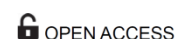


# JERAMI

## Indonesian Journal of Crop Science

Research Article



# RESPONSE TO GROWTH AND YIELD OF PAK CHOY WITH DIFFERENT DOSES OF ARBUSCULAR MYCORRHIZAL FUNGI

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## Article Info

### Received:

01 October 2024

### Accepted:

03 December 2024

### Published:

28 February 2025

### Competing Interest:

The authors have declared that no competing interest exists.

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## Abstract

Pakcoy is a potential horticultural commodity to be cultivated because it is in demand by many Indonesians, especially for Chinese cuisine lovers. The demand for pakcoy always increases every year. However, it has not been supported by sufficient pakcoy productivity. The reasons include the decreasing area of productive land (harvest area). One of the efforts to overcome the reduced harvest area is to expand agricultural land by utilizing marginal land such as Ultisol. Cultivation activities on Ultisol certainly require more optimal handling, including the addition of lime and inorganic fertilizers in large quantities. However, this can damage the potential of the land if done for a long time. Therefore, other alternatives are needed in handling cultivation on Ultisol, one of which is the addition of biological agents such as AMF. For this reason, research has been conducted on the Response to Growth and Yield of Pakcoy Plants (*Brassica rapa subsp. chinensis*) by Giving Doses of Arbuscular Mycorrhizal Fungi. The research aims to get the best dose for the growth and yield of pakcoy plants. This study used a completely randomized design with four treatments and four replications, namely AMF doses of 0 g/plant, 5 g/plant, 10 g/plant, and 15 g/plant. Observation data were analyzed by the F test at a 5% level if the Fcount is greater than Ftable, followed by the DNMR test at a 5% level. The results showed that the application of AMF could improve the growth and yield of pakcoy plants. The best dose of AMF was 10 g/plant

Keywords: AMF, dosage, pakcoy, response ,ultisol



## 1. Introduction

Pakcoy is a horticultural commodity that has great potential to be cultivated and developed because it is in great demand by the Indonesian people, especially Chinese cuisine lovers. Pakcoy contains various essential nutrients, such as protein, fat, carbohydrates, calcium (Ca), phosphorus (P), and iron (Fe), as well as vitamins A, B, C, E, and K, which are beneficial for health and fulfillment of human nutritional needs. From an economic and business perspective, pakcoy cultivation aims to meet the increasing market demand. The selling price of pakcoy is also relatively higher than other types of mustard greens (Hernowo et al. 2011). In addition, pakcoy cultivation is relatively easy because this plant is adaptable to environmental conditions in Indonesia. The Green variety, for example, is able to grow in low to high altitudes with an altitude of 90-1,200 masl and an optimal temperature of 18-27°C.

The demand for pakcoy in Indonesia has increased from year to year. Based on data from the Central Bureau of Statistics and the Directorate General of Horticulture (2021), national pakcoy demand in 2018, 2019, and 2020 reached 635,990 tons, 652,727 tons, and 671,124 tons, respectively. However, pakcoy productivity during the same period was still low, at only 6.59 tons/ha in 2018, 5.72 tons/ha in 2019, and 5.39 tons/ha in 2020. This indicates an increase in demand that has not been matched by an increase in production. One of the contributing factors is the reduction in harvested land area. BPS data (2021) shows that the harvested area of pakcoy has decreased from 61,133 ha in 2017 to 61,047 ha in 2018. This decline continued in 2019 to 60,871 ha, and in 2020, the remaining harvested land area was only 60,670 ha.

The decreasing availability of productive land can have an impact on the availability of pakcoy in the market. One of the leading causes is the increasingly widespread conversion of agricultural land to non-agricultural land. If not controlled, land conversion can threaten the sustainability of pakcoy cultivation and agricultural production in general. Therefore, one strategy that can be applied to overcome land limitations is to utilize marginal land, such as Ultisol, as an alternative agricultural land

## 2. Materials and Methods

This research was conducted in the Wirehouse and Plant Physiology Laboratory, Faculty of Agriculture, Andalas University, from January to March 2023. Materials used in this study include Green variety pakcoy seeds, Ultisol soil, multispora Arbuscular Mycorrhizal Fungi (AMF) (*Glomus* and *Acaulospora*), chicken manure, and inorganic fertilizers such as Urea, SP-36, and KCl. In addition, several chemicals were also used, such as KOH 10%, HCl 2%, lactoglycerol trypan blue, and distilled water.

