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Research Article

Physiological responses and production of Gama Melon Parfum (*Cucumis melo* L. cv. GMP) on different water availability

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ABSTRACT

Gama Melon Parfum (GMP) cultivar is a result of crossbreeding between the Natsuno Omoide and Miyamauri melon varieties in 2011. GMP exhibits a unique phenotypic characteristic, including a bitter taste of the fruit flesh and produces a stronger aroma. The objective of this study was to investigate the physiological responses and productivity of GMP under varying water conditions. The experiment was conducted using a single factor consisting of different levels of water availability with field capacity at 50%, 75%, and 100%, as well as submergence at 2 cm, 4 cm, and 8 cm above the soil surface. Each treatment was replicated three times. The plot size for each replication was 2 m x 2 m, ensuring consistent conditions for all treatments. The results of the study showed that treatment with 100% field capacity increased stem diameter, while treatment with 50% field capacity increased the root-to-shoot ratio of GMP. Submergence treatment at 8 cm decreased stem diameter and the root-to-shoot ratio of GMP. The 50% field capacity treatment reduced the total chlorophyll levels in GMP leaves. Submergence treatment at 8 cm increased the total chlorophyll levels in GMP leaves. The 50% field capacity treatment increased fruit fresh weight, while submergence treatment at 2 cm decreased fruit fresh weight. Submergence treatment at 2 cm reduced fruit water content, whereas submergence treatment at 8 cm increased water content in GMP fruits.

Keywords: drought; Gama Melon Parfume (GMP); growth; plant physiological responses; submergence

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INTRODUCTION

In an effort to reduce dependency on imported cultivars of melon seeds, a series of studies have been conducted to develop new cultivars that can thrive well in local Indonesian environments. In 2011, Prof. Dr. Budi S. Daryono, M.Agr.Sc successfully crossbred the melon cultivars Natsuno Omoide (NO-3) and Miyamauri (MR-5), resulting in a melon with unique characteristics known as Gama Melon Parfum (GMP) (Wahyuni et al., 2024). Gama Melon Parfum exhibits unique phenotypic traits, including a bitter taste of the flesh and the production of volatile compounds with a more fragrant and intense aroma compared to other melons, thus potentially serving as a natural flavor for its fruit aroma (Maryanto et al., 2014). The unique characteristics of this variety include small-sized fruits, brownish-yellow skin with distinct oval markings, white flesh, the absence of a net pattern, a bitter taste, and a highly fragrant aroma suitable for perfume production. The shape, size, and surface features of the GMP fruit skin are inherited from its female parent, specifically the Natsuno Omoide variety (Maryanto et al., 2014). During the development of GMP melon, various chemical substances such as calcium, phenolics, and amino acids are present, contributing to its bitter flavor. Additionally, volatile compounds in GMP cultivars, including alcohol compounds like 3-penten-2-ol, 1-octanol, and Z4-dodecanol, esters such as hexanoic acid and its ethyl and hexyl esters, ketones like 2-butanone and 3-hydroxy, and hydrocarbons like 2-undecend and 3-methyls (Z), contribute to its unique aroma profile. Furthermore, GMP melons contain novel essential aroma compounds such as 3-penten-2-ol, acetic acid hexyl ester, and 2-butanone, 3-hydroxy, which are not typically found in other melon cultivars (Hasbullah et al., 2019).

Cultivating melon plants requires intensive care. Melon plants are highly sensitive to environmental changes and are prone to diseases such as stem rust, fruit rot, and powdery mildew. This leads to decreased productivity and fruit quality, reducing the market value of the fruit and posing a threat of crop failure to farmers (Daryono & Qurrohman, 2009). The production of melon plants is influenced by various factors, including cultivars, water availability, nutrients, growing media, air temperature, and lighting, all of which support the growth and development of melons. Research on environmental changes causing stress to melon plants is still very limited, especially for the GMP melon cultivar. Thus, only a few research findings can be referenced by farmers when their crops are affected by environmental stress.

