DOI :https://doi.org/10.36378/juatika.v6i3.3683
JUATIKA
JURNAL AGRONOMI TANAMAN TROPIKA
VOL. 6 NO. 3 September 2024
eissn 2656-1727
pissn 2684-785X
Hal : 931 – 942

The Effectiveness of Arbuscular Mycorrhizal Fungi (AMF) on Gambier Seedlings' (*Uncaria gambir* (Hunter) Roxb) Growth on Former Coal Mining Land

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ABSTRACT

The availability of land limits gambier development; therefore, an alternative approach is to utilize land previously used for coal mining. This ex-coal mining land can be rehabilitated through the application of Arbuscular Mycorrhizal Fungi (AMF). This study aims to investigate the interaction between the type and dosage of AMF, as well as to identify the optimal type and dosage of AMF for the growth of Gambir seedlings. A Factorial Completely Randomized Design (CRD) was employed, incorporating two factors. The first factor consists of three types of AMF: Acaulospora sp, Glomus sp, and Gigaspora sp. The second factor pertains to the dosage of AMF, which includes 0 g/seedling, 5 g/seedling, 10 g/seedling, 15 g/seedling, and 20 g/seedling. The variables observed include soil chemical analysis, seedling height, number of leaves, and root crown ratio. The results indicate no significant interaction between the type and dosage of AMF on the growth of Gambir seedlings. However, the AMF type Glomus sp at a dosage of 20 g/seedling was found to be the most effective in promoting the growth of Gambir seedlings on ex-coal mining land.

Keywords: Extensification, Gambier, Marginal, Mycorrhizal, Seedlings

1. INTRODUCTION

Gambir is a specific plantation crop commodity in West Sumatra. West Sumatra is the primary market for Gambir exports, with the provinces of North Sumatra, Riau, Riau Islands, Aceh and South Sumatra representing significant secondary markets. Gambir is exported to a number of countries, including India, Pakistan, Bangladesh, China, Japan, the United States, Singapore, Myanmar, Yemen and Malaysia. The primary gambier production regions in West Sumatra are the districts of Lima Puluh Kota and Pesisir Selatan. The total land area dedicated to the cultivation of gambier in Pesisir Selatan Regency was recorded at 10,332 ha, with a production volume of 5,875 tonnes in 2022 (BPS Sumbar, 2022). Gambier production in Pesisir Selatan Regency remained consistent throughout 2021 and 2022, with a notable increase compared to the previous year (BPS Sumbar, 2022). This is due to an expansion of the area under cultivation of this crop. The area of gambier land in Pesisir Selatan Regency was 9,963 ha in 2020, increased to 9,992 ha in 2021, and increased to 10,332 ha in 2022 (BPS Sumbar, 2022). The expansion of gambier production is driven by rising demand. However, this has led to the conversion of forest land, which has had an adverse impact on the flora and fauna ecosystem. To minimise this impact, expansion is recommended on marginal lands, such as ex-mining land.

West Sumatra is one of Indonesia's leading provinces in terms of mining output, particularly coal. Pesisir Selatan Regency is one of the areas in West Sumatra where coal mining operations are conducted. A number of companies are engaged in coal mining operations in the area. Some of these companies are still operational, while others have ceased operations. PT Atoz Nusantara Mining is one of the companies that has conducted coal mining activities on a concession area of 192.08 hectares. The former coal mining land that PT Atoz Nusantara Mining has abandoned has remained unused for an extended period. Mining activities have adversely affected the land, resulting in damage to forest ecosystems and alterations to soil physical, chemical and biological characteristics (Darlis et al., 2024). The physical characteristics of ex-coal mine land present a number of challenges. These include an unbalanced clay and sand texture, high bulk density and low soil porosity value (Aulia et al., 2024). Furthermore, chemical damage to ex-coal mine land is associated with soil acidity (pH), nutrient deficiencies, and toxic mineral residues. A low soil pH can impede the absorption of essential plant nutrients, including phosphorus, calcium, magnesium, and potassium. An excess of metals, including aluminium, manganese, iron, copper, zinc and nickel, can have a toxic effect. Meanwhile, the damage to soil biology is characterised by a reduction in the population of soil life in the topsoil, resulting in the loss or death of these organisms. The loss of topsoil and litter as a carbon source to support potential microbial life is the root cause of the poor condition of soil microbial populations (Oktabriana. S & Syofiani, 2021).

