

The Effect of Different Dosages of Arbuscular Mycorrhizal Fungi on the Growth of Oil Palm (*Elaeis guineensis* Jacq) Seedlings in the CV. Gotama Nursery

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ABSTRACT

This study aims to evaluate the effect of various dosages of Arbuscular Mycorrhizal Fungi (AMF) on the growth of oil palm (*Elaeis guineensis* Jacq) seedlings during the nursery phase. The FMA treatments consisted of 5 grams, 12.5 grams, 15 grams, 17.5 grams, and 20 grams, alongside a control group without AMF application. Key observed variables included plant height, leaf length, leaf width, leaf count, and phosphorus (P) availability in the growing medium over a one-month period. The results demonstrated that AMF application significantly enhanced plant height, leaf length, leaf number, and phosphorus availability in the medium. The 20-gram AMF dosage yielded the most favorable outcomes, with average plant height reaching 22.2 cm by the fourth week and phosphorus availability peaking at 1209.75 ppm—substantially higher than the control group. However, leaf width did not exhibit a significant increase during the observation period, likely due to genetic and environmental factors. In conclusion, optimal AMF dosages (15–20 grams) effectively promote vegetative growth of oil palm seedlings and improve phosphorus availability in the growing medium. Therefore, precise AMF application can support sustainable success in oil palm seedling cultivation.

Keywords: Arbuscula Mycorrhizal Fungi, Oil Palm, Oil Palm seedlings

INTRODUCTION

Oil palm (*Elaeis guineensis* Jacq.) is a critical global commodity, with Indonesia serving as the largest producer, contributing over 50% of the global supply. While the industry is vital for food, cosmetics, and bioenergy sectors, the sustainability and productivity of oil palm plantations are fundamentally established during the nursery phase (Abdul, 2023). Producing high-quality seedlings is a prerequisite for high yields in the field; however, the nursery stage often faces significant constraints. Seedlings are susceptible to abiotic stress and nutrient deficiencies, leading to abnormalities such as stunted growth, etiolation, and poor root development

(Sodikin et al., 2022). These issues are frequently exacerbated by suboptimal growing media and inefficient nutrient uptake, necessitating the use of sustainable bio-technologies to ensure seedling vigor.

Arbuscular Mycorrhizal Fungi (AMF) have emerged as a prominent biofertilizer capable of addressing these nursery challenges. Through a mutualistic symbiosis with plant roots, AMF significantly expands the absorptive surface area of the root system. This association enhances the uptake of immobile macronutrients—particularly Phosphorus (P)—as well as Nitrogen (N) and Potassium (K), while also improving micronutrient assimilation (Cu, Zn, Mn)

(Suswati, 2023; Simanjuntak et al., 2013). Beyond nutrition, AMF colonization induces physiological changes that bolster resistance against drought stress and soil-borne pathogens, making it a critical input for cultivating resilient seedlings in marginal soils.

While the growth-promoting benefits of Arbuscular Mycorrhizal Fungi (AMF) in oil palm cultivation are well-documented, a significant knowledge gap persists regarding the precision of its application across diverse genetic lines. Current literature, such as Wirianata et al. (2021), suggests a broad effective dosage range of 5 to 20 grams per seedling; however, these recommendations are largely generalized and fail to account for the specific physiological interactions between varying dosages and distinct oil palm genotypes. This oversight is critical, as recent evidence from Apria (2022) and Rini et al. (2022) indicates that varieties like Sriwijaya 2 and Simalungun exhibit differential responsiveness and colonization rates when exposed to biological inputs. Applying a uniform dosage across these varieties risks agronomic and economic inefficiencies: insufficient dosages lead to poor colonization, whereas excessive applications can trigger intraspecific competition among fungal spores, ultimately inhibiting symbiosis and inflating production costs (Sodikin et al., 2022). Consequently, there is a lack of comprehensive, systematic studies that evaluate the interaction between specific graded dosages of AMF and the growth performance of distinct high-yielding varieties. Bridging this gap is essential to establish a precision-based inoculation protocol for the pre-nursery stage, ensuring optimal symbiosis without the risk of biological or financial waste.

