Vermicompost and arbuscular mycorrhiza application on growth and yield of *Artemisia annua* in the low land

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**Abstract.** *Artemisia annua* L. is a medicinal plant that used to treat malaria. This plant contains artemisinin which can be used to remove parasites Plasmodium falciparum that cause malaria. The aim of this research was to observe the effect of Vermicompost and mycorrhiza on the growth of *Artemisia* (*Artemisia annua* L.). This research used Completely Randomized Design (RCD) with two factors and three times repetitions. The first factor was Vermicompost fertilizer doses: 0, 50, 100, 150 g plant\(^{-1}\) and the second factor was mycorrhiza doses: 0, 10, 20 g plant\(^{-1}\) which made 12 treatment combinations. The observed variables were plant height, total number of branches, days to flowering, root length, root volume, plant fresh weight, plant dry weight, and root infection percentage. Results showed Vermicompost fertilizer of 150 g plant\(^{-1}\) significantly affected plant height, number of branches, days to flowering and root volume. Mycorrhiza of 20 g plant\(^{-1}\) increased plant height, root length, root volume and root infection mycorrhiza. Both Vermicompost fertilizer and mycorrhiza at various treatment doses did not affected the fresh and dry weight of plants. There was no interaction between Vermicompost fertilizer and mycorrhiza on all variables.

**1. Introduction**

*Artemisia annua* L. is a medicinal plant to overcome malaria that has been resistant to quinine [1]. Artemisinin content found in the leaves of this plant. Lestari et al. [2] stated that on the back of the leaves there are trichomes where artemisinin accumulates.

Artemisia widely grown on the plateau, in Indonesia Artemisia plants can grow well in Tawangmangu with an altitude of 1,500 m or above. In addition to the highlands, these plants need to be cultivated in the lowlands to support artemisinin production. To speed up the production process of artemisin required an effort that is able to increase the growth and development phase. One effort that can be done with the provision of organic fertilizer that serves to support the adequacy of nutrients to the growth *Artemisia annua* plants.

Vermicompost fertilizer is an organic material rich in nutrients that can improve the physical, chemical, and biological properties of the soil [3]. In addition, the use of Vermicompost fertilizer can also be combined with the utilization mycorrhiza. Mycorrhiza can help to improve the absorption of Phosphorus (P) nutrient by plants [4].
Mycorrhizae infects the root system of host plants and helped in nutrient uptake and water absorption. Based on the description above, this study aimed to determine the growth response of *Artemisia annua* on the lowlands with the provision of Vermicompost and arbuscular mycorrhiza fertilizer.

2. Methods
This research was conducted from July 2017 to February 2018 and located in Jengglong Village, Karanganyar Regency, Central Java with altitude of 157 m asl. The experiment using Completely Randomized Design (RCD) with 2 factors. The first factor was the dose of Vermicompost fertilizer consisted of 4 levels: 0, 50, 100, and 150 g/plant. The second factor was mycorrhizae inoculation dose consisted of 3 levels: 0, 10, and 20. There were 12 treatment combinations and repeated 3 times so that 36 experimental units were obtained. Observed variables included plant height, number of branches, days to flowering, root length, root volume, plant fresh weight, plant dry weight, and mycorrhizal infection percentage. The results were analyzed using Analysis of Variant and if there were any significant result continued with Duncan’s Multiple Range Test (DMRT) with 95% confidence level.

3. Result and discussion
3.1. General condition research
The nursery stage is done in Tawangmangu with geographic location 7°39,8'80 "LS and 111°07,8'81" BT. The nursery location was 1062 meters above sea level, at temperatures ranging from 19˚C - 23˚C. After the seeds were about 4 to 5 weeks the plants were transferred to land located in Popongan, Karanganyar with geographical location of 7°36'06.8 "LS and 110°58'59.2" BT, 218 meters above sea level. Conditions of micro climate measured in the temperature of space. The lowest temperature is 21˚C and the highest temperature is 27˚C.