The equipment used in this study included hoes, seed trays, sprayers, digital scales, raffia, cameras, 5-

Ultisol is a type of acid soil that has not been optimally utilized for agriculture. This soil has excellent potential because its area reaches about 29.7% of the total land area of Indonesia. However, there are several obstacles to the utilization of Ultisol as a planting medium, including low soil pH (around 4.67), limited nutrient content, and low soil fertility levels. Therefore, Ultisol management requires a unique strategy in order to support optimal plant growth.

According to Putri et al. (2016), one way to increase the fertility of Ultisol soil is by adding lime and organic fertilizer in high enough doses. However, the continuous use of large amounts of lime and fertilizer can have a negative impact on land potential. Therefore, other alternatives that are more environmentally friendly and sustainable are needed, one of which is increasing the efficiency of nutrient absorption by plants. One method that can be applied is by utilizing biological agents such as Arbuscular Mycorrhizal Fungi (AMF). AMF is able to associate with about 96% of plants, forming a symbiotic mutualism with the root system of the host plant. These fungi form hyphae that develop widely around the roots, thus increasing plants' absorption of nutrients and water (Herawati et al., 2017).

In addition to increasing nutrient absorption efficiency, the use of AMF can also reduce dependence on chemical fertilizers in pakcoy cultivation. The application of this technology allows a reduction in the dose of inorganic fertilizers to half of the standard recommendation so as to provide better economic and environmental benefits. Yuliani (2017) reported that the addition of AMF significantly affected the growth of mustard plants with an optimal dose of 10 g/plant. Meanwhile, Anggraini's research (2012) showed that inoculation of multisport mycorrhiza had a significant impact on the growth and yield of lettuce plants in Ultisol soil, with the best dose of 5 g/plant.

Based on this, this study aims to evaluate the growth and yield of pakcoy (*Brassica rapa subsp. Chinensis*) plants at various doses of AMF and determine the optimal dose that can increase the growth and yield of pakcoy plants

mesh sieves, labeling tools, paddles, vectors, stationery, buckets, knives, polybags measuring 40 × 25 cm, measuring cups, small scissors, envelopes, hot plates, leaf area meters, microscopes, cover glass, and object glass.

The experiment was conducted using a completely randomized design (CRD) consisting of one treatment factor with four levels of AMF dosage, namely AMF 0 g/plant (M0), AMF 5 g/plant (M1), AMF 10 g/plant (M2), and AMF 15 g/plant (M3). Each treatment was repeated four times, resulting in 16 experimental units. In each experimental unit, there were four sample

plants for yield observation and two sample plants for destructive observation, resulting in a total of 96 plants observed. Observation data were analyzed using the F test at the 5% significance level. If there were significant differences, the analysis was continued with Duncan's New Multiple Range Test (DNMRT) at the 5% real level.

The research procedure consisted of several stages, namely preparation of planting media and seedling media, sterilization of planting media and seedling

media, nursery of pakcoy seeds, installation of labels and standard poles, AMF treatment and planting, watering, weeding, fertilizing, pest control, and harvesting.

The observation variables in this study include plant height, number of leaves, leaf area, stem diameter, crown fresh weight, root fresh weight, crown dry weight, root dry weight, crown-root ratio, percentage of colonized roots, relative growth rate, and net assimilation rate.

### 3. Results and Discussion

#### Plant Height

The results of the variance analysis using the F test at the 5% level showed that the application of AMF with

several doses had a significantly different effect on pakcoy plant height. Data on pakcoy plant height can be seen in Table 1.

Table 1. Pakcoy plant height at several doses of AMF at the age of 4 weeks.

| Dose of AMF (g/plant) | Plant Height (cm) |
|-----------------------|-------------------|
| 0                     | 20,22 c           |
| 5                     | 22,12 b           |
| 10                    | 25,82 a           |
| 15                    | 26,01 a           |

Diversity Coefficient = 3,41%

Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% real level.

Data in Table 1 shows that the application of various doses of AMF affects the height of pakcoy plants. The highest plant height was obtained in the 15 g/plant dose of AMF treatment, followed by the 10 g/plant dose treatment, which gave results that were not significantly different from the 15 g/plant dose. This indicates that the dose of 10 g/plant is quite optimal in meeting the nutrient needs of plants, so no further dose increase is required. Meanwhile, compared to the description of the pakcoy Green variety, the plant height in the AMF treatment of 5 g/plant and 0 g/plant was still below the standard criteria for plant height. This is likely due to the non-optimal availability of nutrients needed for plant

growth. Leiwakabessy et al. (2004) stated that nutrient deficiencies can inhibit plant growth and development and have a direct impact on productivity.