Building upon these identified gaps, this study aims to optimize nursery management by determining the precise AMF dosage required for specific oil

palm varieties. To achieve this, the research systematically evaluates the effect of varying AMF dosages on both the morphological and physiological growth of oil palm seedlings, while simultaneously analyzing the differential responses of distinct varieties, such as Sriwijaya 2 and Simalungun, to the inoculation. By examining the interaction effect between dosage and variety, the study seeks to identify the optimal combination necessary for maximizing seedling quality. It is hypothesized that a significant interaction exists between AMF dosage and oil palm variety, suggesting that specific varieties require distinct optimal dosages to achieve peak root colonization, efficient nutrient uptake, and maximum biomass accumulation.

MATERIAL AND METHOD

This study was conducted from September 2, 2024, to July 18, 2025, in Langan Village, Banyuasin Regency, South Sumatra Province. The analysis of phosphorus (P) nutrient content was carried out at the Sembawa Rubber Research Center Laboratory, located at Jl. Brasiliensis Raya, Lalang Sembawa, Sembawa District, Banyuasin Regency, South Sumatra 30953.

The AMF treatments were divided into six dosage levels: 0 g (control), 5 g, 12.5 g, 15 g, 17.5 g, and 20 g per seedling. The AMF inoculum was applied directly to the root zone prior to transplanting, allowing the fungal colonies to promptly establish mutualistic symbiosis with the seedling roots. Phosphorus fertilizer was supplied in the form of triple superphosphate (TSP) containing 46% P₂O₅. One month after planting, empty fruit bunches (EFB) of oil palm were applied as mulch to help retain soil moisture, reduce evaporation rates, and suppress weed growth around the seedlings. Data collection was conducted weekly over a four-week

period to measure morphological parameters of oil palm seedlings, including plant height, leaf length, leaf width, and leaf count. Phosphorus (P) nutrient analysis of the soil used as the growing medium was performed at the Soil Laboratory of the Sembawa Research Center, with assessments carried out for each treatment dosage.

RESULT AND DISCUSSION

Plant Morphology Results

The following section presents a detailed explanation of the morphological observations conducted on oil palm seedlings.

1. Plant Height (Week 1 to Week 4)

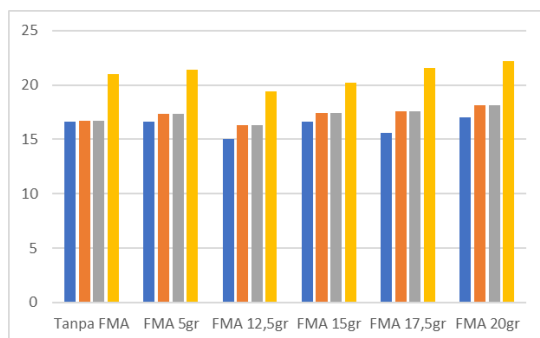


Figure 1. Plant Height (Week 1 to week 4)

Figure 1 illustrates the effect of Arbuscular Mycorrhizal Fungi (AMF) application on plant height from Week 1 to Week 4. The data reveals a positive correlation between AMF dosage and vertical growth, with the 20 g treatment yielding the most significant increase. Seedling height in this treatment rose from 17 cm in the first week to 22.2 cm by the fourth week, outperforming lower dosages and the control.

This finding aligns with previous studies by Wirianata et al. (2021), which indicate that higher AMF dosages increase the density of fungal propagules in the rhizosphere, thereby accelerating the rate of root colonization and subsequent vegetative growth. The superior height increment in AMF-inoculated seedlings can be attributed to

the enhanced uptake of essential nutrients, particularly Phosphorus (P). As noted by Suswati (2023), the external hyphae of AMF expand the root absorption surface area, facilitating the uptake of immobile nutrients like P, which plays a critical role in cell division and meristematic tissue development at the shoot apex. Consequently, while the control plants also exhibited growth due to natural development, the application of AMF significantly optimized the growth rate by alleviating nutrient limitations during the critical early nursery phase (Simanjuntak et al., 2013).

