Growth Responses of Watermelon (*Citrullus Vulgaris* L.) to Vesicular Arbuscular Mycorrhizal Application and Pruning Variation on Peat Soil Growing Media

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ABSTRACT

Watermelon is a horticultural plant liked by many people. Limited land and the conversion of optimal land use make the cultivation activities expand to marginal land. It will undoubtedly affect the quality of the watermelon produced. Mycorrhizal application in sub-optimum land is one way to improve soil conditions and reduce excessive lime and fertilizer inputs. Branch growth is also a determinant of the quality of watermelon production. Pruning as a way of managing branching is very necessary in the cultivation of watermelon. This study was conducted to investigate the interaction between mycorrhizal dose and pruning variations on the growth and yield of watermelon. The study was conducted using a factorial of 2 factors with 3 replications in a completely randomized design (CRD). The first factor was several mycorrhizal doses, namely 10 g/plant, 15 g/plant, and 20 g/plant. The second factor was the variation of pruning, which leaves 3 primary branches which are cut off at the 10th segment and secondary branches on the 1-10, and leaves 2 primary branches which are cut off at the 5th segment and secondary branches on the 11-20th segment. The results showed that there was an interaction between the application of mycorrhizal 15 g/plant with variations in pruning leaving 2 primary branches on the diameter of the watermelon stem, giving mycorrhizal significantly affected leaf area and fruit weight with the best results was obtain when mycorrhizal applied 20 g/plant, and pruning variations had an effect on on the diameter of the stems of watermelon plants with the best results obtained in variations of pruning leaving 3 primary branches.

Keywords: *watermelon, dose, mycorrhizal, pruning, branches*

1. INTRODUCTION

Horticultural crops are one of the agricultural commodities that have a relatively high level of consumption in the community. Opening the market to horticultural products reached an average growth of 11% or beat other agricultural commodities (plantation and food), which was only 7-8%. About 90 out of 323 horticultural products have been widely commercialized, with details 25 types of vegetables, 26 types of fruits, 24 types of ornamental plants, and 15 types of biopharmaceutical plants [1]. Fruits have a higher development potential than other types, attracting public interest in cultivating fruit-producing plants. Watermelon (*Citrullus vulgaris* L.) is a horticultural plant from the Cucurbitaceae family that is in demand because of its sweet fruit taste with a large amount of water content, bright flesh color, crumbly consistency, and good nutrition for health. The presence of the amino acid citrulline, potassium, water, vitamin C, vitamin A (carotenoids), and vitamin K in watermelon has proven to be effective in alternative medicine for hypertension sufferers [2]. Various growing environmental conditions are an obstacle to watermelon cultivation activities. As a planting medium most often used, the soil consists of many types with different soil quality and fertility levels.

Repeated application of chemical fertilizers on the same land triggers the degradation of agricultural land and many development activities that lead to land conversion. This causes the soil to lose a lot of material needed by plants, thereby reducing the availability of productive land [3]. Soil management in this condition certainly requires particular inputs to support plant growth, one of which is the addition of lime and inorganic fertilizers with high doses [4]. However, the

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input of inorganic fertilizers and lime in large quantities and for a prolonged period can interfere with the potential of the land used. Alternatives to reducing the limitations of sub-optimum soil can be done by adding mycorrhizae. The presence of mycorrhizae in peat soils (histosols) positively influences the growth and development of maize plants [5]. Some mycorrhizal species are fungi that are relatively resistant to changes in soil pH. The presence of mycorrhizae can also streamline the use of organic fertilizers, which have a relatively slow rate of nutrient release and reduce the input of inorganic fertilizers. The addition of mycorrhiza, bokashi fertilizer, and 50% inorganic fertilizer on glutinous corn had the best effect on the number of leaves and plant dry weight [6]. The intercropping of chili and cabbage plants achieved the highest fruit weight with the addition of mycorrhizae and the dose of NPK fertilizer requirement [7].

