agarwood-producing plant seeds Due to AMF and LOF treatment at the age of after 16 weeksof seedlings

Dosis FMA (g)	**Dosis POC (ml/l)**				
	0,00	**0,75**	**1,50**	**2,25**	**3,00**
10	3,25 A d	4,00 B cd	4,75 B c	6,00 B b	7,00 C a
20	3,50 A d	4,25 AB cd	5,00 AB c	6,50 BC b	7,50 B a
30	3,75 A c	4,75 AB b	5,25 AB c	7,25 AB a	7,75 B a
40	3,75 A c	5,00 A c	5,75 A b	8,00 A a	10,25 A a
KK = 10,99%					

Note: The numbers followed by the same uppercase letter in the same row and the numbers followed by the same lowercase letter in the same column are not significantly different ccording to theLSD 5%.

Based on Table 2, it can be observed that there is a significant interaction between the dosage of FMA (Arbuscular Mycorrhizal Fungi) and the dosage of POC (Liquid Organic Fertilizer) regarding the increase in the number of leaves on agarwood-producing plants. The application of 10 g, 20 g, and 30 g of FMA results in the highest increase in the number of leaves when combined with a POC dosage of 3 ml. The application of 40 g of FMA has a similar effect on the increase in the number of leaves across all POC dosage applications. Table 2 also shows that the application of 0 ml POC has a similar effect on the increase in the number of leaves with the application of 30 g and 40 g of FMA. The application of 0.75 ml and 1.50 ml POC results in the highest increase in the number of leaves with the application of 40 g of FMA. The application of 2.25 ml POC has a similar effect on the highest increase in the number of leaves with the application of 30 g and 40 g of FMA. The application of 3 ml POC has a similar effect on the increase in the number of leaves across applications 40 g of FMA dosage.

The significant interaction between the application of FMA (Arbuscular Mycorrhizal Fungi) dosage and POC (Liquid Organic Fertilizer) dosage regarding the increase in the number of leaves on agarwood-producing plants is due to the mechanisms involving both in enhancing the health and growth of plants. This includes a symbiotic mutualistic interaction between FMA and plant roots. FMA forms a symbiotic mutualistic relationship with plant roots. The mycorrhiza (fungus) on FMA forms structures such as mycelium that reach into the soil and create root-like structures, enhancing nutrient absorption by plants.

In this relationship, plant roots provide carbohydrates from photosynthesis to FMA, while FMA assists plants in nutrient absorption, especially phosphorus. Liquid Organic Fertilizer (POC) as an Additional Nutrient Source. POC contains organic substances, nutrients, and microorganisms that can increase nutrient availability in the soil. Additional nutrients from POC can strengthen the symbiotic relationship between FMA and plants by providing the resources needed for the growth of mycorrhiza and plants. Optimization of Phosphorus Availability.

FMA plays a critical role in increasing phosphorus uptake by plants. Phosphorus is crucial for leaf formation and overall plant growth. The application of FMA dosage can improve phosphorus uptake efficiency, especially at specific dosages. Specific Dose Interaction. The research results show that FMA dosages of 10 g, 20 g, and 30 g result in the highest increase in the number of leaves at a POC dosage of 3 ml. This may reflect an optimal point where the interaction between FMA and POC achieves maximum results.

The interaction between FMA and POC creates a synergistic effect, where the combination of both provides better results than the application of each separately. Thus, through the synergy of increased nutrient absorption through FMA and the provision of additional nutrients from POC, this interaction can significantly enhance the growth of agarwood plants, especially in terms of the increase in the number of leaves(Satria *et al*., 2022). The specific dose factors of each component also provide an additional dimension that needs to be considered in managing agarwood cultivation in former gold mining areas. The percentage of live seeds is influenced by various biotic and abiotic factors. Biotic factors such as seed quality, plant seeds used from both species came from healthy seeds. The characteristics of healthy plants are that they have green leaves and stems, the seeds are not diseased, the stems are straight, which is in accordance with the Indonesian national standard (SNI) 01-5006.1-2006 regarding seed quality which states that healthy seeds are fresh seeds. that are not attacked by pests and diseases, and do not show symptoms of nutrient deficiency (stems are notstraight and pale yellow in color). The high percentage value of live seedlings Aquilaria malacensis seedlings had the best growth response to the AMF dose treatment with the highest LOF concentration.

3. Agarwood-producing Plant Seed Height Increase

Based on the analysis of variance, the seedling height of agarwood-producing plants indicates that there is no interaction between the dosage of FMA (Arbuscular Mycorrhizal Fungi) and the dosage of POC (Liquid Organic Fertilizer). Individually, both types of FMA and POC dosage have a significant effect. The data can be seen in Table 3.