This problem is the main obstacle for the local community to utilise the former coal mine land, especially for agricultural activities, because of the inhibition of the growth of plants planted on the land. In fact, the extent of former mining land in the area is an opportunity for the expansion of agricultural areas, especially the expansion of gambier land.

Ex-coal mining land must be rehabilitated without delay to prevent environmental pollution and ensure its suitability for agricultural use. One potential solution for restoring soil quality on ex-coal mining land is the use of Arbuscular Mycorrhizal Fungi (AMF). Arbuscular mycorrhizal fungi (AMF) are a highly effective type of mycorrhiza, widely used for their excellent association abilities. AMF can enhance plant growth in low-fertility soil, degraded land, and expand the plant root system's nutrient-acquiring capacity. Smith and Read (2008) noted that while the symbiosis of AMF with plants on fertile land does not yield significant benefits, it can enhance overall plant growth in extreme conditions. This is corroborated by the research of Kartika et al. (2010), which identified three genera of AMF in ex-coal mining land: Glomus sp., Acaulospora sp., and Gigaspora sp. The study's results by Prasetyo et al. (2019) also indicated that the most dominant genera in ex-mining land were Glomus sp. and Acaulospora sp. Wisnubroto et al. (2024) also conducted an exploration and identification of Arbuscular Mycorrhizal Fungi (AMF) on ex-coal mining land on five types of slopes, resulting in the discovery of four types of spores: Glomus sp., Acaulospora sp., Gigaspora sp. and Sclerocystis sp.

The efficacy of AMF in land revegetation is contingent upon a number of variables, in addition to the specific AMF species employed. The dosage of the inoculant applied to the plant is another crucial factor. The research findings of Ali et al. (2023) indicate that the optimal dose of Arbuscular Mycorrhizal Fungi (AMF) inoculant for promoting the growth and development of Robusta coffee seedlings is 20 g/plant and 25 g/plant. This is based on the fact that coffee is a plant in the same family as Gambir plants.

The distinction between the present study and previous research is that previous research was exploratory and descriptive in nature. Consequently, the AMF species obtained from ex-coal mining soil was employed as the treatment in the present study.

Furthermore, the study conducted by Ali et al. (2023) solely employed the AMF Glomus sp. and the sole variable was the AMF dose. This study aims to ascertain the interaction between the AMF type and the AMF dose and identify the optimal AMF and AMF dose for the growth of Gambir seedlings planted in ex-coal mining soil.

2. MATERIAL AND METHOD

The research, in the form of an experiment, was carried out from February to May 2024 and took place at the Experimental Garden UPT, Faculty of Agriculture, Andalas University, Padang. The location is at the coordinates 0 ° 54'50.6 "S and 100 ° 28'13.1" E, with an altitude of ± 200 meters above sea level (masl), and the Plant Physiology Laboratory, and the Soil Laboratory, Faculty of Agriculture, Andalas University, Padang

The materials used in this study were 2-month-old Cubadak variety Gambir seedlings obtained from Pesisir Selatan Regency. Arbuscular Mycorrhizal Fungi (AMF) types Acaulospora sp, Glomus sp, and Gigaspora sp in the form of sand media. Former coal mining soil taken from the former mining area of Kenagarian Tambang, IV Jurai District, Pesisir Selatan Regency. Inorganic fertilizers (Urea, SP-36, and KCL), cow manure, distilled water, 10% KOH, 2% HCL, and lacto glycerol trypan blue.

The equipment used in this study were a soil drill, hoe, shovel, plastic bucket, clear plastic bag measuring 30cm x 45cm, label paper, stationery (pen, book, marker), 10kg bench scale, 20kg steamer, stove, 3kg gas, sack, 15cm x 20cm polybag, 70% paranet, ruler, standard pole, watering can, meter, plastic clip, paper envelope, stencil paper, scissors, digital scale, oven, and documentation tools.

The study was conducted using an experimental method arranged using a factorial Completely Randomized Design (CRD). The first factor consisted of 3 AMF types levels: Acaulospora sp, Glomus sp, and Gigaspora sp. The second factor consisted of 5 levels of AMF doses, namely, 0 g/seedling, 5 g/seedling, 10 g/seedling, 15 g/seedling, and 20 g/seedling.