In the horticultural plant group, mycorrhizae play a role in increasing plant secondary metabolism and tolerance to drought and soil chemical content so that the stability of plant production can be maintained [8]. Giving mycorrhizae 15 g/plant gave the best results on the fresh weight of tubers in potato plants [9]. In contrast, administration of 10 g and 12.5 g mycorrhizae mixed with watermelon effectively suppressed attack intensity and incubation period of fusarium wilt disease [10]. Research on giving mycorrhiza to watermelon has not been done much, and it is necessary to do research.

Increased production of watermelon plants can also be done through improvements to other cultivation techniques, namely manipulation of growth through pruning. Watermelon plants with the characteristic of having spreading branches and can grow very long require pruning in their cultivation. Management of watermelon branches is needed to optimize the existence of primary branches as productive branches that will produce fruit. So that the resulting photosynthate is focused on the formation of flowers and fruit. Pruning can be done by removing the unproductive branches directly or slowing down the growth of branches by trimming the shoots of watermelon plants. This activity has been proven to stimulate the growth of productive shoots while reducing the risk of pest and disease attacks on watermelon plantations [11]. This study aimed to obtain the dose of mycorrhizae that gave the best effect on watermelon growth on peat soil media.

2. RESEARCH METHODS

This research was carried out from January to April 2021 at RT 11 Simpang Fixed Darul Ichsan Village, West Dumai District, Dumai City, Riau, with an average height of 3 meters above sea level.

This study was designed based on a completely randomized design (CRD) with two factors. The first factor was the mycorrhizal dose which consisted of 3 levels, namely A1 (10 g/plant), A2 (15 g/plant), and A3 (20 g/plant). The second factor is the variation of pruning, which consists of 2 levels, namely B1 (pruning by leaving three primary branches, pruning the primary branch of the 10th segment from the shoot, and pruning secondary branches at internodes 1-10) and B2 (pruning leaving two primary branches, pruning branches). Primary 5th segment of shoots and pruning of secondary branches on sections 11-20). Each treatment was repeated three times to obtain 18 experimental units consisting of 4 plants per experimental unit. The total number of plants required is 72 plants. Observational data were analyzed using analysis of variance (F test) and continued with Duncan's Multiple Range Test (DMRT) at a level of 5% [12].

Provision of mycorrhizae is given at the bottom of the planting hole before the seeds are inserted. In the early stages of planting, lanjars are also made to direct the growth of watermelons and as a place for fruit to fall. Pruning of shoots on the main stem to limit the growth of lateral shoots (potential primary branches) was carried out when the watermelon segment growth had exceeded the number of segments to be maintained (>3 segments), which was 7 DAP. Then, the selection of primary branches (2 or 3 branches) that have the best growth is carried out as the maintained branch. According to each treatment, the pruning of primary branch shoots was carried out at 35 DAP. Pruning of secondary branches was carried out after pruning of primary branches at 40 DAP. Pruning activities are carried out using pruning shears that have been soaked in alcohol beforehand and are not carried out during cloudy weather to avoid infection with diseased pruning wounds.

Plant length, stem diameter, and broadest leaf area were observed periodically from 3 weeks after transplanting to plant age five weeks after transplanting with an interval of 1 week. Observation of plant length was carried out using a meter, while stem diameter was obtained by measuring using a caliper. The most expansive leaf area was determined by selecting the leaf in the center of the branch when the first observations were made. The leaf area measurement was carried out using the photographic method and the ImageJ application. Age of emergence of flowers is done by counting the number of days when the first anthesis of male and female flowers. After harvest, the weight and sugar content of the fruit were also observed. Fruit sugar content is calculated based on the number read on the refractometer. The level of mycorrhizal root colonization was determined based on the root staining process.