Table 3. Plant Seed Height Increase due to AMF and LOF treatment at seedling age of after 16 weeks

Dosis FMA (g)	**Dosis POC (ml/l)**					**Rata-Rata**
	0,00	**0,75**	**1,50**	**2,25**	**3,00**	
10	15,0	22,5	27,5	30,0	35,0	26,00 c
20	17,5	25,0	30,0	35,0	45,0	30,50 b
30	17,5	27,5	30,0	35,0	45,0	31,00 b
40	20,0	30,0	35,0	40,0	57,5	36,50 a
Rata-Rata	17,50 E	26,25 D	30,62 C	35,00 B	45,62 A	
KK = 18,86%						

Note: The numbers followed by the same uppercase letter in the same row and the numbers followed by the same lowercase letter in the same column are not significantly different ccording to theLSD 5%.

Based on Table 3, FMA with a dosage of 40 g provides an average seedling height for agarwood-producing plants that is higher than other dosages, reaching 36.50 cm. POC dosage also has a significant effect on the seedling height of agarwood-producing plants. The average results show that a POC dosage of 3 ml reaches 45.62 cm. The occurrence of separate mechanisms between FMA and POC, where both contribute independently to plant growth.

FMA can influence nutrient absorption through a symbiotic relationship with plant roots, while POC can directly provide additional nutrients to the soil(Satria *et al*., 2022). The absence of interaction between the application of POC (Liquid Organic Fertilizer) and FMA (Arbuscular Mycorrhizal Fungi) on the height of agarwood seedlings can be influenced by several factors, including the existence of Separate Mechanisms (Independent Actions) between the application of POC and FMA. FMA enhances nutrient absorption and improves the condition of plant roots, while POC provides additional nutrients and improves soil structure.

The same impact on seedling height. Factors such as nutrient availability, water absorption, and improved plant health may have a similar impact on the height of agarwood seedlings without depending on each other. Both factors may have a positive additive contribution, but they do not modify or enhance each other's effects. Optimal Conditions Without Dependency. In situations where the dosage of POC and FMA has reached its optimal conditions, no additional improvement can be achieved through the interaction between the two. POC and FMA dosages have already provided an optimal level of nutrition and soil support for the growth of agarwood plants. Linear or Saturated Response. The addition of POC or FMA dosages has reached a level where plants respond linearly or even reach a saturation point, where further addition does not provide additional increases in seedling height. This is because this is because the higher the dose of LOF given and the higher the dose of AMF given to agarwood-producing plants, the higher the growth of agarwood-producing plant seeds. In addition, this plant is able to utilize N2 in the air, and the organic matter produced by this plant is rich in N nutrients (Kimi *et al.*,2020 and Satria *et al*, 2022)).

4. *Widest Leaf Width of Agarwood Seedlings*

Based on the analysis of variance, it is evident that there is an interaction between the treatment doses of FMA and POC on the longest leaf length of seedlings from agarwood-producing plants. The longest leaf length of seedlings from agarwood-producing plants can be observed in Table 4.

Table 4. Widest Leaf Width of Agarwood-Producing Plant Seeds due to AMF and LOF treatment at 16 weeks of seedling

Dosis FMA (g)	**Dosis POC (ml/l)**				
	0,00	**0,75**	**1,50**	**2,25**	**3,00**
10	4,7500 B d	5,6250 B c	6,1250 C bc	6,5000 B b	7,4750 C a
20	5,0250 AB c	6,2500 AB b	6,5500 BC b	6,7500 B b	8,0000 C a
30	5,2500 AB c	6,4750 A b	6,9500 AB b	6,9750 B b	9,1250 B a
40	5,5750 A d	6,7250 A c	7,3700 A bc	7,7500 A b	10,3750 A a
KK = 6,99%					

Note: The numbers followed by the same uppercase letter in the same row and the numbers followed by the same lowercase letter in the same column are not significantly different ccording to theLSD 5%.

Table 4 also indicates that the application of POC dosages 0 ml, 0.75 ml, and 1.5 ml has the same effect on the percentage of live seedlings with the application of FMA dosages of 10 g and 40 g. The application of POC dosages 2.25 ml and 3 ml has the same effect on the longest leaf length in all FMA dosage applications. The research results indicate a significant interaction between FMA and POC dosages on the longest leaf length of agarwood-producing plants. A dosage of FMA 10 g may have reached its optimal limit for the application of POC dosages of 1.50 ml and 3 ml, while higher FMA dosages of 40 g are needed to see an improvement with POC dosage of 3 ml.