Based on Figure 1, it can be seen that the height of pakcoy plants has increased every week. Plant height growth at various doses of AMF showed a relatively uniform response from week 1 to week 3 after planting. However, starting from the 4th week after planting, there was a more significant difference between treatments. This result is in line with the research of Sastrahidayat (2011), who reported that the effect of mycorrhiza on tomato plant height only appeared significant in the 4th and 5th weeks after planting.

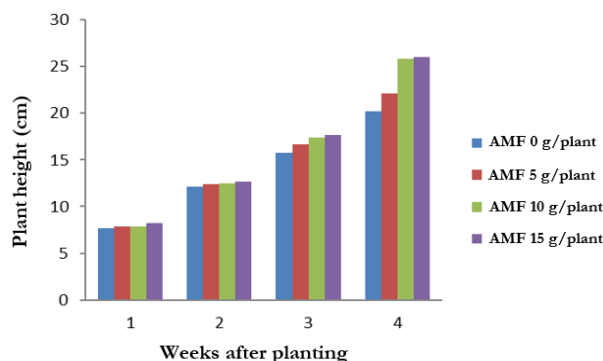


Figure 1. Growth graph of pakcoy plant height at several doses of AMF at the Age of 1-4 weeks after planting.

The graph in Figure 1 also shows that pakcoy plants treated with AMF have greater plant height compared to plants that do not receive AMF. The application of AMF at a dose of 15 g/plant resulted in faster plant height growth than other treatments. This may be due to the colonization of AMF, which helps increase the absorption of nutrients, especially phosphorus, which is very important for plant growth. According to Carling and Brown (1982), mycorrhizal plants show increased physiological activity in absorbing soil nutrients, especially phosphorus, as well as other elements such as potassium (K), calcium (Ca),

and magnesium (Mg), which play a role in supporting plant growth.

### Number of Leaves

The results of the F test showed that the application of AMF with several doses had a significantly different effect on the number of leaves of pakcoy plants. Data on the number of leaves of pakcoy plants at the Age of 4 weeks after planting with several doses of AMF can be seen in Table 2.

Table 2. Number of leaves of Pakcoy Plants at Several Doses of AMF Age 4 weeks after planting

| Dose of AMF (g/plant) | Number of Leaves (blade) |
|-----------------------|--------------------------|
| 0                     | 13,50 c                  |
| 5                     | 15,25 b                  |
| 10                    | 17,25 a                  |
| 15                    | 18,25 a                  |

Diversity Coefficient = 4,84%

*Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% absolute level.*

The data in Table 2 shows that the application of AMF with a dose of 15 g/plant produces the highest number of leaves of pakcoy plants. However, this result was not significantly different from the dose of AMF treatment of 10 g/plant, which indicated that the dose of 10 g/plant was quite optimal in increasing the number of leaves of pakcoy plants. Meanwhile, the application of AMF at a dose of 5 g/plant and 0 g/plant produced fewer leaves.

The increase in the number of leaves in the AMF treatment of 10 g/plant and 15 g/plant may be due to the optimal absorption of nutrients from the soil by plants so that the nutritional needs of plants are met and vegetative growth, including plant height (Table 1), increases. This is in accordance with the opinion of Lakitan (1993), which states that leaf formation is closely related to plant height. The taller the plant, the more leaves are formed because leaves emerge from the nodes on the stem.

In addition, the addition of AMF also increases the number of roots, which affects the capacity of the roots to absorb and translocate nutrients to all parts of the plant. This increase in root function has a direct impact on plant growth, including an increase in the number of leaves. This is in line with the opinion of Nihayatie (1987), which states that the rise in the number of leaves is influenced by the availability of nutrients, especially nitrogen (N). Nitrogen plays an essential role in plant cell formation, chlorophyll synthesis, protein, and amino acids, which support optimal leaf growth and development.

### Leaf Area

Based on the results of the analysis of variance of the leaf area of pakcoy plants at the age of 4 weeks after planting, it shows that the application of AMF with various doses has a significantly different effect on the leaf area of pakcoy plants. Data on the leaf area of pakcoy plants can be seen in Table 3.