One common environmental stress encountered is the excess or insufficiency of water availability in nature. Sufficient water availability is crucial for supporting the growth and development of melon plants. Water available for plants is the water between the field capacity and the wilting point. Field capacity is the condition of the soil where the maximum amount of water can be held by the soil against gravitational force. Meanwhile, the wilting point is the condition of soil with very low water content, causing plant roots to be unable to absorb water, resulting in temporary wilting (Widnyana et al., 2017). Water limits the growth of plants. An excess water causes submergence, which in turn causes aeration stress, while a shortage of it frequently results in drought stress (Rajanna et al., 2018). When plants experience drought stress or submergence, they respond in terms of growth, physiology, anatomy, biochemistry, and molecular biology. Plants counteract the effects of stress through various mechanisms, depending on the nature of the stress and the physiological processes involved. These mechanisms can be accomplished by plants through avoidance, tolerance, and resistance. These responses allow plants to maintain their lives through changes in physiological processes, even though periodic stresses may reduce the performance of the plants. If a plant can withstand stress conditions, then it has a level of resistance to stress (Hendrati et al., 2016).

Based on this background, this study aimed to further understand the influence of water availability on the physiological response and productivity of GMP melon plants in order to determine the appropriate water availability to enhance the physiological response and productivity of GMP melon plants.

MATERIALS AND METHODS

The research was conducted from September 2023 to January 2024 at the Sawit Sari Research Station Greenhouse, Universitas Gadjah Mada, to grow GMP melon seedlings with treatments of different field capacities and submergences. The Plant Physiology Laboratory and The Joint Research Facility (FALITMA), Faculty of Biology, Universitas Gadjah Mada, were utilized to measure the physiological response of GMP melon plants.

The materials used in this research included GMP melon plant seeds, rice husk charcoal, soil, compost, NPK fertilizer, AB mix fertilizer, distilled water, 80% acetone, 3% sulfosalicylic acid, glacial acetic acid, phosphoric acid, ninhydrin, toluene, proline, aluminum foil, and filter paper. The equipment used in this research included a hoe, seedling tray, 35 cm x 30 cm bucket, 20 cm x 40 cm polybags, bamboo stakes with a height of 1.5 meters, meter, tape measure, pH meter, lux meter, soil tester, scale, scissors, oven, mortar and pestle, test tubes, test tube rack, glass funnel, Erlenmeyer flask, hotplate, stirrer, water bath, coolbox, spectrophotometer, logbook, and stationery.

The experiment was conducted with a single factor consisting of different levels of water availability: field capacity at 50%, 75%, and 100%, as well as submergence at 2 cm, 4 cm, and 8 cm above the soil surface. In the submergence treatment, the water level (at 2 cm, 4 cm, and 8 cm above the soil surface) was maintained by adding a certain amount of water every day. Each treatment was replicated three times. The plot size for each replication was 2 m x 2 m, ensuring consistent conditions for all treatments. Drought and submergence stresses were applied after the plants entered the generative phase or when the plants were 40 days old. In the treatment without submergence, water availability was maintained at the predetermined field capacity conditions. During submergence conditions, the water level was maintained for a period of 5 days of stress, while under water scarcity conditions, it was kept for a period of 10 days of stress. Each treatment was replicated four times. Each pot consisted of one plant, resulting in a total of 30 GMP melon plants used.