Furthermore, treatments with higher doses, particularly those ranging from 15 g to 20 g, produced more pronounced growth improvements. This superior performance is attributed to the higher volume of infective propagules, which accelerates the formation of external hyphae. According to Suswati (2023) and Simanjuntak et al. (2013), a denser hyphal network maximizes the interception of immobile nutrients, especially Phosphorus (P).

2. Leaf Length (Week 1 to Week 4)

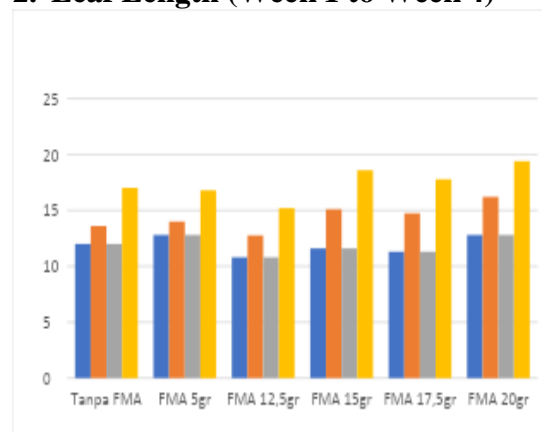


Figure 2. Leaf Length (Week 1 to week 4)

Figure 2 presents the results of AMF application on oil palm leaf length, indicating a consistent weekly increase over the one-month observation period. The findings demonstrate that AMF treatments at doses ranging from 5 g to

20 g produced superior outcomes in leaf elongation compared to the control group. This enhancement is attributed to the improved uptake of essential macronutrients, particularly Nitrogen (N) and Phosphorus (P), facilitated by the symbiotic association.

According to Simanjuntak et al. (2013), the presence of AMF on Ultisol soil significantly increases the availability of Nitrogen, a critical component for chlorophyll synthesis and vegetative growth. The increased leaf length in inoculated seedlings suggests that the fungal hyphae effectively absorbed nutrients beyond the depletion zone of the roots, supporting faster cell division and elongation.

Furthermore, Wirianata et al. (2021) noted that adequate P uptake mediated by AMF provides the necessary energy (ATP) for metabolic processes, resulting in broader and longer leaf blades. This physiological advantage allows the seedlings to maximize their photosynthetic capacity, which is vital for biomass accumulation during the nursery phase (Suswati, 2023).

3. Leaf Width (Week 1 to Week 4)

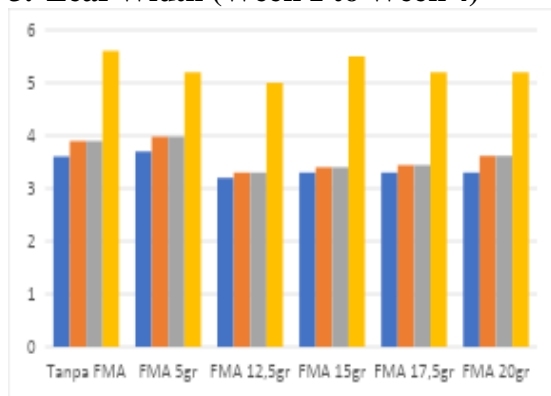


Figure 3. Leaf Width (Week 1 to Week 4)

Figure 3 that the application of Arbuscular Mycorrhizal Fungi (AMF) on oil palm seedlings produced results that differed distinctly from those observed in plant height and leaf length. While the optimal doses for vertical growth were consistently within the 15 g

to 20 g range, the leaf width parameter—measured from Week 1 to Week 4—showed the most favorable outcomes at the 0 g (control) and 5 g doses.