Each combination of experiments was repeated 3 times so that there were

45 experimental units. Each experimental unit consisted of 4 sample plants (1 non-destructive plant sample and 3 destructive plant samples) so that there were 180 sample plants.

The experiment was implemented with soil sampling, and then the preparation of the planting medium was continued. The soil to be used for the study was sieved and soaked for 3 days and then dried. The dry soil was put into plastic and then tyndalized in a steamer containing boiling water for 2 hours. The tyndalized soil was then air-dried. The tyndalization process was also carried out on cow manure. The soil and cow manure that had been tyndalized were then mixed with a volume ratio of 1: 1 and incubated for one week before planting. The soil that had been mixed with cow manure was put into a 15cm x 20cm polybag.

70% paranet was installed on the Gambir plant nursery land as shade. Labels and standard poles were installed when preparing the experimental units and adjusted to the placement plan. The provision of AMF was made by spreading mycorrhiza into the planting hole, and then the Gambir seedlings were planted by immersing the roots into the planting hole that had been treated with AMF.

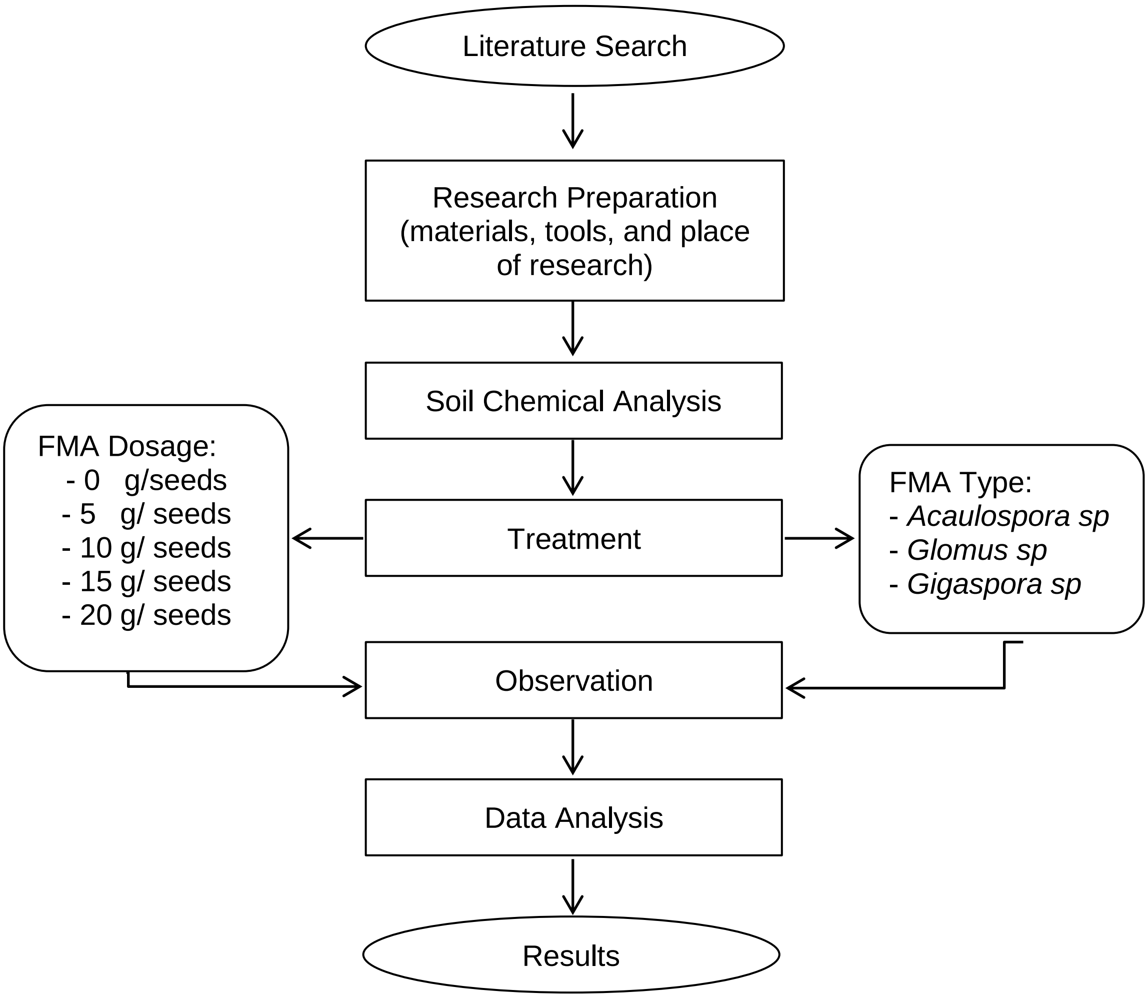

Figure 1. Research Flow Diagram

The maintenance carried out was watering the plants, loosening, weeding, fertilizing and controlling pests and diseases. Observations made were seedling height, number of leaves, and root crown ratio.

The observation data were analyzed statistically using analysis of variance (ANOVA). The variance analysis results that showed significant differences were continued with Duncan's Multiple Range Test (DMRT). Data analysis used the Statistical Tool for Agricultural Research (STAR) application. The flow diagram of the research implementation can be seen in Figure 1.

3. RESULT AND DISCUSSION

3.1. Soil Chemical Analysis

Soil chemical analysis aims to determine the initial condition of the soil, especially related to its fertility. Several important parameters measured include pH, nutrient content (nitrogen (N), phosphorus (P), and potassium (K)), and organic matter content (C-Organic). The results of the initial soil analysis can be seen in Table 1.

Table 1. Chemical analysis of ex-coal mining soil

Types of Analysis	Method	Results	Criteria
pH H2O (1:5)	Elektrometri	4,42	Very Sour
N-Total (%)	Kjeldhal	0,12	Poor
P-Availability (ppm P2O5)	Bray 1	6,12	Poor
P-Total (mg P2O5/100g)	Ekstrak HCL 25%	17,21	Poor
K-Total (mg K2O/100g)	Ekstrak HCL 25%	11,09	Poor