3. RESULTS AND DISCUSSION

3.1. Field Overview

The peat soil media used in this study is shallow peat taken from the eucalyptus (Melaleuca leucadendra) plantation environment. Shallow peat is very suitable for cultivating plants with short or not very deep roots, such as horticultural groups. The level of soil acidity is a major limiting factor in peatland management. In this study, the peat soil at the beginning of planting had a pH of 4.62, then increased to the range of 6.00 at one week after transplanting. The initial pH measurement was carried out when the peat soil was taken in the eucalyptus plantation, so the pH obtained at the beginning was very low. The process of reducing water content, mixing with lime, and the application of mycorrhizae gives a significant increase in pH in the soil used [13]. Based on field observations, the peat used is of the hemic (half-cooked) group. This classification is based on the level of peat maturity seen from the condition of the soil water content and the part that has not been decomposed. The presence of N and P nutrients in the peat soil used in this study was categorized as moderate to high. Although the presence of these two nutrients is quite a lot in peat soil, the conditions are not directly available to plants. The availability of P in peat soil can be increased through the use of P solvent mycorrhizae [14].

Other conditions found in the field are related to the intensity and volume of rain which will also affect the temperature around the planting environment. During the study, the rain intensity that occurred was relatively high and increased at the beginning of the generative phase. An increase also appeared in the volume of rain that fell in the same phase. The air temperature during the study ranged from 27-31°C; meanwhile, during the generative phase, the air temperature only reached 27-29°C. The existing temperature range does not meet the optimal temperature for watermelon growth, which is +/- 25°C during the vegetative phase, and a higher temperature is needed for fruit ripening, which is around 30°C [15]. In conditions of high rainfall intensity, the whole irradiation required as a condition for growing watermelon plants is also not met. Some of these conditions indirectly affect plant growth.

3.2. Plant Stem Diameter

The presence of mycorrhizae will improve the structure of the growing media by making better root penetration. The presence of hyphae in the roots will help the absorption of nutrients in plants. A significant effect on stem diameter will be obtained if there is a match between the mycorrhizal composition added and the plant variety used [16]. The addition of mycorrhizae can increase the ability of roots to absorb nutrients so that it is also possible to fulfill plant nitrogen needs. Assimilation will improve along with the availability of N in plants, increasing the rate of photosynthesis. The stem diameter data is presented in Table 1.

Table 1. Watermelon stem diameter at the age of 5 WAP treated with mycorrhizal doses and pruning variations

Mycorrhizae	**Pruning**	
	3 primary branches + 10th internode from the shoot and 1-10. internode secondary branch	2 primary branches + 5th internode from the shoot and 11-20. internode secondary branch
	...cm...	
10 g	0.55 a A	0.41 b B
15 g	0.50 a A	0.47 ab A
20 g	0.52 a A	0.51 a A
CV = 7,88%		

Note: Means with different letters in the same row and column differ significantly ($p \leq 0.05$) according to Duncan's New Multiple Range tests

Based on Table 1, it can be seen that the diameter of the watermelon stems ranged from 0.41-0.55 cm at 5 WAP. The growth of plant organs, including stem diameter, is strongly influenced by the availability of nitrogen in sufficient quantities. The enlarged stem diameter indicates the occurrence of cell enlargement due to the availability of adequate carbohydrates, water, hormones, and vitamins needed by plants in carrying out metabolic processes. Nutrient uptake in plants will determine the continuity of metabolic processes to give a positive response to stem diameter [17]. The rapid growth of shoots is followed by the release of inhibitory substances towards the stem. Pruning can eliminate the effect of inhibitory substances so that it can increase the diameter of the plant stem [18]. Pruned plant parts, especially shoots, will stop the upward growth, and the assimilation produced earlier is utilized for stem diameter. The type of pruning (topping and pruning) gave the best results on stem diameter when carried out in the range of 14-35 DAP [19]. Proper pruning will also allow sunlight to reach all parts of the plant, especially the leaves to produce assimilation, which is used for plant metabolism.