This phenomenon can be attributed to the metabolic cost of establishing the symbiotic relationship. According to Suswati (2023), AMF are obligate biotrophs that depend entirely on the host plant for carbon (photosynthates) to fuel their growth and spore production. In the early nursery stage, when the seedling's photosynthetic area is limited, high dosages (15–20 g) may lead to rapid and intense root colonization. This creates a significant "carbon drain," where a large portion of the plant's energy is diverted to the fungus rather than being allocated to vegetative expansion, such as leaf widening.

Furthermore, Sodikin et al. (2022) highlight that while AMF generally improves growth, an imbalance between fungal demand and host capacity can result in temporary growth depression. In this study, the higher dosages likely triggered intense competition for carbohydrates between the fungal partner and the host's sink tissues (leaves), limiting lateral leaf expansion despite the adequate nutrient supply. Conversely, the 0 g and 5 g treatments imposed little to no metabolic burden, allowing the seedlings to allocate more immediate resources to leaf width development during these initial weeks.

4. Leaf Count (Week 1 to Week 4)

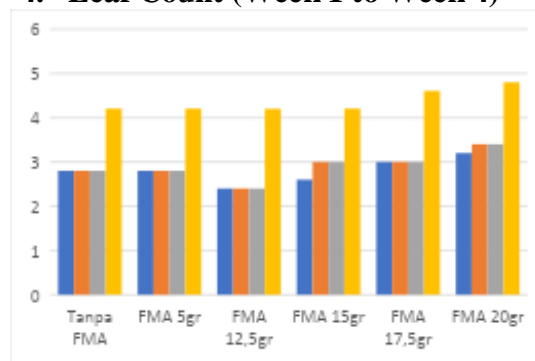


Figure 4. Leaf Count (Week 1 to Week 4)

Figure 4 demonstrates that the application of Arbuscular Mycorrhizal Fungi (AMF) on oil palm seedlings resulted in leaf count outcomes that closely mirrored the trends observed in plant height and leaf length. From Week 1 to Week 4, the most effective dosage range was consistently between 15 g and 20 g, with the optimal leaf count recorded at 17.5 g to 20 g.

This increase in leaf production suggests that higher levels of AMF inoculation effectively stimulated the activity of the shoot apical meristem. According to Simanjuntak et al. (2013), the increased number of leaves is directly correlated with enhanced Phosphorus (P) uptake facilitated by the fungal hyphae. Phosphorus is a vital component of ATP and nucleic acids, which are essential for cell division and the initiation of new leaf primordia.

Furthermore, Wirianata et al. (2021) observed that optimal AMF colonization triggers an increase in the production of growth-promoting hormones, such as cytokinins and gibberellins, which regulate shoot development. The significant increase in leaf count at the 20 g dosage indicates that the symbiosis provided a net benefit to the host plant, where the improved nutrient acquisition outweighed the carbon cost of maintaining the fungus. Consequently, this promoted vigorous vegetative growth and biomass accumulation, ensuring better seedling quality (Sodikin et al., 2022).

5. Phosphorus (P) Distribution in Soils

No.	Identitas Contoh		Hasil Pengujian	
	Kode Pengirim	Kode MT Contoh	Kadar Air IKU 103 (Gravimetri)	P ₂ O ₅ IKU 109 (Spektrofotometri)
		%.....ppm...
1.	FMA 20 g	T.228/VII/25	1,60	1209,75
2.	FMA 17,5 g	T.227/VII/25	1,15	943,68
3.	FMA 12,5g	T.225/VII/25	1,19	795,20
4.	FMA 15 g	T.226/VII/25	1,59	803,67
5.	Tanpa FMA	T.230/VII/25	0,99	204,76
6.	FMA 5g	T.229/VII/25	1,00	102,13

Figure 5. P distribution in soils.