C-Organic (%)	Walkley dan Black	2,64	Medium

Table 1 shows that the pH of the ex-coal mining soil is 4.42, which is included in the criteria for very acidic soil where acidic soil conditions can inhibit microbial activity, including N mineralization from organic matter and nitrification (Havlin et al., 2005). In addition, soil conditions that are too acidic can inhibit plant growth because they can bind important nutrients such as phosphorus, making them unavailable to plants.

The results of the soil's N, P, and K nutrient content are low. The low total N content indicates that nitrogen availability in the soil is also low. Nitrogen is an important nutrient for plant vegetative growth. Low available P and total P content will affect plant growth. Lack of phosphorus in plants will cause plants to become stunted. The total K content is also low, even though total K plays an important role in the process of photosynthesis and transportation of nutrients in plants. Plants require balanced nutrients for the growth process. Lack of N disrupts the absorption of P and K for the plant growth phase. P nutrients are needed in large quantities after N nutrients, because P nutrients play a role in plant growth from the vegetative phase to the generative phase.

Another important parameter to see soil quality is the C-organic content. The results of the C-organic analysis on ex-coal mining soil are included in the moderate criteria. C-organic content is important for improving soil structure, increasing water holding capacity, and providing a food source for soil microorganisms.

3.2 Seedling Height Increase

The increase in the height of Gambir seedlings results from subtracting the last observation from the first observation on the height of Gambir seedlings. The increase in the height of Gambir seedlings in the treatment of various types and doses of AMF can be seen in Table 2.

Table 2 shows that there is no interaction between the type of AMF and the dose of AMF on the increase in the height of Gambir seedlings, but each single factor significantly affects the increase in the height of Gambir seedlings. Table 2 also shows that the treatment of AMF of the Glomus sp type has a significantly different effect on the increase in the height of Gambir seedlings compared to the Acaulospora sp and Gigaspora sp types. However, the treatment between the Acaulospora sp and Gigaspora sp types has an insignificant effect on the increase in the height of Gambir seedlings. AMF of the

Glomus sp type gave the highest average increase in seedling height, namely 32.21 cm.