Table 3. Leaf Area of Pakcoy Plants at Several Doses of AMF Age 4 weeks after planting

| Dose of AMF (g/plant) | Leaf Area (cm <sup>2</sup> ) |
|-----------------------|------------------------------|
| 0                     | 68,13 b                      |
| 5                     | 80,53 b                      |
| 10                    | 127,21 a                     |
| 15                    | 128,75 a                     |

Diversity Coefficient = 11,73%

Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% real level.

Data in Table 3 shows that the application of AMF with various doses affects the leaf area of pakcoy plants. The largest leaf area was obtained in the AMF treatment with a dose of 15 g/plant. However, the application of AMF with a dose of 10 g/plant gave an effect that was not significantly different from the dose of 15 g/plant, so the dose of 10 g/plant can be considered as the optimal dose in increasing the leaf area of pakcoy. Overall, the results showed that the higher the dose of AMF given, the wider the leaves produced.

The increase in leaf area is likely caused by the role of AMF in increasing the efficiency of nutrient absorption by plant roots, including in hard-to-reach parts. With increased nutrient uptake, plant nutritional needs are met, which in turn supports plant growth, including leaf area. According to Lone et al. (2015), the uptake of nutrients such as nitrogen, phosphorus, and other microelements can be enhanced through the

addition of mycorrhiza, which contributes to an increase in plant leaf area.

In addition, Sbrana et al. (2014) explained that mycorrhizal symbiosis can modify primary and secondary metabolism in host plants, which has an impact on increasing the production of photochemical compounds in roots and leaves. This is in line with the research of Mohammadi et al. (2011), which states that mycorrhiza can be symbiotic with rhizobium, and this symbiosis plays a role in increasing nitrogen availability for plants.

#### Stem Diameter

The results of the F test showed that the application of AMF with several doses had a significantly different effect on the stem diameter of pakcoy plants. Data on stem diameter of pakcoy plants can be seen in Table 4.

Table 4. Stem Diameter of Pakcoy Plants at Several Doses of AMF Age 4 weeks after planting

| Dose of AMF (g/plant) | Stem Diameter (mm) |
|-----------------------|--------------------|
| 0                     | 3,75 c             |
| 5                     | 4,67 b             |
| 10                    | 5,83 a             |
| 15                    | 6,22 a             |

Diversity Coefficient = 10,48%

Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% real level.

The data in Table 4 shows that the application of AMF with various doses has different effects on the diameter of pakcoy plant stems. The application of AMF at a dose of 15 g/plant produced the most prominent stem diameter compared to the other treatments, namely doses of 10 g/plant, 5 g/plant, and 0 g/plant. This shows that the application of AMF 15 g/plant is able to increase the stem diameter of pakcoy plants more optimally. Overall, the results showed that the higher the dose of AMF given, the greater the stem diameter produced.

The increase in stem diameter is thought to be caused by AMF colonization of plant roots, which increases nutrient availability. Better nutrient availability stimulates cell enlargement and the development of plant tissues, including the stem. Munawar (2011) states that nutrient uptake by plants determines the continuity of metabolic processes, thus having a positive impact on the growth and development of stem diameter.

In addition, the presence of AMF also plays a role in improving the structure of the growing medium by increasing root penetration into the soil. Mycorrhizal

hyphae that develop around the roots expand the root absorption area and make it easier for plants to absorb nutrients, even from the smallest soil pores that are difficult to reach by plant roots. According to Salisbury and Ross (1995), stem diameter growth occurs due to the division and development of cambium vessel cells, which are strongly influenced by the supply of nutrients from the growing medium. If the supply of nutrients is hampered, the photosynthesis process will also be disrupted, which in turn inhibits the formation of new

cells in the meristematic tissue and has an impact on the growth of plant stem diameter.

### Fresh Weight of Crown

Analysis of variance using the F test at the 5% level showed that the application of several doses of AMF gave a significantly different effect on the fresh weight of pakcoy plant crowns. Data on the fresh weight of the pakcoy plant can be seen in Table 5.

Table 5. Fresh Weight of Pakcoy Plant Canopy at Several Doses of AMF Age 4 weeks after planting

| Dose of AMF (g/plant) | Fresh Weight of Crown (g) |
|-----------------------|---------------------------|
| 0                     | 71,06 c                   |
| 5                     | 87,70 b                   |
| 10                    | 112,86 a                  |
| 15                    | 121,48 a                  |

Diversity Coefficient = 10,06%

Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% real level.