3.2. Growth variables
Plant height is a variable that is often used as a growth indicator or as a parameter in measuring the effect of treatment or as an indicator to determine the influence of the environment. The number of branches is closely related to the number of leaves formed. The number of leaves will increase along with the increase in the number of branches. In this case the leaves are important because in Artemisia, 89% of the artemisinin content is found in the leaves [5]. The flowering period is the change in the vegetative period to generative. Table 1 shows that the dosage of Vermicompost fertilizer has a significant effect on plant height, number of branches and days to flowering of Artemisia plants.

| Vermicompost dose (g/plant) | Height of plant (cm) | Number of branches | Flowering age (days) |
|---------------------------|----------------------|--------------------|----------------------|
| 0                         | 84.47a               | 1.00a              | 81.55c               |
| 50                        | 86.79a               | 1.22a              | 72.00bc              |
| 100                       | 92.43a               | 1.33ab             | 52.33ab              |
| 150                       | 106.03b              | 1.88b              | 42.55a               |

The highest average of plant height is in the treatment with fertilizer dosage of 150 g/plant (106.03 cm), while the lowest average height of the plant was found in treatment 0 g/plant Vermicompost (84.47 cm). From the results it can be seen that Vermicompost gives high yields of plants that increase along with the addition of dosage of Vermicompost given.

Vermicompost fertilizer can increase vegetative growth that is plant height [6]. The application of Vermicompost stimulates the plants to grow more fertile and higher than the plants without Vermicompost [7]. In line with the statement of Manivannan et al. [8] that the application of
Vermicompost into the soil can increase the soil organic matter because Vermicompost is an organic fertilizer that contains high organic matter and increased microbial activity so as to increase the growth of plants.

The application of Vermicompost showed significant effect on the number of branches. Table 1 shows that the highest average number of branches is in the treatment with 150 g/plant Vermicompost (1.88). This is because the plant is able to well-absorb the Nitrogen (N). High Nitrogen uptake can increase vegetative growth including the formation of new branches [9].

Flowering time is closely related to the transition from the vegetative phase to the generative phase of the plant [10], in general flowering time can be a reference as sign that the plant has entered the generative phase. According to Jagadish et al. [11] the sign plant entering flower stage can be seen visually when the anthers are open and the flowers bloom. The results showed that the dosage of Vermicompost had significant effect to the first time the flower emerged, while the mycorrhiza did not. There is no interaction from both treatment

Table 1 showed that the fastest flowering stage is reached by treatment Vermicompost 150 g/plant with average time 42.55 DAP, while the treatment Vermicompost 0 g/plant placed the latest (81.55 DAP). It can be concluded that the average flowering will be faster along with the increasing dose of Vermicompost fertilizer. Vermicompost improves the growth and development of plants because it contains various nutrients, especially phosphorus; it is the phosphorous that can accelerate flowering [12]. Table 2 shows the mycorrhizal dose has a significant effect on the height of the Artemisia plant.

Table 2. The effect of Artemisia annua dose on the average of plant height (cm), number of branches and flowering age (days) at 11 weeks of age.

| Mycorrhiza dose (g/plant) | Height of plant (cm) | Number of branches | Flowering age (days) |
|--------------------------|----------------------|--------------------|----------------------|
| 0                        | 80.51\textsuperscript{a} | 1.16\textsuperscript{a} | 50.75\textsuperscript{a} |
| 10                       | 95.65\textsuperscript{b} | 1.33\textsuperscript{a} | 64.33\textsuperscript{a} |
| 150                      | 101.13\textsuperscript{b} | 1.58\textsuperscript{a} | 71.25\textsuperscript{a} |

Based on Table 2, mycorrhizal dose of 20 g/plant showed the highest average plant height (101.13 cm), not significantly different with dose 10 g/plant treatment(95.65 cm). Increased plant height is affected by mycorrhizal infections, making the rooting conditions of the plant better. Good rooting conditions are because mycorrhiza was able to increase the extent of nutrient uptake available in soil by external hyphae. Muis et al. [13] suggested that external hyphae is the most important part of mycorrhizal because this hyphae will help to increase the absorption of nutrients, especially phosphorus. In accordance with the research of Shabnam and Iqbal [14] that phosphorus applied to plants is able to give effect to plant height.