The GMP melon seeds were obtained from the Genetics Laboratory, Faculty of Biology, Universitas Gadjah Mada. The GMP melon seeds were sorted by soaking them in water and incubated at a temperature of 25-30°C for 24 hours. The purpose of the soaking process was to separate empty and impure seeds from good quality seeds and to accelerate the imbibition process for faster growth (Stefia, 2017). Sinking seeds were selected for sowing while floating seeds were discarded. The soaked seeds were drained and sown in seedling media in an upright position with the embryonic axis (root, stem, and leaves) facing downwards to facilitate good growth and prevent tipping over. Seeds were sown for 10 days until two leaves emerged (Triadiati et al., 2019). Seeds that had grown the first two leaves were ready to be transplanted into larger planting media in polybags. The planting media used consisted of soil, compost, and rice husk charcoal in a ratio of 3:1:1. The size of the polybags used was 20 cm x 40 cm. Each polybag was filled with planting media weighing 6 kg, consisting of 3 kg of paddy soil, 1.5 kg of compost, and 1.5 kg of rice husk charcoal.

The traits observed for growth response included plant height (cm per plant), stem diameter (mm per plant), leaves number (leaves/plant), plant biomass (g) consisting of fresh weight (g), dry weight (g), moisture content (%), and root-to-shoot ratio. Physiological responses during stress periods included leaf chlorophyll content (mg g^{-1}) and leaf carotenoid content (mg g^{-1}). Fruit productivity observations included the total number of fruits (fruits per plant), fresh weight of fruits (g per plant), fruit moisture content (%), and fruit color (fruits per plant).

Data from observations of growth and physiological traits were analyzed using one-way ANOVA at a 95% confidence level. The Duncan multiple range test (DMRT) was conducted with $\alpha = 0.05$ to identify significant differences between treatment means. The software used for data analysis was SPSS 26 statistical software. Data were presented in tables and graphics.

RESULTS AND DISCUSSION

Physiological responses

The increase in plant height is a result of increased cell division and elongation due to increased assimilates (Song et al., 2015). Therefore, plant height is often used as an indicator to show the growth response of a plant and as a trait to determine the effects of treatments given in a study. In this research, the plant height trait was used to compare the growth response of different groups of GMP melon plants with different treatments. Plant height data was measured from the base of the stem to the tip of the longest leaf using a meter tape and expressed in centimeters (cm). Based on the results of ANOVA analysis, it was shown that overall, the stress treatments did not have a significant effect on the height of GMP melon plants in all plant groups. Based on Figure 1, it was obtained that before the stress period, plant height growth was very good until the age of 40. Then, during the stress period, plant height tended not to increase and even began to decrease. After the stress period, the plants were returned to normal conditions. However, this return did not immediately cause the plants to recover and resume their lives. Submerged plants, in several replications, could not survive and eventually wilted, resulting in the plants drying up and dying.

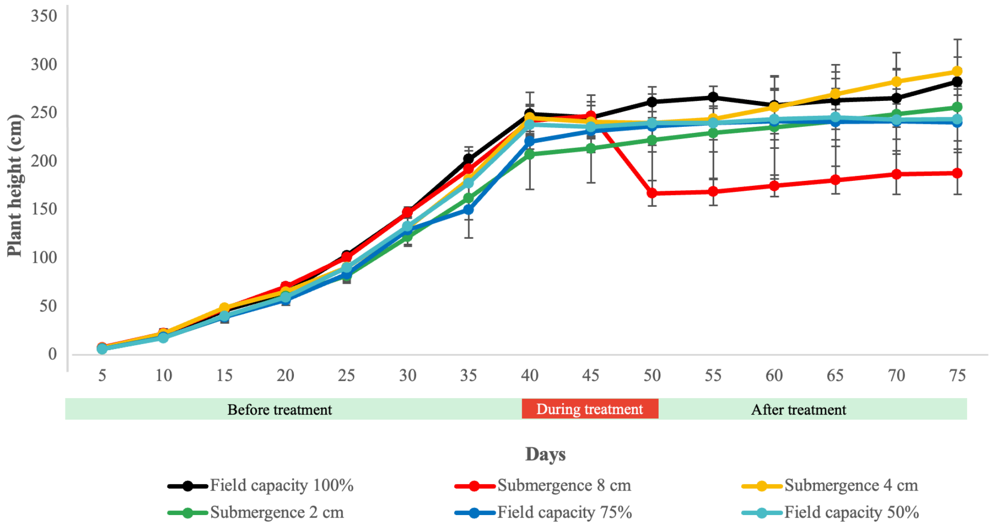

Figure 1. The influence of treatment with 2 cm, 4 cm, and 8 cm submergence, as well as 50%, 75%, and 100% field capacity, on the growth of plant height of melon GMP plants.