The data in Table 5 shows that the application of AMF at a dose of 15 g/plant produces the highest crown fresh weight, which is 121.48 g. Meanwhile, the plants given AMF at a dose of 15 g/plant produce the highest crown fresh weight. Meanwhile, plants treated with AMF at a dose of 10 g/plant showed results that were not significantly different from the 15 g/plant treatment. In contrast, plants without AMF (0 g/plant) had the lowest crown fresh weight.

Crown fresh weight is closely related to other growth parameters, such as plant height, number of leaves, and leaf area. In this study, the taller the plant and the more and broader the leaves, the greater the crown fresh weight. This shows that the application of AMF is able to increase the growth of pakcoy plant crowns better because the nutrients needed by plants are available in sufficient quantities.

Optimal nutrient fulfillment will increase the photosynthesis process so that plant growth, especially

crown parts such as leaves, will be maximized. This is in line with the opinion of Muis et al. (2012), who state that plants given biological agents such as AMF have a larger surface area and a more significant number of leaves, thus supporting the photosynthesis process. In addition, Prawinata et al. (1981) explained that the fresh weight of plants reflects the content of nutrients and water in plant tissues. The success of plant growth is primarily determined by its ability to absorb water and nutrients from the growing media.

### Root Fresh Weight.

Based on the results of the analysis of variance of the fresh weight of pakcoy plant roots at the Age of 4 weeks after planting, it shows that the provision of several doses of AMF gives a significantly different effect on the fresh weight of pakcoy plant roots. Data on the fresh weight of pakcoy plant roots can be seen in Table 6.

Table 6. Fresh Weight of Pakcoy Plant Roots at Several Doses of AMF Age 4 weeks after planting

| Dose of AMF (g/plant) | Root Fresh Weight (g) |
|-----------------------|-----------------------|
| 0                     | 6,68 b                |
| 5                     | 87,70 b               |
| 10                    | 112,86 a              |
| 15                    | 121,48 a              |

Diversity Coefficient = 12,12%

Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% real level.

Based on the data in Table 6, it can be seen that the application of AMF with a dose of 15 g/plant produces the highest root fresh weight. However, this result was not significantly different from the AMF treatment at a dose of 10 g/plant. This indicates that the dose of 10 g/plant is the optimal dose for increasing the fresh weight of pakcoy plant roots. Meanwhile, plants without AMF treatment (0 g/plant) had the lowest root fresh weight, which was 6.68g.

The increase in root fresh weight in AMF-inoculated plants is thought to be caused by the rise in the number and volume of roots due to AMF colonization. Fitter and Hay (1998) stated that root fresh weight is highly dependent on the volume and number of roots, where the greater the number of roots formed, the greater the root volume, so the root fresh weight increases.

In addition to affecting the number and volume of roots, AMF inoculation also plays a role in improving soil structure and aggregates, thus supporting optimal root development. Dwidjoseputro (1994) states that

root growth and development are influenced by soil structure, moisture content, temperature, and soil nutrient content. AMF plays a role in breaking down bound phosphorus in the soil by producing phosphatase enzymes so that phosphorus that was previously difficult to make available becomes more easily absorbed by plants (Toana, 2013). This mechanism is especially beneficial in marginal soils, which generally have low nutrient content and several other limiting factors.

### Crown Dry Weight

Based on the results of the analysis of variance of the crown dry weight of pakcoy plants at the Age of 4 weeks after planting, it shows that the application of AMF with several doses gives a significantly different effect on the crown dry weight of pakcoy plants. Data on the dry weight of the pakcoy plant can be seen in Table 7.

Table 7. Dry Weight of Pakcoy Plant Canopy at Several Doses of AMF Age 4 weeks after planting

| Dose of AMF (g/plant) | Crown Dry Weight (g) |
|-----------------------|----------------------|
| 0                     | 0,91 d               |
| 5                     | 1,39 c               |
| 10                    | 2,19 b               |
| 15                    | 3,60 a               |

Diversity Coefficient = 11,37%

Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% real level.

Based on the data in Table 7, it can be seen that the application of AMF with a dose of 15 g/plant produces the highest crown dry weight of pakcoy plants. The value of crown dry weight is directly proportional to the crown fresh weight. The results showed that the application of AMF with various doses had a significant effect on the fresh weight of the crown, so it can be assumed that the increase in the fresh weight of the crown also had an impact on increasing the dry weight of the crown of pakcoy plants.