Figure 5 presents the results of laboratory analysis of soil chemical properties reveals a substantial increase in available Phosphorus P₂O₅ following the application of Arbuscular Mycorrhizal Fungi (AMF). As shown in the test results, the P₂O₅ concentration escalated significantly from 204.76 ppm in the control treatment (Tanpa FMA) to a peak of 1,209.75 ppm at the maximum dosage of 20 g AMF. This six-fold increase suggests a high efficiency of AMF hyphae in mobilizing phosphorus through the secretion of organic acids and phosphatase enzymes, which effectively release fixed phosphorus into a plant-available form. Interestingly, a slight decline was observed at the 5 g dosage (102.13 ppm), potentially indicating an initial phase of nutrient immobilization or a variation in soil-microbe dynamics at lower inoculation densities. Overall, the positive correlation between AMF dosage and phosphorus availability underscores the critical role of mycorrhizal inoculation in enhancing soil nutrient profiles during the pre-nursery stage. P₂O₅ is represents the soil phosphorus levels determined via spectrophotometry in ppm (parts per million) units.

Phosphorus (P) Nutrient Analysis show contrast result, the phosphorus analysis revealed a marked increase in P availability, particularly at the 20 g AMF dosage, which reached 1209.75 ppm—substantially higher than the control (204.76 ppm). This significant surge in available phosphorus can be attributed to the activity of extra-radical hyphae. According to Suswati (2023), AMF hyphae secrete phosphatase enzymes and organic acids into the rhizosphere, which solubilize immobile inorganic phosphorus (such as Al-P and Fe-P in acidic soils) into forms available for plant uptake.

The data indicates a dosage-dependent response: the 12.5 g treatment yielded 795.20 ppm, suggesting that

dosages above 10 g begin to noticeably enhance phosphorus availability. Conversely, the 5 g AMF treatment (102.13 ppm) did not show significant improvement and was even lower than the control. This anomaly may be due to soil heterogeneity or the initial metabolic cost of fungal establishment at low spore densities, where nutrient immobilization by the fungi itself might temporarily occur before benefits are realized (Simanjuntak et al., 2013).

Comparison with Previous Studies
The positive trend in nutrient availability aligns with Lestari et al. (2018), who found that combining AMF with P fertilizers (SP-36) significantly improved plant height, stem diameter, and root length in oil palm seedlings. Although their study noted no substantial changes in leaf width or count within the first month, the subterranean improvement in P availability creates a foundation for long-term vegetative vigor. The analysis confirms that P distribution is significantly influenced by microbial activity in the upper soil layers. In oil palm plantations, phosphorus tends to accumulate in the topsoil where root activity and microbial interactions are most intense. As noted by Simanjuntak et al. (2013) and Suswati (2023), this nutrient plays a crucial role in root development, energy transfer (ATP synthesis), and the formation of reproductive structures. Therefore, the ability of high-dose AMF (20 g) to drastically increase soil P status demonstrates its potential as an effective biofertilizer for improving the chemical fertility of nursery media.

CONCLUSION

Growth Enhancement: The application of Arbuscular Mycorrhizal Fungi (AMF) at doses ranging from 5 to 20 grams in one-month-old oil palm seedlings resulted in increased plant height, leaf length, and leaf count on a

weekly basis throughout the one-month observation period. The 20g dose produced the most significant growth, followed by 17.5g, while seedlings without AMF still grew but at a comparatively lower rate. These results indicate that AMF plays a positive role in accelerating growth by enhancing phosphorus uptake, with optimal doses supporting healthier and more vigorous seedlings.

Leaf Width Parameter: AMF application at doses of 5 to 20 grams did not produce a significant increase in leaf width during the one-month period. This suggests that leaf width is more strongly influenced by genetic and environmental factors, which tend to remain stable over short timeframes, rather than by AMF treatment.

Phosphorus Availability: The 20g AMF dose significantly increased phosphorus availability in the growing medium, reaching 1209.75 ppm—substantially higher than the control (204.76 ppm). Doses above 10g showed a clear improvement in phosphorus levels, while the 5g dose did not yield a significant change. These findings underscore the importance of appropriate AMF dosing to enhance phosphorus availability and support plant growth.

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