Effectiveness of using the dose of mycorrhiza bio–fertilizers to increase growth and production of red paprika (*Capsicum annum* L.) in Ultisol Aceh

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**Abstract.** Using dose mycorrhizal bio–fertilizers can spur the growth and production of red paprika (*Capsicum annum* L.) on Ultisol Aceh. Besides that, it can also increase root colonization by mycorrhizal and P₂O₅ uptake, which red paprika plants need to produce high growth and yield. The purpose of this research was to study the effect of dose bio-fertilizer mycorrhizal on the growth and production of red paprika in Ultisols Aceh. The research was arranged by a non-factorial randomized block design with three replications. The investigated factor was the dose of bio-fertilizer mycorrhizal from local specific strain mixing between *Glomus mosseae* and *Gigaspora sp*. The dose of the mycorrhizal bio-fertilizer used was control (without mycorrhizal) of each plant, 5, 10, and 15 gram. The observed parameters were plant height and stem diameter of red paprika at 15, 30, and 45 days after transplanting; additionally, the parameter of red paprika production was observed at 125 days after transplanting and P₂O₅ uptake and root colonization by mycorrhizae at 60 days after transplanting. The results showed that the best dose of mycorrhizal bio-fertilizers on growth and production, root colonization, P₂O₅ uptake was found in the treatment of doses of 10-gram mycorrhizal bio-fertilizer for each plant.

1. **Introduction**

Red paprika (*Capsicum annum* L.) is a fruit vegetable plant from the Solanaceae family. This plant has a fairly high nutritional value in terms of nutrition. Paprika contains a large amount of vitamin C and provitamin A, where the concentration of vitamin C ranges from 63 to 243 mg/100 g of paprika [1]. The current market demand for paprika commodities is increasing both from the local market to the international market. Based on the [2], paprika production in the last five years has tended to decline. Many factors can cause the decline in paprika production, for instance, the limited use of biological fertilizers, low soil fertility, and the impact of excessive use of inorganic fertilizers. Inorganic fertilizers have a negative effect and can create changes in soil structure, compaction, decreased nutrient content,
and environmental pollution. Continuous application of this fertilizer in the long term will escalate soil acidity and directly impact microorganisms in the soil. If this is allowed to advance, the level of soil fertility will decline [3]. Soil fertility is an important indicator that must be considered, as for Ultisol soils [4].

Especially in Aceh, the development of paprika has great potential and can be carried out on Ultisol soil. The main obstacle in using Ultisol is the low pH and low nutrients that plants can utilize. Actions to increase soil fertility by using biological fertilizers need to be done. In general, the characteristics of Ultisol soils include having a low pH, low cation exchange capacity, low base saturation, low nutrient content such as N, P, K, Ca, and Mg, and high Al-contents, resulting in the unavailability of sufficient nutrients for plant growth. The central concept of Ultisols (last Ultimus) is red-yellow soils, which have undergone the ultimate process of climate destruction, resulting in this type of soil having an inner cross-section (> 2 m), indicating an increase in clay content and accumulating called argillic horizon [5]. Using mycorrhizae, it is hoped that P deficiency in Ultisol can be overcome and N and K. Besides that, mycorrhizae also act as a selective membrane to reduce exposure of plant roots to heavy metals, for instance, Al, by reducing the amount of Al absorbed biologically in plant tissues [6]; [7].

Mycorrhizae are organisms from the fungus group and have a symbiotic mutualism between fungi and plant roots [8]. This bio-fertilizer can also act as a biological barrier against root pathogen infection, increase plants' water availability, and increase growth-inducing hormones [9]. Mycorrhiza can also increase the growth and yield of chili crops on Entisol soils [10], efficient fertilizer up to 20-25% N, P fertilizer [11], and can expand the nutrient uptake area for plants [12]. Mycorrhizae have great potential as biological fertilizers because they are microorganisms that have an important role in absorbing nutrients in the soil to increase plant growth and yields [13].

The study results by [9] suggested that to increase P nutrient uptake in drought stress conditions, 10 g of mycorrhizal inoculum was recommended, especially for chili crops. Furthermore, the results of research on various marginal lands in Indonesia show that the application of biological fertilizers such as arbuscular mycorrhiza fungi (Glomus sp. and Gigaspora sp.) can increase the production of various crops (soybeans, peanuts, tomatoes, and rice) as well as the availability of nutrients for plants by between 20% -100% [14], [3]. Therefore, it is necessary to research to determine the effectiveness of mycorrhizal as biological fertilizers on the growth and production of paprika crops and root colonization by mycorrhizae for the P-availability for Ultisol soils in Aceh.