This result is thought to be because Glomus sp is more suitable and adaptable to Gambir seedlings planted on ex-coal mining land. Wisnubroto et al. (2024) stated that a higher level of suitability indicates a stronger symbiosis between AMF and host plants. Glomus sp has spores that germinate faster than Acaulospora sp and Gigaspora sp, so symbiosis is faster and distributes plant nutrients. Armansyah et al. (2019) stated that Glomus is better able to adapt and reproduce than Acaulospora and Gigaspora. The uptake of nutrients by mycorrhiza involves hyphae in the soil which are then channeled into the root cells.

Table 2. Increase in height of Gambir seedlings from 14 - 84 HST

FMA type	FMA Dosage (g/seeds)					Average
	0	5	10	15	20	
	……………..(cm)……………….					
Acaulospora sp	22,93	27,93	29,73	30,87	34,90	29,27±4,86[b]
Glomus sp	24,23	28,50	30,57	34,73	43,00	32,21±7,22[a]
Gigaspora sp	24,17	27,73	28,97	30,87	33,17	28,98±4,28[b]
Average	23,78±2,42[D]	28,06±2,61[C]	29,76±3,29 [BC]	32,16±3,10[B]	37,02±5,93[A]	

Notes: Numbers followed by the same lowercase letter in the same column and numbers followed by the same uppercase letter in the same row are not significantly different according to the Duncan Multiple Range Test at the 5% level.

The results obtained in the FMA type treatment indicate that Glomus sp helps the absorption of water and nutrients more effectively in Gambir seedlings than other types of FMA, so that plant growth metabolism can occur properly. Marlina (2020) stated that FMA plays a role in stimulating the formation of plant growth hormones such as auxin. cytokinin and gibberellin. Hormones play a role in cell division and elongation; if the amount of hormones produced is greater, the process of increasing the size and number of cells becomes faster, and the plant height becomes higher than that of other treatments.

The increase in the height of Gambir seedlings given AMF dose treatment showed significantly different results. At an AMF dose of 0 g/seedling, an increase in the AMF dose of 20 g/seedling showed an increase in the height of Gambir seedlings. The AMF dose treatment of 0 g/seedling produced the lowest average increase in seedling height, which was 23.78 cm. The AMF dose of 20 g/seedling had a significantly different effect on the increase in the height of Gambir seedlings compared to other AMF dose treatments. The AMF dose of 20 g/seedling produced the highest average increase in seedling height, which was 37.02 cm. These results indicate that AMF with a dose of 20 g/seedling is the best AMF dose for the increase in Gambir seedlings compared to other AMF doses in this study. This is in line with the results of research by Ali et al. (2023) which showed that giving Glomus sp type FMA as much as 20 g/seedling and 25 g/seedling to Robusta coffee seedlings had the highest average seedling height value compared to without FMA inoculation, doses of 5 g/seedling, 10 g/seedling, and 15 g/seedling.

The height of Gambir seedlings continued to increase, which was known when observing seedlings aged 14 HST to 84 HST. The results of observations of the height of Gambir seedlings aged 14 HST to 84 HST can be seen in Figure 2. Figure 2 shows that the height of Gambir seedlings continues to increase with each observation conducted at a weekly interval. The increase in the height of Gambir seedlings began to appear significant when the seedlings were 56 HST to 84 HST old.

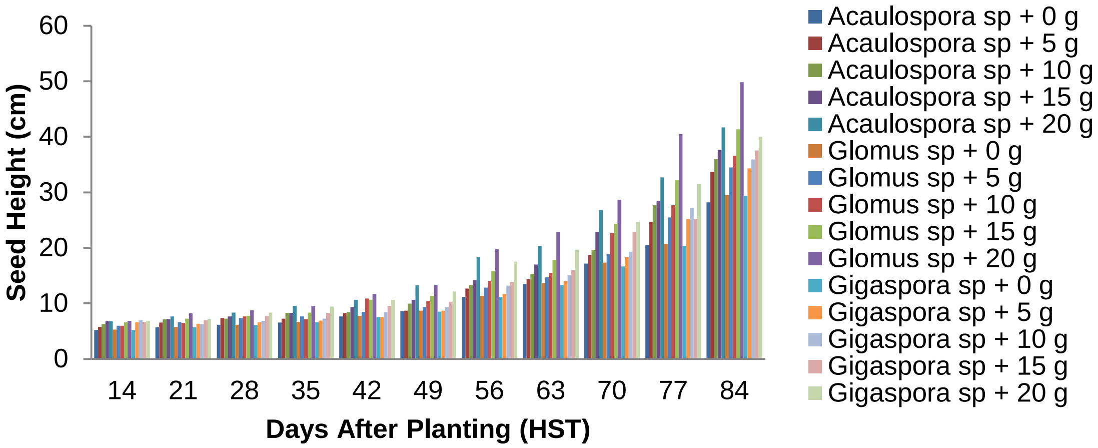

Figure 2. The increase in the height of Gambir seedlings starts from 14 HST to 84 HST