Crown dry weight is influenced by the amount of nutrients that can be absorbed by the roots and environmental conditions that support the photosynthesis process. Dwidjoseputro (1994) states that if photosynthesis takes place optimally, the photosynthate produced will be more and can be used to support the growth of various parts of the plant, including the crown.

According to Rao and Subha (1994), AMF can increase nutrient uptake, especially phosphorus, by activating the enzymes phosphatase, nitrogenase, and

dehydrogenase, making nutrients more available to plants. Phosphorus plays a vital role in the process of plant growth, as it functions in various biochemical reactions related to carbohydrate, fat, and protein metabolism, which ultimately contributes to an increase in plant dry weight. Danu et al. (2012) also stated that plants inoculated with AMF tend to have better growth and biomass because AMF plays a role in increasing the availability of nutrients so that plants are able to grow more optimally compared to plants without AMF.

### Root Dry Weight

The results of the analysis of variance of the dry weight of the roots of pakcoy plants at the Age of 4 weeks after planting showed that the application of AMF with several doses gave a significantly different effect on the dry weight of the roots of pakcoy plants. Data on dry weight of pakcoy plant roots can be seen in Table 8.

Table 8. Dry Weight of Pakcoy Plant Roots at Several Doses of AMF Age 4 weeks after planting

| Dose of AMF (g/plant) | Root Dry Weight (g) |
|-----------------------|---------------------|
| 0                     | 0,50 c              |
| 5                     | 0,61 c              |
| 10                    | 0,78 b              |
| 15                    | 0,95 a              |

Diversity Coefficient = 10,81%

*Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% real level.*

Based on the data in Table 8, the application of several doses of AMF has different effects on the dry weight of pakcoy plant roots. AMF treatment with a dose of 15 g/plant showed the best impact on root dry weight. The increase in root dry weight is related to root fresh weight (Table 6); the more significant the root fresh weight, the greater the root dry weight

produced. This indicates that the addition of AMF has a positive effect on the root growth of pakcoy plants. Delvian (2005) stated that plants with mycorrhiza have a higher dry weight than plants without mycorrhiza. In addition to increasing plant dry weight, AMF inoculation also has an impact on root dry weight.

The increase in root dry weight due to the addition of AMF shows that AMF, which forms hyphae in plant roots, is able to increase the efficiency of nutrient absorption. Several studies have shown that AMF will colonize and develop a symbiotic mutualism relationship with plant roots. The addition of AMF increases the ability of pakcoy roots to absorb water

and nutrients from the soil. This happens because the roots colonized by AMF can expand the range of roots in the process of nutrient absorption, especially phosphorus (Nasaruddin, 2012). In line with Talanca and Adnan (2005), AMF infection in plant roots can expand the root absorption field, enabling the absorption of nutrients such as P, Ca, N, Mn, K, and Mg through hyphae that develop on the root hairs.

### Root-Crown Ratio

The crown-root ratio is obtained from the comparison between the crown dry weight and the root dry weight. The observation of the root-crown ratio aims to determine the development of plants, namely the crown and roots, in the application of several doses of AMF. The results of the analysis of variance of the root-crown ratio showed that the application of AMF with several doses gave a significantly different effect on the root-crown ratio of pakcoy plants. Data on the root crown ratio of pakcoy plants can be seen in Table 9.

Table 9: Root-Crown Ratio of Pakcoy Plants at Several Doses of AMF

| Dose of AMF (g/plant) | Root-Crown Ratio (g) |
|-----------------------|----------------------|
| 0                     | 1,82 c               |
| 5                     | 2,27 b               |
| 10                    | 2,80 b               |
| 15                    | 3,78 a               |

Diversity Coefficient = 17%

*Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% real level.*

Based on the data in Table 9, the AMF dose of 15 g/plant gave the best effect on the root-crown ratio. The observation results showed that the crown dry weight (Table 7) was more significant than the root dry weight (Table 8), thus affecting the root-crown ratio. The root-crown ratio illustrates how much photosynthesis results are accumulated in plant organs. According to Gardner et al. (1991), a high root-crown ratio indicates that a larger crown is produced. However, crown and root growth can run in balance,

so the root-crown ratio does not always reflect the optimal development of plants.