Plants that were submerged tended not to increase in plant height for some time until the plants started to adapt again and resume their lives. This is because when plants start to experience environmental stress, such as drought and submergence, they begin to respond as indicated by their growth and development. The mechanism of plant response when there is stress is differentiated into three types: escape, avoidance, and tolerance. Escape response occurs when plants are able to complete their life cycle before stress occurs. Avoidance response occurs when plants are able to maintain relatively high tissue water potential during drought stress and maintain low tissue water potential during submergence stress. Tolerance response occurs when plants recover and can complete their life cycle even though they have been subjected to stress (Ichwan et al., 2017).

Based on Figure 1, it can also be seen that submerged plants tended not to increase in plant height for some time until the plants started to adapt again and resume their lives. Therefore, the response that occurs in GMP melon plants after being subjected to stress, whether submergence stress or drought stress, was tolerance response. In some plants in the submergence group, stress had a supportive effect on plant growth and development, such as producing many root shoots and increasing the number of branches, leaves number, and stem diameter due to sufficient water availability. This also affected plant height, with the highest increase in plant height occurring in the 4 cm submergence stress group.

Growth can be expressed, among other things, by the increase in stem diameter according to the age and life stage of the plant. Therefore, stem diameter can be used as an indicator of the growth response of plants to the conditions they are facing. Plant stem diameter data was consistently measured at the height of ± 4 cm from the soil surface using calipers and expressed in millimeters (mm). After the stress treatments were applied, there was a significant effect on stem diameter. Based on one-way ANOVA and post hoc Tukey's test with $\alpha = 0.05$, the 2 cm, 4 cm, and 8 cm submergence treatments, as well as the 100%, 75%, and 50% field capacity treatments, significantly affected the stem diameter of GMP melon plants at 45 days after sowing (DAS). Post hoc DMRT test with $\alpha = 0.05$ revealed that the 8 cm, 4 cm, and 2 cm submergence groups differed significantly from the groups of plants at 100%, 75%, and 50% field capacity.

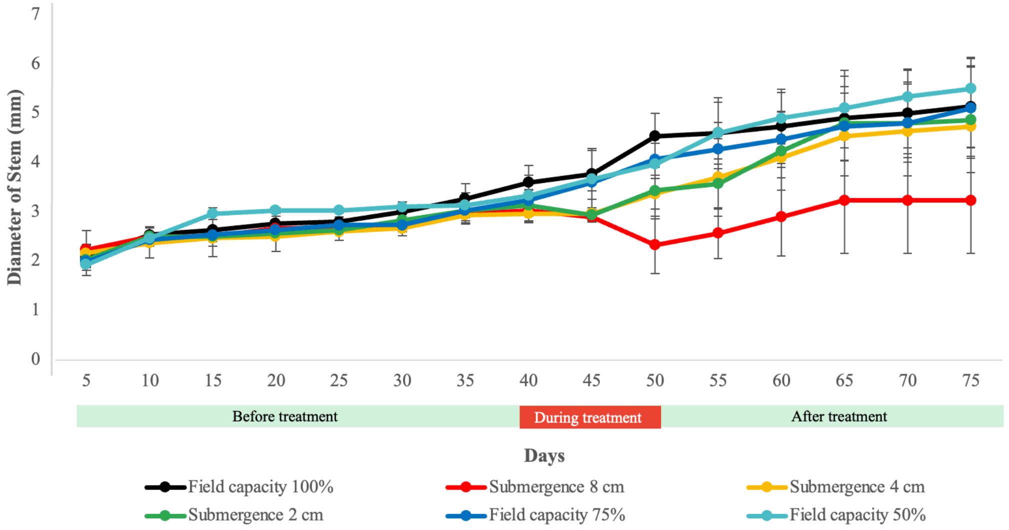

Figure 2. The influence of treatment with 2 cm, 4 cm, and 8 cm submergence, as well as 50%, 75%, and 100% field capacity, on the growth of stem diameter of melon GMP plants.