The simultaneous application of FMA and POC can support the growth of agarwood leaf length by increasing nutrient availability, activating plant hormones, and improving soil quality. In this context, the interaction between FMA and POC dosages plays a crucial role in optimizing the plant's response to the given treatments (Satria et al.,2022). The higher the dose of AMF given to the producing lant, the wider the width of the widest leaf of agarwood- producing plant seeds. In addition, this plant is able to

utilize N2 in the air, and the organic matter produced by this plant is rich in N nutrients (Kimi *et al*.,2020)

4. Longest Leaf Length

Based on the analysis of variance, it is indicated that there is an interaction between the treatment of FMA dosage and POC dosage on the widest leaf width of agarwood-producing plant seedlings. The average widest leaf width of agarwood-producing plant seedlings can be seen in Table 5.

Table 5. Longest Leaf Lengh of Agarwood-Producing Plant Seeds due to AMF and LOF treatment at 16 weeks of seedling

Dosis FMA (g)	**Dosis POC (ml/l)**				
	0,00	**0,75**	**1,50**	**2,25**	**3,00**
10	1,9250 A d	2,2250 A c	2,3500 B bc	2,5500 A b	2,8500 C a
20	1,9000 A d	2,3250 A c	2,7500 A b	2,6500 A b	3,0500 BC a
30	2,0000 A d	2,3000 A c	2,5500 AB b	2,6250 A b	3,0750 B a
40	2,0750 A d	2,4000 A c	2,5750 A bc	2,7250 A b	3,4250 A a
KK = 5,84					

Note: The numbers followed by the same uppercase letter in the same row and the numbers followed by the same lowercase letter in the same column are not significantly different ccording to theLSD 5%.

Based on Table 5, it can be observed that there is a significant interaction between the dosage of FMA and POC on the widest leaf width of agarwood-producing plants. The application of FMA dosages of 10 g, 20 g, 30 and 40 g resulted in an increase in the widest leaf width when combined with a POC dosage of 3 ml. The application of FMA dosage of 40 g had the same effect on the widest leaf width for all POC dosages. Table 5 also indicates that the application of POC dosages of 0 ml, 0.75 ml, 2.25 ml, and 3 ml had the same effect on the widest leaf width for all FMA dosages. Meanwhile, the application of POC dosage of 1.50 ml had the same effect on the widest leaf width for the application of FMA dosages of 20 g and 30 g.

The positive interaction between the application of Arbuscular Mycorrhizal Fungi (FMA) and Liquid Organic Fertilizer (POC) affecting the growth of agarwood leaf width can be explained through several mechanisms related to increased nutrient availability, increased soil microbial activity, and soil condition improvement. FMA forms a symbiotic relationship with plant roots, creating arbuscular mycorrhizal mycelium structures that can enhance the absorption of nutrients, especially nutrients that are less soluble in water, such as phosphorus and other minerals. POC, as a liquid organic fertilizer, can provide organic nutrients that are more easily accessible to plants. The combination of increased mineral absorption by FMA and the provision of organic nutrients by POC provides better nutritional support for the growth of agarwood leaves(Satria *et al*., 2021 and Satria *et al*., 2022). POC provides sources of organic nutrients that support the growth and activity of soil microbes. This microbial activity plays a crucial role in breaking down organic matter into forms that can be used by plants. Increased microbial activity can enhance the circulation of nutrients in the soil, which in turn supports plant growth, including leaf width. Hormone stimulation can also influence leaf width growth. FMA can stimulate the production of plant hormones, which can affect the growth and development of leaves(Intan *et al*., 2019). The combination with POC may provide additional support in triggering plant hormone responses leading to broader leaf growth.

6. *Root Weight of Agarwood-Producing Plant Seedlings*

The analysis of variance results indicates that there is an interaction between the AMF treatment and the POC treatment on the root weight of agarwood-producing plant seedlings (Appendix 4 and Table 3). The best response is shown in the treatment of 40 grams of AMF with a POC treatment of 3.00 ml, which is significantly different from other treatments at 3 months after planting (MAP).

Table 6. Root Weight of Agarwood-Producing Plant Seedlings due to AMF and POC Treatment at 16 Weeks After Planting (WAP).

Dosis FMA (g)	**Dosis POC (ml)**				
	0	**0,75**	**1,50**	**2,25**	**3,00**
			--------------------g--------------------		
10	11.3000 c C	12.3175 b B	12.9925 c B	13.1600 c AB	13.8675 c A
20	12.2325 b C	13.0750 b BC	13.5550 c AB	13.7150 c AB	13.9900 c A
30	13.0275 b D	14.1000 a C	15.1225 b B	15.8875 b B	19.2300 b A
40	14.3925 a C	15.8600 a C	16.8500 a B	17.5800 a B	24.6975 a A
KK = 4.12%					

The higher the dose of AMF (Arbuscular Mycorrhizal Fungi) and the higher the concentration of POC (Yomari Liquid Organic Fertilizer) given to agarwood-producing plants, the higher the root weight of agarwood-producing plant seedlings. Nitrogen is crucial for the formation and growth of vegertative parts of plants such as leaves, stems and roots. Meanwhile, phosphorus can help enhance lant growth, produce chlorophyll, increase protein levels, and accelerate leaf growth (Satria *et al*., 2021 and Satria *et al.*, 2022).