Observations show that growth is more dominant in the crown (stem and leaves) compared to the roots, which indicates that photosynthate accumulates more in the crown than the roots. This is in line with the resulting crown weight (Table 5), where AMF application improves crown growth (stems and leaves) because plant nutrient needs can be met, which in turn affects plant dry weight and root-crown ratio. Sarief (1986) stated that the availability of nutrients absorbed

by plants is one of the essential factors affecting plant growth, both in the crown and roots. The root-crown ratio is a crucial factor in plant growth that reflects the ability of plants to absorb nutrients and metabolic processes that occur, including the division of photosynthate between the crown and roots.

#### Percentage of Roots Colonized by AMF

The application of several doses of AMF showed a diverse percentage of root colonization. The rate of AMF colonization obtained ranged from 0-39.37%. Data on the percentage of AMF colonization can be seen in Table 10.

Table 10. Percentage of AMF Colonization in the Roots of Pakcoy Plants at Several Doses at the Age of 4 weeks after planting

| Dose of AMF (g/plant) | Colonized root (%) | Criteria |
|-----------------------|--------------------|----------|
| 0                     | 0,00 c             | Very Low |
| 5                     | 18,75 b            | Low      |
| 10                    | 37,50 b            | Medium   |
| 15                    | 39,37 a            | Medium   |

Diversity Coefficient = 11,19%

Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% real level.

Based on the results of the analysis of variance on pakcoy plants at the age of 4 weeks after planting, it can be seen that the provision of several doses of AMF has a significantly different effect on the percentage of AMF colonized roots. Application of AMF at a dose of 15 g/plant showed a higher rate of colonization compared to the doses of 5 g/plant and 10 g/plant. Meanwhile, in plants without AMF treatment (0 g/plant), there was no colonization at all, with a percentage of 0.00, which shows a very low result. This indicates that the higher the dose of AMF given, the higher the level of AMF colonization in the roots of pakcoy plants.

In addition, the level of AMF colonization is influenced by the compatibility between AMF and the type or variety of host plants. Hadianur et al. (2016) stated that the effectiveness of AMF on host plants varies wildly, depending on the kind of AMF, the type of host plant, environmental conditions, and the interaction between AMF and compounds produced by the host plant. The ability of AMF to infect the root system of plants varies, in accordance with the findings of Budi (2014), who explained that the compatibility of AMF with its host starts from the response of fungal spores to plant roots triggered by flavonoid signals from root exudates. If the match exists, then symbiosis will be formed.

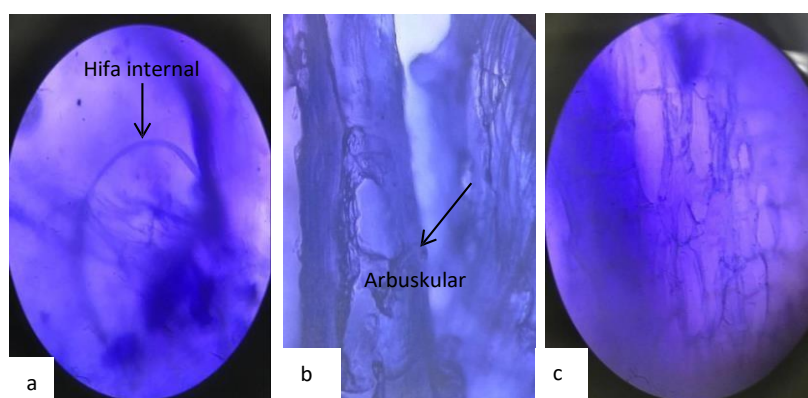


Figure 2. AMF Colonization in the Roots of Pakcoy Plants Age 4 M weeks after planting with 400x Magnification, (a).AMF colonized root, (b). Arbuscular, (c). Roots not colonized by AMF

Based on Figure 2, it can be seen that the symbiosis between AMF and pakcoy plants forms a hyphal and arbuscular network structure in pakcoy roots. In plants that are not colonized by AMF, there is only root tissue.

Hyphae play a role in absorbing water and nutrients formed from the spore germination process, while arbuscular is formed from branching hyphae that are in plant cells and function in nutrient translocation.

Hadianur et al. (2016) stated that AMF spores have different abilities in colonizing plants, which are influenced by soil type and climatic conditions around the AMF application area. Soil with low pH (acidic) is a suitable medium for AMF development, in accordance with the results of soil analysis in this study.