Based on Figure 2, after the stress treatment was given, there was a significant effect on the stem diameter. The control treatment showed the largest stem diameter because the volume of water contained in the plant media was kept consistently sufficient and not excessive to support the growth and development of GMP melon plants. As a result, the process of water absorption by the roots could proceed optimally, ensuring that the water content in the plant body was sufficient for the synthesis of energy sources and cell division. This indirectly also supported the development of plant stem diameter. In contrast, the 8 cm submergence treatment showed the lowest stem diameter results. The more submergence on the soil surface and the more submerged the plant stems, the more tissue damage occurs in the plants. Plant stems submerged in water generally undergo elongation, resulting in a decrease in stem diameter (Jing et al., 2024). Stem elongation is a response known as an escape strategy that allows plants to carry out metabolism aerobically and fix CO_2 with their stems above the water surface (Sarma et al., 2023). Therefore, in submergence groups, stem diameter tended to decrease.

When plants are in dry conditions, plant stems tend to shrink or decrease, and secondary stem growth is disturbed. This is because most cell components consist of water; when the water supply in the soil starts to decline, the roots will absorb less water, causing plant cells to shrink and dry out (dos Santos et al., 2022; Hendrati et al., 2016). In submergence conditions, GMP melon plants are submerged in water, reducing the supply of oxygen and carbon dioxide, which disrupts the process of photosynthesis and respiration. As a result, insufficient or excessive water availability can inhibit plant growth, as expressed by a small stem diameter.

The primary process of photosynthesis occurs in the leaves, making leaves crucial in increasing a plant's biomass. Photosynthates are distributed by the plant through the phloem tissue to support its growth and development by forming new cells, replacing dead cells, and forming plant organs. The greater the leaves number, the greater the photosynthates produced by photosynthesis. Based on ANOVA analysis, stress treatments did not significantly affect the leaves number of GMP melon plants in all treatment groups.

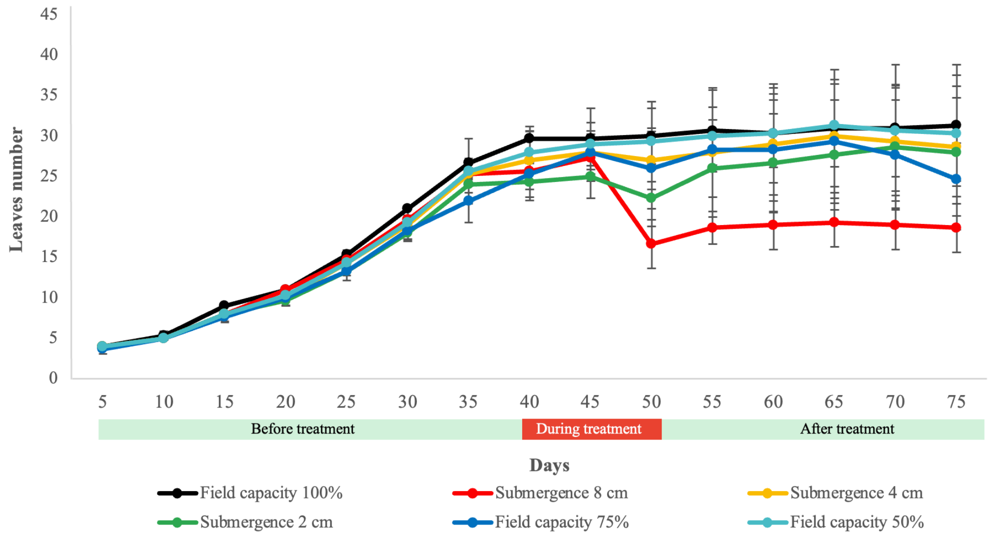

Figure 3. The influence of treatment with 2 cm, 4 cm, and 8 cm submergence, as well as 50%, 75%, and 100% field capacity, on the growth of the number of leaves of melon GMP plants.