2. Materials and methods

This research was carried out at the Green House, Horticulture Laboratory, Soil and Plant Laboratory, Faculty of Agriculture, Syiah Kuala University, from March to July 2021. The tools used in this study were hoe, pots with 12 kg soil volume, label paper, analytic scale, watering pots, transparent plastics, sieves, hand sprayers, tarpaulin, object-glass, a caliper, glass slides, autoclave, tape measurement, microscope, camera. And writing tools.

The materials used in this study were paprika seeds of the Red Star F1 variety. Mycorrhiza biofertilizer of mixed genus Glomus mosseae + Gigaspora 360 g. Ultisol soil, NPK Mutiara (16:16:16), manure, organic pesticides, KOH solution with a concentration of 10%. Active insecticide profenofos and azoxystrobin difenoconazole, fungicide with active ingredients: Azoxystrobin difenoconazole and aquades.

The design used in this study was a non-factorial randomized block design (RBD) with 3 replications. Mycorrhiza dose factor (D) consisted of 4 levels each plant, namely: D0 = 0 gram, D1 = 5 gram, D2= 10 gram, D3 = 15 gram. To determine the effect of treatment factors on the growth and production of paprika and other parameters, it was tested by analysis of variance at a probability level of 0.05. The analysis of variance showed a significant treatment effect at the 5% level; then, further tests were carried out on the average value of the treatment to determine the difference between treatments using the Fisher’s LSD test (Fisher’s Least Significant Difference Test) procedure.
2.1 Propagation of Mycorrhiza Bio-fertilizers

Mycorrhiza bio-fertilizers used in this study were mycorrhiza genus *Glomus mosseae* and *Gigaspora* sp obtained from mycorrhiza propagation at the Mycorrhiza House, Faculty of Agriculture, Syiah Kuala University.

The methods used in the implementation of mycorrhiza propagation are:

a. The soil was sifted using a 9 mesh sieve to make it smooth and not mixed with gravel; then, the soil was put into 12 plastic bags, each bag containing 10 kg.

b. Then the soil was sterilized using an autoclave at a temperature of 121ºC for 30 minutes to eliminate all microorganisms in the soil.

c. The soil that is ready to be sterilized is put into a pot for planting media. The host plant used for the propagation of mycorrhiza bio-fertilizer is corn crops.

d. After the soil is ready, a planting hole is made, and 5 g of mixed mycorrhiza starter is added to each pot, then two corn seeds are added per planting hole and then covered with soil.

e. After the plants were 45 days after planting, the corn plants were topped by cutting the upper leaves 1/3 of the part; then, the plants were left stressed and not watered with the aim that mycorrhizae could form spores on the roots of corn plants.

f. After the corn plant underwent a stressing process for 1 month and the plant became dry, the plant was dismantled in the root area then cut the fine roots with a size of 1 cm; then, the roots were mixed with zeolite media.

g. Biofertilizer is ready to be applied to paprika crops.

2.2 Preparation of planting media

2.2.1. Seed media preparation. The seedbed media used were ultisol soil and manure with a ratio of 2:1. The media was sifted to make it smooth and then mixed evenly. Next, the mixed media was put into a polybag for a paprika seedling.

2.2.2. Seed planting media. The medium for planting seeds for transplanting is Ultisol soil (topsoil) from Blang Bintang, Aceh Besar. Ultisol soil is cleaned first from grasses and plant roots. Then the soil is put into a pot with a volume of 10 kg of soil and then mixed with manure at a dose of 270 g each pot.

2.2.3. Seedling and mycorrhiza applying. Seeds were sown in polybags with a size of 15 cm x 10 cm. Planting holes made with a depth of 2 cm. The application of mycorrhiza bio-fertilizer was carried out at half of the dose tested for each plant, namely 0 (without mycorrhiza), 5, 10, and 15 gram. The paprika seeds must be directly contacted with a mycorrhiza bio-fertilizer to facilitate mycorrhiza symbiosis with plant roots at the time of seeding. Furthermore, the seeds that have been planted are stored and covered with plastics (*sungkop*) that have been prepared.