This is because the AMF given to Gambir seedlings with different doses can expand the area of water and nutrient absorption plants need. Zulkoni et al. (2020) stated that large water absorption by plants in symbiosis with AMF will carry nutrients that are easily dissolved and carried by mass flow such as N, K and sulfur (S), so that the absorption of these elements increases. In line with Makarov (2019) who stated that mycorrhizal mycelium is able to absorb N from the soil more effectively than plant roots because AMF has a wider reach, and finer hyphae than root hairs allow hyphae to enter soil pores that roots cannot reach.

The flow of phosphorus in hyphae follows the flow of cytoplasm in plant root cells, while the flow of nutrients from mycorrhiza to the host plant is thought to flow through the arbuscular (Rokhminarsi., 2020). External hyphae in mycorrhiza are able to absorb phosphate elements from the soil which are then converted into polyphosphate compounds. The polyphosphate compounds are then transferred into the hyphae and broken down into organic phosphate, which plant cells can later absorb (Simanjuntak et al., 2023). In addition, Maulana and Harahap (2023) stated that high P absorption is also caused by mycorrhizal hyphae secreting phosphatase enzymes that can release P from specific bonds in the soil. so that phosphorus elements are available to plants.

The main nutrients that affect plant height are nitrogen (N) and phosphorus (P). According to Sulistyawati (2011), plant height growth is caused by the activity of the apical meristem, namely the part of the plant shoot that actively divides, so that the plant will grow taller. The availability of nitrogen greatly influences cell division and enlargement. Phosphorus (P) is needed by plants for the formation of new cells in growing tissues and to strengthen the stem so that it will later have an impact on plant height growth (Lukman, 2010). Plants also need potassium for various physiological functions. including carbohydrate metabolism, enzyme activity, osmotic regulation, water use efficiency, nitrogen element absorption, protein synthesis and assimilate translocation which will indirectly affect plant height. (Rahmawan et al., 2019).

3.3 Leaf Number Increase

The increase in the number of leaves of Gambir seedlings is the result of subtracting the last observation (84 HST) with the first observation (14 HST) on the number of Gambir seedlings. The increase in the number of leaves of Gambir seedlings in the treatment of various types and doses of AMF can be seen in Table 3.

Table 3. Increase in the number of leaves of Gambir seedlings from 14 to 84 days after

FMA type	FMA Dosage (g/seeds)					Average
	0	5	10	15	20	
	……………..(strands)………..……					
Acaulospora sp	28,33	30,00	32,67	35,67	39,33	33,20±5,07^{b}
Glomus sp	28,67	32,33	32,67	39,33	47,33	36,07±7,71^{a}
Gigaspora sp	28,67	30,00	31,33	32,67	40,67	32,67±4,58^{b}
Average	28,56±3,78^{D}	30,78±2,91^{CD}	32,22±2,11^{C}	35,89±3,41^{B}	42,44±5,17^{A}	

Notes: Numbers followed by the same lowercase letter in the same column and numbers followed by the same uppercase letter in the same row are not significantly different according to the Duncan Multiple Range Test at the 5% level.

Table 3 shows that there is no interaction between the type of AMF and the dose of AMF on the increase in the number of leaves of Gambir seedlings, but each single factor significantly affects the increase in the number of leaves of Gambir seedlings. Based on Table 6, it can be seen that the treatment of the type of AMF has a significantly different effect on the increase in the number of leaves of Gambir seedlings. The treatment of the Glomus sp type has a significantly different effect on the increase in the number of leaves of Gambir seedlings compared to the Acaulospora sp and Gigaspora sp types. However, the treatment between the Acaulospora sp and Gigaspora sp types has an insignificant effect on the increase in the number of leaves of Gambir seedlings. The Glomus sp type gives the average result of the increase in the number of leaves of Gambir seedlings with the highest value, namely 36.07 strands.