As seen in Figure 3, the leaves number decreased after stress treatments, especially under 8 cm submergence conditions. This was because melon plants were highly stressed by submergence conditions of up to 8 cm, which hindered the formation of new leaves, while many lower leaves were submerged, causing wilting and death. The highest increase in leaves number was observed in the group of plants with 100% field capacity. This was attributed to the consistent availability of water, which meets the plant's requirements, ensuring adequate water for metabolism. With optimal water availability, plants grow and develop efficiently (Elemike et al., 2019). This also allows water to be distributed maximally through the xylem tissue and transpired through the stomata, ensuring maximum physiological and biochemical processes (Maylani et al., 2020). Conversely, insufficient or excessive water availability can disrupt nutrient assimilation, ion uptake, and enzyme activity, affecting both physiological and morphological processes in plants (Ahanger et al., 2017; Rini et al., 2020). Therefore, stress treatments involving excessive submergence or drought result in less leaf growth compared to the control. These indicated that the increase in leaves number is influenced by appropriate water availability.

In this study, each plant group experienced different leaf growth patterns. Some plants showed a significant increase in leaves number without a corresponding increase in leaf area, as seen in the submergence group, while others showed an increase in leaf area without an increase in leaves number, as observed in the drought group. Additionally, some plants experienced an increase in both leaf area and leaves number, as seen in the control group. These growth patterns were related to the leaves' ability to absorb sunlight.

Plant biomass represents the amount of organic matter resulting from photosynthesis stored in the plant. Plant biomass is expressed through fresh weight and dry weight characteristics. Fresh weight encompasses all plant organs, including roots, stems, leaves, and fruits, providing a measure of plant growth quality. Fresh weight estimates morphological, qualitative, and quantitative plant development. The dry weight reflects the accumulation of organic compounds successfully synthesized by the plant from inorganic compounds, primarily water and carbon dioxide. Overall, based on ANOVA analysis, it was generally shown that different water availability treatments exerted an equivalent effect or did not significantly affect plant biomass. According to Table 1, the highest increase in biomass was observed in the 4 cm submergence group. Consistent with the study by (Rachmawati & Retnaningrum, 2013) on rice plants, the submergence treatment with a higher soil NO_3 level compared to non-submergence conditions enables plants to use available nitrate to support their growth and development. Plants in the 4 cm submergence group showed more optimal new branch growth compared to other groups. This could be because, in the 8 cm submergence group, plants elongate their stems more to meet O_2 and CO_2 needs to support aerobic respiration and photosynthesis (Rachmawati & Retnaningrum, 2013). Many melon plants in the 8 cm submergence group died and were intolerant, resulting in low fresh weight, whereas, in the 2 cm submergence group, nitrate levels were not as high as in the 4 cm submergence group to support plant growth.

Table 1. Growth traits, chlorophyll, and carotenoid levels of melon GMP plants grown under various water availabilities.