7. Percentage of Roots of Agarwood-Producing Plant Seedlings Infected with AMF

The analysis of variance results show that there is an interaction between the AMF (Arbuscular Mycorrhizal Fungi) treatment and the POC (Yomari Liquid Organic Fertilizer) treatment on the widest leaf width of agarwood-producing plant seedlings (Appendix 4 and Table 3). The best response is shown in the treatment of 40 g AMF dosage with 3.00 ml POC treatment, which significantly differs from other treatments at 16 weeks after planting (MAP). This may be due to the mycorrhizal fungi with the AMF dosage and POC concentration being able to thrive in a planting medium dominated by sandy soil with larger soil pores compared to clayey soil. This condition is believed to be suitable for the development of larger AMF spores, capable of infecting plant roots (Kimi *et al*., 2020; and Asmaraman *et al*., 2018).

Table 7. Percentage of Roots of Agarwood-Producing Plant Seedlings Infected with AMF due to AMF and POC treatments at 16 Weeks After Planting (WAP).

Dosis FMA (g)	**Dosis POC (ml)**				
	0	**0,75**	**1,50**	**2,25**	**3.00**
			-------------------- % --------------------		
10	17.5000 a D	19.0000 a C	20.0000 a C	23.0000 a B	25.0000 a A
20	32.7500 b E	34.5000 b D	36.2500 b C	38.2500 b B	44.2500 b A
30	36.0000 b E	43.5000 c D	46.5000 c C	51.5000 c B	58.0000 c A
40	57.5000 c E	62.5000 d D	65.7500 d C	85.7500 d B	95.5000 d A
KK = 1.85%					

Note: Numbers followed by the same uppercase letter in the same row and numbers followed by the same lowercase letter in the same column are not significantly different according to the LSD.

According to Brundrett (1996), mycorrhiza is a form of mutualistic symbiotic relationship between fungi and plant roots, where both symbionts benefit from each other. Arbuscular mycorrhizae (CMA) are considered obligate symbionts, meaning that CMA can function only after infecting the host plant. CMA can infect the root system of the host plant, as depicted in Figure 1, and subsequently produce an extensive network of hyphae. This mycorrhizal association enables the plant to enhance its capacity for nutrient absorption from both organic liquid fertilizer (POC) and water (Satria *et al*., 2022).

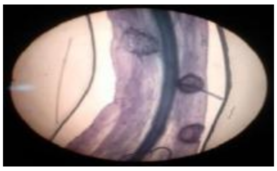

Fig.1. Form of roots infected by Arbuscular Mycorrhizae (CMA) as viewed under a microscope at 400X magnification.

The colonization increase by Arbuscular Mycorrhizae (CMA) begins with the formation of an appressorium. The appressorium is a crucial structure in the life cycle of CMA, representing a key event for a successful interaction with the potential host plant. Subsequently, the contact phase is followed by the symbiotic phase. From that phase onward, the fungus perfects the complex morphogenetic process by producing intercellular and intracellular hyphae, vesicles, and arbuscules. The main structures of CMA are arbuscules, vesicles, external hyphae, and spores (Dewi, 2007). According to Sufaati *et al*., (2011), arbuscules are hyphal structures originating from branching hyphae inside the cortex cells of the host plant's roots. Arbuscules have a small tree-like appearance and function as sites for the exchange of primary metabolites (especially glucose and phosphorus) between the fungus and plant roots. The distribution of external hyphae is influenced by biotic and abiotic factors such as soil chemical and physical properties, organic matter, and microflora and microfauna present in the soil as the growing medium (Trisilawati *et al*., 2012).

IV. CONCLUSION

Based on the results of the above research, it can be concluded that: 1. there is an interaction between the administration of AMF doses and the concentration of liquid organic fertilizer on the growth of seedlings of agarwood-producing plants (Aquilaria malacensis Lamk.) on former gold mining soil, and 2. Administration of 40 grams of AMF with a concentration of 3.00 ml/l of liquid organic fertilizer is the most effective in increasing the percentage of survival, the number of leaves, the height of seedlings, the widest leaf width, and the percentage of agarwood-producing plant seedlings infected with CMA.

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