The greater number of leaves in the Glomus sp type treatment is related to the development and density of spores. Glomus sp spores are relatively small and germinate faster, so the absorption of nutrients will be better and will support the increase in the number of leaves. In addition, the results of observations of the number of leaves in this study are directly proportional to the results of observations on the parameters of the increase in the height of Gambir seedlings, meaning that the increase in the number of leaves of Gambir seedlings is related to the increase in the height of Gambir seedlings. The higher the Gambir seedlings, the more leaves are formed.

The number of leaves increased from the AMF dose level of 0 g/seedling to the AMF dose of 20 g/seedling. The results of the AMF dose treatment of 0 g/seedling on the increase in the number of leaves of Gambir seedlings gave a different effect that was not significant compared to the AMF dose treatment of 5 g/seedling. The AMF dose treatment of 20 g/seedling was the most effective treatment with the highest average increase in the number of leaves, which was 42.44 strands compared to other doses. The AMF dose was positively correlated with the increase in the number of leaves of Gambir seedlings. The higher the AMF dose given, the more leaves appeared on the Gambir seedlings. The increase in the number of leaves that appeared on the Gambir seedlings was observed when the seedlings were 14 HST to 84 HST, and can be seen in Figure 3.

In Figure 3, it can be seen that the number of leaves of Gambir seedlings continues to increase with each observation. The increase in the number of leaves is significant when the Gambir seedlings are 56 HST to 84 HST. The increase in the number of leaves in Gambir seedlings cannot be separated from the role of the nutrient N, which helps in the cell division process, so young leaves in Gambir seedlings reach their perfect shape more quickly.

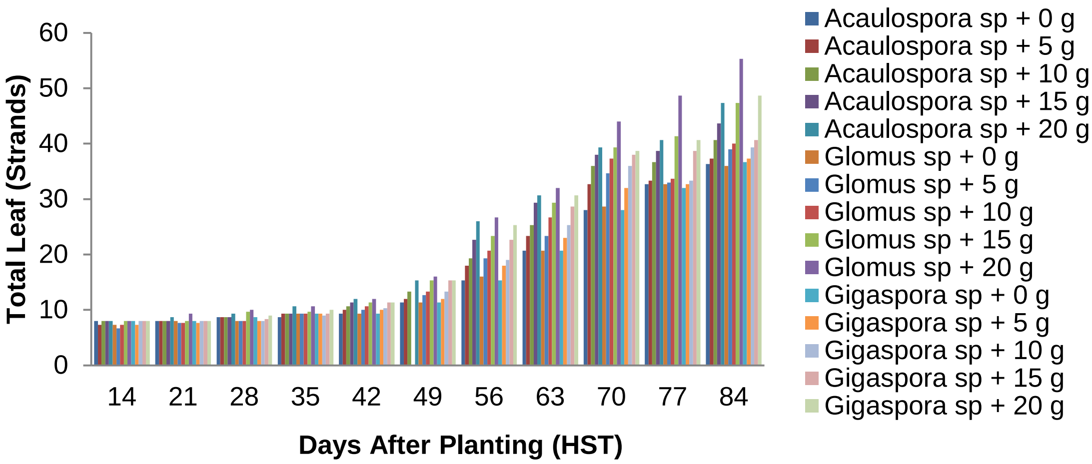

Figure 3. The increase in the number of leaves of Gambir seedlings starts from 14 HST to 84 HST

According to Lakitan (2011), plants that do not receive additional nitrogen will grow stunted and the leaves formed will also be smaller, thinner and fewer in number. Meanwhile, plants that receive additional nitrogen will form more and wider leaves. Supported by Sasmita et al. (2020) states that the ability of mycorrhizae to absorb nutrients through the roots will affect growth in height, number of leaves and leaf area. The nutrient N has the function of increasing leaf growth, making leaves healthier, increasing leaf area, giving leaves a greener color, increasing protein levels in the soil and as the main component of various compounds in plants, namely amino acids, chlorophyll, and alkaloids.