According to Tjondronegoro and Gunawan (2000), AMF from the *Glomus* species is proven to be better at tolerating soil acidity (pH). Based on this, the use of multisporous AMF (*Glomus* and *Accaulospora*) in this study aims to ensure that one of the spores of multisporous AMF can work well in the roots of pakcoy plants grown on marginal soils such as Ultisol.

### Relative Growth Rate

The results of the analysis of variance of the relative growth rate of pakcoy plants show that the application of AMF with several doses has a significantly different effect on the relative growth rate of pakcoy plants. Data on the relative growth rate of pakcoy plants can be seen in Table 11.

Based on the data in Table 11, it can be seen that the highest value of relative growth rate (LTR) was obtained at the AMF dosage of 15 g/plant. However, the dose of 10 g/plant had the same effect on LTR. Meanwhile, at the dose of 0 g/plant, the lowest relative growth rate was obtained. Increasing the dose of AMF can increase the value of LTR because it is influenced by nutrient uptake, which affects plant dry weight (Tables 7 and 8). This is in line with the opinion of Fitriyah (2016), which states that plant dry weight is closely related to the relative growth rate, where the increase in LTR in the plant growth phase is related to the ability of plants to absorb nutrients and water used for the formation of chlorophyll in the leaves to carry out photosynthesis. Furthermore, the photosynthate produced will be focused on plant vegetative growth and increase plant dry weight.

AMF inoculation can also improve soil structure, which has an impact on plant growth. Setyanti et al. (2021) suggested that soil with good aeration will increase LTR higher than soil with poor aeration because poor aeration can interfere with plant and root growth.

Table 11. Relative Growth Rate of Pakcoy Plants at Several Doses of AMF Age 3-4 weeks after planting.

| Dose of AMF (g/plant) | Relative Growth Rate (g/day) |
|-----------------------|------------------------------|
| 0                     | 0,39 c                       |
| 5                     | 0,50 b                       |
| 10                    | 0,59 b                       |
| 15                    | 0,62 a                       |

Diversity Coefficient = 14,28%

Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% real level.

### Net Assimilation Rate (NAR)

The results of the analysis of variance of the net assimilation rate of pakcoy plants show that the application of AMF at several doses has a significantly

different effect on the net assimilation rate of pakcoy plants. Data on the net assimilation rate of pakcoy plants can be seen in Table 12.

Table 12. Net Assimilation Rate of Pakcoy Plants at Several Doses of AMF Age 3-4 weeks after planting

| Dose of AMF (g/plant) | Net Assimilation Rate (g/cm <sup>2</sup> /day) |
|-----------------------|------------------------------------------------|
| 0                     | 0,34 c                                         |
| 5                     | 0,36 b                                         |
| 10                    | 0,41 a                                         |
| 15                    | 0,45 a                                         |

Diversity Coefficient = 10,76%

Description: Numbers followed by the same lowercase letter indicate that they are not significantly different based on the DMRT test at the 5% accurate level.

Based on Table 12, the AMF dose of 15 g/plant produced a higher NAR value compared to the AMF doses of 10 g/plant and 5 g/plant. Pakcoy plants without AMF treatment produced the lowest LAB value. The higher the dose of AMF is given, the higher

the LAB value is obtained because LAB is related to leaf area, as shown in Table 3. A large leaf area produces an enormous LAB value as well because the leaves absorb light for photosynthesis. According to Suryaningrum et al. (2016), LAB is an average measure

of leaf photosynthetic efficiency in a cultivated plant. Basri et al. (2015) also stated that if photosynthesis goes well, then plant growth will run optimally.

In addition, according to Indriana (2020), LAB in plants is influenced by various factors, such as plant type and Age, environmental conditions, light, water, chlorophyll content, temperature, and humidity. In line

with the opinion of Gardner et al. (1991), the rate of net assimilation is not only influenced by plant type, plant age, growth phase, chlorophyll content, and genetics but also by environmental conditions, especially sunlight, water, nutrients, temperature, humidity, and physical, biological, and chemical conditions of the soil.

## 4. Conclusions

Based on the results of the study, AMF application with various doses was proven to be able to increase the growth and yield of pakcoy plants. AMF application with a dose of 10 g/plant showed the best effect in improving the growth and yield of pakcoy plants

compared to other doses. To increase the productivity of pakcoy plants on marginal lands such as Ultisol, it is recommended to apply AMF treatment with a dose of 10 g/plant because this dose provides optimal results in supporting the growth and yield of pakcoy plants.

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