3.3. Biomass

The plants’ fresh weight shows the level of water uptake and nutrients absorbed by the plant for the metabolism which resulting in increased fresh weight. Plants’ dry weight is one indicator for the quantity of plant growth. The plants’ dry weight shows the result of photosynthesis due to the interception of solar energy by plants [15]. Table 3 shows that the plants’ fresh and dry weight observed showed no significant effect for all treatments.

Table 3. The effect of Vermicompost dose on the average fresh weight and dry weight (g) of Artemisia annua plants

| Vermicompost dose (g/plant) | Fresh weight of plant (g) | Dry weight of plant (g) |
|-----------------------------|---------------------------|-------------------------|
| 0                           | 65.33\textsuperscript{a}  | 17.00\textsuperscript{a} |
| 50                          | 71.11\textsuperscript{a}  | 16.89\textsuperscript{a} |
| 100                         | 64.32\textsuperscript{a}  | 17.11\textsuperscript{a} |
| 150                         | 90.11\textsuperscript{a}  | 19.66\textsuperscript{a} |
Based on Table 3 and 4 the combination treatment of Vermicompost fertilizer 150 g/plant and mycorrhizal 10 g/plant resulted the highest average fresh weight of plant that is 90.11 grams and 91.66 grams. These results are suitable with the research of Herlina et al. [16] which states that the dose of Vermicompost 150 g/plant gives the highest yield of fresh weight of soybean (Glycine max L. Merril). [17] Addition of mycorrhizal inoculum 10 g/plant can increase nutrient uptake P (phosphorus).

**Table 4.** The effect of mycorriza dose on the average fresh weight and dry weight (g) of Artemisia annua plants

| Mycorriza dose (g/plant) | Fresh weight of plant (g) | Dry weight of plant (g) |
|-------------------------|---------------------------|-------------------------|
| 0                       | 57.66a                    | 14.67a                  |
| 10                      | 91.66a                    | 21.58a                  |
| 20                      | 68.83a                    | 16.75a                  |

The treatment dose of Vermicompost 150 g/plant and mycorrhiza 10 g/plant in Table 3 and 4 resulted the highest average dry weight of plant (19.66 grams and 21.58 grams). The difference in dry weight of plant is at how much nutrients absorbed by the plant. Fresh weight of plant and dry weight of plant plays an important role in plant growth, because plants can grow steady if fresh weight and dry weight of plants is high [18].

3.4. Root growth

Root is an organ which is important for the growth and development of plants. Based on Table 5 the treatment of Vermicompost dose significantly affected the root volume, but it has no influence on the root length. There was no interaction between the dosage Vermicompost and mycorrhiza on both variables.

**Table 5.** The effect of Vermicompost dose on the average volume of plant roots (cm$^3$) and root length(cm)

| Vermicompost dose (g/plant) | Root volume (cm$^3$) | Root length (cm) |
|-----------------------------|----------------------|-----------------|
| 0                           | 16.11a               | 27.44           |
| 50                          | 15.55a               | 23.00           |
| 100                         | 15.00a               | 27.77           |
| 150                         | 24.77b               | 32.44           |

Root volume an important variables of plant growth because the roots serve as the foundation of stems, nutrient absorbers, minerals and water from the soil. The root is a vegetative organ that supply water, minerals and materials that are essential for the growth and development of plants [19].