2.2.4. Mycorrhiza planting and applying. Seedlings are ready to be transplanted after 30 days with the characteristics of having 4-5 leaves. At the planting time, specifically for a dosing plant of 0 g, mycorrhizae were not given. Furthermore, planting is done by applying half the dose of mycorrhiza bio-fertilizer from a dosing plant of 5, 10, and 15 gram because at the time of seeding, the seeds have been given half of the dose tested. Seedlings are placed in planting holes that have been applied with mycorrhiza and then covered with soil. Planting is done in the afternoon to avoid stress. Seedlings are maintained in a greenhouse until harvest.

2.2.5. Fertilization. Mutiara NPK fertilizer (16:16:16) is applied two times. The first NPK Mutiara was applied after transplanting the plants into pots as much as a dosing plant of 1.31 gram (0.65 g each pot). The second fertilization dose is used at the age of 45 days after transplanting. The steps to make a
fertilizer solution are to weigh 0.65 g each pot of fertilizer and then dissolve it in 250 ml of water. Fertilization is applied by pouring around the plant roots.

2.3. Plant maintenance
Seedling replanting is done to replace plants that die after transplanting. Seedling replanting is performed for 5-7 days after transplanting. Watering is done once a day in the morning by using watering pots. Weed cleaning is done by cleaning the grasses that grow around the paprika crops in pots. The installation of stakes is carried out using bamboo with a length of 120 cm, which supports the paprika crops and avoids the crops falling. The installation of stakes is carried out at the age of 15 days after transplanting. The removal of water shoots is carried out after the plant is 7-30 days of transplanting by removing the shoots that grow at the base of the leaf stalk. Controlling of trip pests that attack paprika crops uses insecticides with the active ingredients profenofos and azoxystrobin difenoconazole. Diseases that attack paprika crops in the field, such as anthracnose fruit rots (Colletotrichum gloeosporioides), were controlled with a fungicide with the active ingredient Azoxystrobin difenoconazole. Harvesting is carried out at the age of 105 to 125 days after transplanting (5-time harvesting) at 5-days intervals. The main criteria for harvesting are marked with red color fruit of paprika. Harvesting is done by picking the fruit.

2.4. Parameters
Observation of plant height by measuring from the base of the main stem to the highest growing point. Plant height measurements were carried out at 15, 30, and 45 days after planting. Stem diameter was observed at the age of 15, 30, and 45 days after transplanting by measuring the paprika plant stem base using a caliper. Observations were made by counting the number of plant branches that produce flowers and fruits. Observations were made when the plants were 60 days after transplanting. Weighing of wet plant weight was carried out after the 4th harvest at 125 days after transplanting. The dry weight of the plant was weighed after the plant was placed in the oven for 2 x 24 hours at a temperature of 60°C or reached a constant weight. Weighing is done using an analytical scale. The weighing of plant roots was carried out after the plants at the age of 125 days after transplanting. The dry weight of the plant roots was weighed after the roots were in the oven for 2 x 24 hours at a temperature of 60°C or reached a constant weight.

Calculation of fruit weight per plant was carried out after the paprikas were harvested, at the age of 105, 110, 115, 120, 125 days after transplanting by weighing the paprika using an analytic scale. Measurements were carried out for 5 harvests with an interval of 5 days. The number of fruits counted as those harvested at 105, 110, 115, 120, and 125 days after transplanting. Calculation of the number of fruit crops by adding the first harvest to the fifth harvest. The percentage of roots infected with mycorrhizae was observed using a microscope (45 days after transplanting) based on the Nirmalasari method (2005) [15]. Former soil analysis was carried out before the soil was used for planting. The final soil analysis is carried out after the plants are ready to be harvested. Each soil sample per pot was taken approximately 500 g and sieved using a 0.5 mm sieve, then dried for 7 days. P-available soil analysis was carried out using the Bray II method.

3. Results and discussion
3.1 Effect of mycorrhizal dose on growth and yield of paprika in ultisol soils
The average paprika crop growth and production parameters, root colonization, P₂O₅ uptake with mycorrhiza dose treatment after being tested with Fisher’s LSD test (Fisher’s Least Significant Difference Test) 0.05 can be seen in Table 1.
Table 1. Average growth and production of paprika crops, root colonization, P$_2$O$_5$ uptake in mycorrhizal doses