3.3. Plant Leaf Area

Leaves are one of the crucial organs in plants that are used as a place for photosynthesis to occur. Plant growth will be determined by the ability of the leaves to capture light for the needs of photosynthesis. The chlorophyll content in the leaves can affect the rate of photosynthesis and the resulting photosynthate. As part of the chlorophyll-forming element, Nitrogen is closely related to the increase in plant leaf area. Nutrient uptake such as nitrogen, phosphorus, and other microelements can be increased by adding mycorrhizae [20]. Through this role, the addition of mycorrhizae will affect the leaf area. The plant leaf area data are presented in Table 2.

Table 2. Leaf area of watermelon plants at the age of 5 WAP, which were treated with mycorrhizal doses and pruning variations

Mycorrhizae	Pruning: 3 primary branches + 10th internode from the shoot and 1-10. internode secondary branch	Pruning: 2 primary branches + 5th internode from the shoot and 11-20. internode secondary branch	Average
	...cm^2...		
10 g	259.75	302.02	1280.88 b
15 g	373.50	338.66	356.08 A
20 g	309.98	322.90	316.44 ab
Average	314,41	321.193	
CV =13,5%			

Note: Means with different letters in the same row and column differ significantly (p≤0.05) according to Duncan's New Multiple Range tests

The addition of mycorrhizae will produce different responses to different types of plants. Based on this study, the best leaf area was obtained by giving mycorrhizae 15 g/plant. The provision of mycorrhizae allows plant access to maximize nutrient absorption in parts that are difficult to reach by plant roots. Mycorrhizal symbiosis allows modification of primary and secondary metabolism in the host plant, thereby triggering the production of phytochemicals in plant roots and shoots [21]. Mycorrhiza at a depth of 10-30 cm causes more efficient utilization of inorganic hydrogen and phosphorus in the root area. The wider the reach of the roots, the more nutrients that can be absorbed [22].

The total leaf area of the plant can increase along with the increase in the root ratio [18]. Pruned shoots will reduce the growth of apical meristems that act as sinks. A large number of leaves on watermelon plants will cause the nutrients produced to be distributed more to the vegetative part. The position of the leaves that shade each other will lose power as a source and are more consumptive of the photosynthate produced by leaves that receive sunlight.

3.4. The Weight of Fruit

The weight of fruit is one of the observation variables used to determine the effect of treatment in influencing crop yields. Watermelon fruit weight data are presented in Table 3.

Table 3. The weight of fruit watermelon plants treated with mycorrhizal doses and pruning variations

Mycorrhizae	Pruning: 3 primary branches + 10th internode from the shoot and 1-10. internode secondary branch	Pruning: 2 primary branches + 5th internode from the shoot and 11-20. internode secondary branch	Average
	...kg...		
10 g	1.68	1.64	1.660 b
15 g	1.83	1.75	1.790ab
20 g	1.83	1.86	1.840a
Average	1.78	1.75	
CV = 6,46%			

Note: Means with different letters in the same column differ significantly (p≤0.05) according to Duncan's New Multiple Range tests

Soil with good nutrient content is expected to be able to meet the needs of plants during the generative phase, namely in terms of supporting fruit growth. Soil conditions with a low pH used cause the nutrients at the beginning of planting cannot be utilized by plants. Mycorrhizal application as a way to reduce lime input which was applied simultaneously with watermelon seed transplantation, caused the mycorrhizal response to be not seen at the beginning of planting. Based on observations, the increase in fruit weight occurred along with a significant increase in the dose of mycorrhizal applied, but it did not match the fruit weight in the description of the seeds (5.5-7.5 kg). Increasing the amount of mycorrhizal application in marginal soils can increase P uptake in soil [23]. No phosphorus nutrients work to convert carbohydrates, as in the conversion of flour into sugar. The results of carbohydrate changes will play a role in fruit formation; if the availability of phosphorus in the soil is available to plants, it will increase the size and weight of the harvested fruit [24].

The pruning variations used showed results that were not significantly different. This study found that the pruning of the shoots of the primary branches after the fruit was formed caused the secondary branches to experience swift growth. Secondary branches that are pruned only on specific segments cause secondary branches on the left to experience remarkable growth. This means that this secondary branch will continue to sink and take up most of the photosynthate produced. In this condition, the process of fruit formation and ripening becomes slow. Maximum net photosynthesis generally increases with leaf development and reaches a maximum just after full leaf development. When it reaches the maximum point, the growth and development of the fruit will be better. All photosynthesis results will be used for flower and fruit development during the generative phase [25].