Treatment	Water availabilities					
	Submergence (cm)			Field capacity (%)		
	8	4	2	100	75	50
Fresh weight (g)	166.67± 68.37a	232.67± 55.65a	164.00± 50.24a	201.33± 9.29a	178.00± 35.09a	201.00± 40.11a
Dry weight (g)	13.00± 6.00a	19.33± 5.51a	13.33± 7.02a	17.33± 5.51a	12.67± 2.89a	13.67± 4.51a
Moisture content (%)	92.33± 0.58a	92.00± 1.00a	92.33± 2.08a	91.33± 3.06a	92.67± 1.15a	93.00± 2.65a
Root-shoot ratio	0.02± 0.01c	0.03± 0.00c	0.03± 0.01c	0.03± 0.01bc	0.04± 0.01b	0.05± 0.02a
Chlorophyll content (mg g^{-1})	1.69± 0.13a	1.23± 0.15b	1.12± 0.03b	1.14± 0.23b	1.10± 0.23b	0.99± 0.06b
Carotenoid content (mg g^{-1})	0.11± 0.03a	0.09± 0.01ab	0.08± 0.01ab	0.08± 0.01ab	0.07± 0.02b	0.06± 0.00b

Note: Numbers in a row followed by different letters indicate significant differences based on Duncan's multiple range test ($\alpha \leq 0.05$). Values are mean ± SD.

The root-to-shoot ratio is one of the indicators of plant adaptation to unfavorable conditions (Rusmana et al., 2021). The root-to-shoot ratio is used to determine the plant's ability to maintain functional balance in a stressed environment. Based on one-way ANOVA, the 2 cm, 4 cm, and 8 cm submergence treatments, as well as 100% field capacity (control), 75%, and 50% field capacity, exerted a significant effect on the root-to-shoot ratio. With the DMRT post hoc test at α=0.05, it was known that the 8 cm submergence group, 4 cm submergence group, 2 cm submergence group, and 100% field capacity group differ significantly from the 75% and 50% field capacity groups. According to Table 1, the highest increase in the root-to-shoot ratio was demonstrated by the 50% field capacity group. The results obtained are consistent with the statement by Fitter and Hay (1998) that the root-to-shoot ratio is plastic, meaning it increases under conditions of water, nitrogen, oxygen, and low-temperature availability. When water becomes a limiting factor, metabolites involved in energy production, especially sugars and amino acids, will shift from the shoot to the root. Shoot growth is encouraged when nitrogen (N) and ample water are available. Conversely, root growth is encouraged when nutrient factors, especially nitrogen and water, are limited (Gargallo-Garriga et al., 2014).

Chlorophyll and carotenoids in leaves are among the main pigments involved in plant photosynthesis. Changes in chlorophyll and carotenoid levels in plant species are related to the water status or availability in their environment. Chlorophyll and carotenoid levels were measured using a spectrophotometer with wavelengths of 645 nm and 663 nm for chlorophyll and 470 nm for carotenoids. According to Table 1, the 2 cm, 4 cm, and 8 cm submergence treatments, as well as 100% field capacity (control), 75%, and 50% field capacity, exerted a significant effect on leaf chlorophyll levels. With the DMRT post hoc test at α=0.05, it was known that the 8 cm submergence group differed significantly from other treatment groups. The highest increase in leaf chlorophyll content was observed in the 8 cm submergence group. Additionally, Table 1 also shows that the 2 cm, 4 cm, and 8 cm submergence treatments, as well as 100% field capacity (control), 75%, and 50% field capacity, generally exerted an equivalent effect or did not significantly affect leaf carotenoid levels. It was observed that the highest leaf carotenoid content is in the 4 cm submergence group. Leaf chlorophyll and carotenoid levels increased with increasing water stress compared to the control treatment. This could be because the position of plants in the submergence group received more sunlight than the different field capacity groups, allowing leaves to absorb and convert solar energy more. This results in more chlorophyll being present in the chloroplasts of leaves under submergence conditions, especially in the 8 cm submergence group located at the end of the greenhouse, thus receiving more sunlight and longer irradiation intensity. Another factor that could also contribute to the high chlorophyll content under submergence conditions was the different timing of water stress application between the submergence and field capacity groups, where submergence stress was only maintained for 5 days, while field capacity stress was applied for 10 days. If the submergence treatment in the submergence group is prolonged, chlorophyll levels will likely decrease because plants will experience heavier water stress. Additionally, this could be due to the larger leaf area used during the test compared to the drought stress group. The study by (Proklamasiningsih et al., 2012) explains that a larger leaf surface area is expected to contain more chlorophyll.