Based on Table 5 the best response for the average root volume is at the dose of 150 g/plant. Vermicompost gives a significant effect because it contains very high Nitrogen. According to Samavatipour et al. [20] the availability of Nitrogen in large quantities will facilitate plant metabolism and will eventually affect the growth of organs such as stems, leaves, and roots. Table 6 shows the dose of mycorrhizal effect on the variables of root volume and root length variables.

**Table 6.** Mean volume of plant roots (cm$^3$) and root length(cm) Artemisia annua on mycorriza dose treatment

| Mycorriza dose (g/plant) | Root volume (cm$^3$) | Root length (cm) |
|-------------------------|----------------------|-----------------|
| 0                       | 13.75a               | 22.50a          |
| 10                      | 18.33ab              | 26.83ab         |
| 20                      | 21.50b               | 33.66b          |

Based on Table 6 the highest average root volume was on dose mycorrhizal 20 g/plant that is 21.50 cm$^3$ and the average of the lowest root volume at dosage of 0 g/plant 0 is 13.75 cm$^3$. The results show that the higher the given dosage of mycorrhiza cause the average root volume is also higher. This is supported by Sitanggang et al. [21] which states that the volume of roots increases through the
addition of mycorrhizal inoculants. The addition of mycorrhizal will increase the ability of plant roots to increase water uptake and nutrients.

The next observed variable is the root length. **Table 6** shows that the highest root length was produced in mycorrhizal inoculation doses of 20 g of plant-1 with an average of root length 33.66 cm. The length of the shortest root is in the treatment without mycorrhizal or dose 0 g/plant with an average of 22.50 cm. These results proved that the higher the dose of mycorrhizal given would increase the root length of the plant. It is related to the function of mycorrhizal that cooperate with plant roots. Research Wicaksono et al. [22] explains that mycorrhizal symbiosis with plant roots can increase long growth of plant roots.

### 3.5. **Mycorrhiza infection**

The percentage of mycorrhizal infection in plant roots was estimated using the root painting method. The results showed that mycorrhiza significantly affected root infections, but Vermicompost and the interaction between Vermicompost and mycorrhizae had no significant effect. **Table 7** shows the dose of mycorrhizal effect on Artemisia root infections.

| Mycorrhiza dose (g/plant) | Mycorrhizal infection (%) |
|---------------------------|---------------------------|
| 0                        | 10.33^a                    |
| 10                       | 14.66^a                    |
| 20                       | 32.33^b                    |

Based on **Table 7**, the highest root infections were 32.33% at dose of 20 g/plant; whereas at the dosage of 0 g/plant showed the lowest root infection (10.33%). This suggests that the more doses of mycorrhiza added, the higher the rate of infection. Suggest that mycorrhiza with plant roots can increase water content and nutrient uptake capacity such as phosphorus [23], nitrogen and other micronutrients.

Mycorrhizal infections of Artemisia root are round and have a brown spore wall or slightly yellowish. The main characteristic that distinguishes CMA with other mycorrhizal-forming fungi is the presence of arbuscular and vesicular. Based on the statement of [24], arbuscular is a hyphae that forms branches in the cortical tissue where through this arbuscular, the exchange of nutrients between host plants with mycorrhizal fungi occurred. Figure 1 and Figure 2 below show the difference of Artemisia's uninfected roots and the roots infected by mycorrhiza.

![Figure 1](image1.png) **Figure. 1** Uninfected *Artemisia annua* root mycorrhiza

![Figure 2](image2.png) **Figure. 2** Infected root of *Artemisia annua*
4. Conclusions
The conclusions of this study are as follows: the addition of Vermicompost with dose 150 g/plant increased growth of *Artemisia annua* (plant height, number of branches, days when first flower emerged and root volume). The addition of mycorrhizal with dose 20 g/plant can increase plant’s height, root length, root volume and mycorrhizal infection percentage. The application of Vermicompost fertilizer and mycorrhizae in various treatment doses did not improve the plants’ fresh and dry weight.

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