3.5. Mycorrhizal Colonization Rate

Mycorrhizal colonization in roots can be categorized according to The Instate of Mycorrhizal Research and Development; USDA is 0-5% classified as very low (grade 1), 6-25% classified as low (grade 2), 26-50% classified as moderate (grade 3), 51-75% are classified as high (grade 4), and 76-100% are classified as very high (grade 5). The presence of mycorrhizae in the root area can increase P uptake from the soil by plants [26]. Mycorrhizal colonization data are presented in Table 4.

Table 4. Mycorrhizal colonization rate on watermelon plants treated with mycorrhizal doses and pruning variations

Mycorrhizae	Pruning	
	3 primary branches + 10th internode from the shoot and 1-10. internode secondary branch	2 primary branches + 5th internode from the shoot and 11-20. internode secondary branch
	...%...	
10 g	25	25
15 g	50	75
20 g	25	75

Mycorrhizae have the ability to adapt to heavy metal contaminated soil conditions in maintaining their colonization [27]. Based on the research that has been done, it was found that the percentage of mycorrhizal colonization on watermelon roots ranged from 25% - 75%. Mycorrhizal hyphae and phosphatase enzymes produced by fungi were proven to be able to catalyze the hydrolysis of phosphorus complexes to become available. Mycorrhizae that colonize roots will form specific structures in the form of vesicles and arbuscules. The vesicle structure is described as an ovoid shape in which it contains compounds and functions as a food reserve. While the arbuscules are shaped like tree branches that are seen inside the plant host cell [28]. The following are the results of observations of mycorrhizal colonization on watermelon roots are presented in Figure 1.

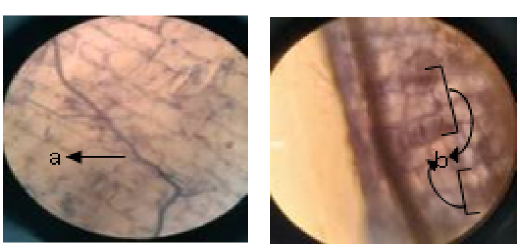

Figure 1. Roots of watermelon (*Citrullus vulgaris* L.) which were colonized by mycorrhizae (a) arbuscula, (b) vesicula, as seen at a magnification of 400 x.

Different mycorrhizal spores showed different abilities to colonize plants. This is also related to the type of soil and climatic conditions around the mycorrhizal application area. Mycorrhizae with Glomus intraradices spore type gave the best effect compared to other types on watermelon planting [29]. Mycorrhizae from Glomus species have been shown to respond better in tolerating soil acidity (pH) [30]. This is also the basis for using multispore mycorrhizae in this study, which is expected that one of the spores composing multispore mycorrhizae can work well in watermelon roots planted in acid soil. The intensity of colonization may be disproportionate to its effect on crop yields. Colonization rates may be reduced if the soil contains a large amount of available phosphate.

4. CONCLUSION

Based on the research that has been done, it can be concluded that:

1. The application of 15 g/mycorrhizal plant and the variation of pruning leaving 2 primary branches indicated an interaction in influencing the diameter of the watermelon plant stem
2. Mycorrhizal application has an effect on the leaf area and fruit weight of watermelon plants. The best results were obtained by giving a 20 g/mycorrhizal plant.
3. Variations in pruning only affect the diameter of the watermelon plant stem. The best results were obtained in pruning variations by leaving 3 primary branches.

CONTRIBUTION OF AUTHORS

This work was carried out in collaboration among all authors. Author RT performed the research and performed the data, conducted the statistical analysis, and wrote the first draft of the manuscript. Author WW designed the study, checked data analysis, read and approved the final manuscript. Author AA read and approved the final manuscript.

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