| Parameters                                      | Mycorrhiza Dose (g) | Fisher’s LSD |
|------------------------------------------------|---------------------|--------------|
| Plant height 15 DAP (cm)                       | 0 (D0) 5 (D1) 10 (D2) 15 (D3) | 0.05         |
| Plant height 30 DAP (cm)                       | 17.64 ab 23.48 b 33.11 c 19.65 ab | 4.94         |
| Plant height 45 DAP (cm)                       | 37.12 ab 52.32 a 41.75 c 39.49 bc | 4.17         |
| Stem diameter (cm) 15 DAP (mm)                 | 4.41 4.11 5.18 4.52        | -            |
| Stem diameter (cm) 30 DAP (mm)                 | 6.85 7.51 7.80 7.58        | -            |
| Stem diameter (cm) 45 DAP (mm)                 | 9.07 9.84 9.86 9.46        | -            |
| Number of productive branches (branches)       | 8.50 a 9.00 ab 10.67 c 9.67 bc | 1.16         |
| Number of fruits each plant (fruits)           | 5.83 a 9.17 b 11.00 c 7.50 ab | 1.72         |
| Fruit weight each plant (g)                    | 219.38 a 424.58 b 495.88 b 229.08 a | 83.75        |
| Plant wet weight (g)                           | 110.25 a 130.23 b 131.98 b 115.55 a | 14.50        |
| Plant dry weight (g)                           | 44.61 a 49.89 bc 51.32 c 46.02 ab | 5.16         |
| Wet weight of plant roots (g)                  | 15.45 a 19.16 b 19.76 b 16.02 a | 2.02         |
| Dry weight of plant roots (g)                  | 5.13 a 7.67 b 8.11 b 5.16 a | 1.19         |
| Root colonization (%)                          | 1.28 a 63.43 b 76.72 c 63.43 b | 9.15         |
| Former P-availability                          | 39.24 a 42.09 b 43.28 b 42.11 b | 1.62         |
| Final P-availability                           | 40.29 a 44.18 b 45.32 c 44.16 b | 1.62         |

Note: Numbers followed by the same letter in the same row are not significantly different at the 0.05 level (Fisher’s LSD test)

Table 1 shows the plant height at 15, 45 days after planting, root colonization (%), and the highest available soil P-availability (Former and Final tests) was found in the 10 gram each plant mycorrhizal dose treatment, which was significantly different from other treatments. This was also followed by plant height at 30 days after transplanting but not significantly different from the mycorrhizal dose of 15 gram each plant. Then the diameter of the stems aged 15, 30, and 45 days after planting tended to be larger, and found that there was a treatment of 10 gram each plant compared to other treatments. Furthermore, the number of productive branches was higher at the mycorrhizal dose of 10 gram each plant. It was not significantly different from the mycorrhizal dose of 15 gram each plant and significantly different from other doses. The highest initial available P was found at a dose of 10 gram each plant but not significantly different at 5 and 15 gram each plant. In the parameters of the number of fruit planted, root colonization and the highest final available P were found at a dose of 10 g per plant and significantly different from other doses. While the other parameters found the highest yield at a dose of 10 gram for each plant and not significantly different at a dose of 5 gram for each plant.

The results showed that the best dose of mycorrhizal biofertilizer was 10 gram each plant on the growth and production parameters of paprika crops. However, some parameters were not significantly different from other doses. The dose of 10 gram each plant is the ideal dose of mycorrhizal biofertilizer.
for the growth of chili and several other commodities [9]; [16]. Furthermore, paprikas and chilies are plants with similar traits and characteristics. The dose of mycorrhizal biofertilizer was effective in increasing the growth and yield of paprika crops. This is in line with research by [17] and [13], where a mycorrhizal dose of 10 gram each plant was able to increase the growth and yield of chili and patchouli crops on Andisol soils [18-20].

The best root colonization parameters were also found at a dose of 10 gram each plant, significantly different from other treatments. The colonization rate is categorized as very high, which means that mycorrhizae can play an active role in problematic soil conditions such as Ultisol soils deficient in P-bound elements. This is certainly directly related to the P-available soil parameter, which has a very significant effect on increasing the availability of P in the soil for plants, because mycorrhizae show a response to phosphate reactions bound by Al and Fe through the role of mycorrhizae by producing phosphatase enzymes and organic acids such as oxalate to improve availability of P in the soil for plants [3]; [9]. The diameter of the stems aged 15, 30, and 45 days after transplanting did not show a significant effect between each treatment. It is presumed that the diameters of plants generally do not differ due to the influence of internal and external factors in supporting the physiological processes of the plants, which are relatively the same and do not show significant differences. This is in line with several studies by [13].

4. Conclusions
From this research, the best growth and production results for growth, production, root colonization, and P$_{2}$O$_{5}$ uptake were obtained at a dose each of 10-gram mycorrhizal biofertilizer plant; however, it is necessary to research Ultisol soil in the field.

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