The P element also influence leaf formation. According to Ansyar et al. (2017), the P element is an important part of plant metabolism and is used to form phosphate sugars needed by plants during photosynthesis. Arbuscular mycorrhizal fungi form external hyphae to reach and absorb P nutrients that are far from the roots by changing the biochemistry and physiology of the rhizosphere to increase accessibility to root hairs, thereby expanding the area of nutrient absorption by the roots (Rastono et al., 2023). After absorption, P is distributed to various tissues such as growing roots, developing leaves, flowers and seeds (Bucher, 2007).

3.4 Root Crown Ratio

The root crown ratio is the result of the comparison between the weight of the crown, which consists of the stem, branches, and leaves, and the weight of the plant roots. The root crown ratio of Gambir seedlings in the treatment of various types and doses of AMF at the age of 84 HST can be seen in Table 4.

Table 4. Root crown ratio of Gambir seedlings aged 84 HST

FMA Type	FMA Dosage (g/seeds)					Average
	0	5	10	15	20	
	……………..(g/g)……………….					
Acaulospora sp	1,43	1,61	1,83	1,48	1,93	1,66±0,33[b]
Glomus sp	1,45	1,90	1,91	2,15	2,25	1,93±0,34[a]
Gigaspora sp	1,39	1,69	1,83	1,74	1,72	1,67±0,31[b]
Average	1,43±0,14[B]	1,73±0,23[A]	1,86±0,38[A]	1,79±0,36[A]	1,96±0,35[A]	

Notes: Numbers followed by the same lowercase letter in the same column and numbers followed by the same uppercase letter in the same row are not significantly different according to the Duncan Multiple Range Test at the 5% level.

Table 4 shows that there is no interaction between the type of AMF and the dose of AMF on the ratio of the root crown of Gambir seedlings. However, each single factor significantly affects the ratio of the root crown of Gambir seedlings. The treatment of the type of AMF has a significantly different effect on the ratio of the root crown of Gambir seedlings. The type of AMF has an insignificant effect on the ratio of the root crown of Gambir seedlings. The type of Acaulospora sp has an insignificant effect on Gigaspora sp. The type of Glomus sp is the best type of AMF and has a significantly different effect on the ratio of the root crown of Gambir seedlings compared to the types of Acaulospora sp and Gigaspora sp. The type of Glomus sp shows the average results of the root crown ratio with the highest value, namely 1.93.

The root crown ratio obtained in the Glomus sp treatment indicates that the growth of Gambir seedlings in the crown section has increased. This is of course related to the water and nutrient absorption process by AMF. Gambir seedlings get enough water and N elements to use for plant metabolism because N elements significantly affect the root crown ratio. The growth of new shoots is stimulated by N, so that the shoots become a place to utilize stronger assimilation results than the roots, as a result, shoot growth is greater than root growth. This causes the root crown ratio to increase further.

The high root crown ratio value indicates that the dry weight of the crown produced is greater than the dry weight of the roots. The root crown ratio value indicates dominant growth to the crown or to the roots. The role of roots in plant growth is as important as the crown, if the crown functions to provide carbohydrates through the process of photosynthesis, then the function of the roots is to provide nutrients and water needed in plant metabolism.

The treatment of AMF doses of 10 g/seedling. 15 g/seedling and a dose of 20 g/seedling each gave a different but insignificant effect on the root crown ratio of Gambir seedlings. However, it gave a significantly different effect compared to the AMF dose of 0 g/seedling. This means that the administration of AMF doses has been able to increase the root crown ratio of Gambir seedlings compared to without the administration of AMF. The difference in Gambir seedlings' appearance with the treatment of AMF types and doses can be seen in Figure 4.

Figure 4. Gambir seeds with FMA type and dosage treatment

4. CONCLUSION

The results obtained indicate that the optimal type of AMF is Glomus sp and the optimal dose of AMF is 20 g/seedling for the promotion of growth in Gambir seedlings on ex-coal mining soil. This is evidenced by the observed increases in seedling height, the number of leaves, and the root crown ratio.

ACKNOWLEDGMENTS

We would like to express our gratitude to the Research and Community Service Institute of Andalas University for providing financial support for this research project, which was conducted as part of the Basic Research SKIM of the Faculty of Agriculture at Andalas University. The grant number is: The project is funded by SP2D 0000254SP2DPN-UNANDKONTRAKI2024 2.

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