Productivity

The productivity of melon plants is influenced by various growth factors, one of which is adequate water availability. Water stress in the form of drought or submergence certainly affects the growth and yield of melon fruits. According to Table 2, it was found that the submergence treatments of 2 cm, 4 cm, and 8 cm, as well as field capacities of 100% (control), 75%, and 50%, significantly affected the fresh weight and fruit water content. With the DMRT post hoc test at α = 0.05, the above treatments showed significant differences between groups, where the submergence groups of 2 cm and 4 cm differed significantly from the 75% and 50% field capacity groups, while plants in the 100% field capacity group did not differ significantly from all treatments. The highest increase in fruit weight was observed in the 50% field capacity group. Regarding water content, the highest increase was observed in the submergence group with 8 cm. Drought stress results in a decrease in fruit weight due to low water availability. This disrupts the physiological processes of plants, thus causing a reduction in fruit weight and water content. The disruption of physiological processes in plants also leads to insufficient assimilates to increase fruit weight because more assimilates are allocated to leaf formation. Therefore, it can be concluded that melon plants are highly tolerant to drought conditions, so drought does not disturb the physiological processes of melon plants in carrying out their generative phase well. In the control plants, fruit formation occurred slightly later compared to the 75%, 50% field capacity, and 2 cm submergence groups, so their weight was not yet maximum; if left longer, the weight of the control plants may reach the maximum.

Table 2. Productivity traits of melon GMP grown under various water availabilities.

Treatment	Water availabilities					
	Submergence (cm)			Field capacity (%)		
	8	4	2	100	75	50
Total number of fruits	1.67± 2.08a	1.67± 1.53a	0.67± 0.58a	1.33± 1.16a	1.00± 1.00a	2.33± 1.16a
Fresh weight of fruits (g)	14.62± 4.93bc	9.88± 4.23c	33.97± 8.52ab	31.97± 16.76abc	41.34± 17.36a	52.87± 13.10a
Fruit moisture content (%)	94.67± 0.58a	93.00± 1.00ab	86.67± 0.58c	93.00± 2.00ab	92.33± 3.06ab	90.67± 1.15b

Note: Numbers in a rows followed by different letters indicate significant differences based on Duncan's Multiple Range Test (α ≤ 0.05). Values are mean ± SD.

According to Table 2, it was generally observed that the submergence treatments of 2 cm, 4 cm, and 8 cm, as well as field capacities of 100% (control), 75%, and 50%, exerted an equivalent effect or did not show a significant influence on fruit number. As seen in Table 1, the highest number of fruits was in the 50% field capacity group. In the drought stress group, fruit growth and development tended to be higher compared to the submergence group. The decline in the submergence group was suspected to be due to the saturation of water content, thus disrupting the plant's generative process. Increased water stress tends to reduce plant flowering activity, resulting in slower fruit formation. In the fruit formation process, plants will go through a flowering phase. Flowering is a transition phase from the vegetative phase to the generative phase, characterized by the emergence of flower buds followed by pollination and fruit formation phases. In this phase, nutrients play an essential role in accelerating flowering and increasing the percentage of flowers that become fruits (Suryawaty & Wijaya, 2012). In the study by (Fernandes et al., 2018), water stress significantly affected fruit formation activity. The number of fruits will decrease as water stress increases. In the plant flowering process, water stress tends to reduce the number of flowers produced, thus causing a decrease in the number of fruits.

Figure 4. Comparison of the effects of treatments A: 8 cm submergence, B: 4 cm submergence, C: 2 cm submergence, D: control (100% field capacity), E: 75% field capacity, and F: 50% field capacity at 75 DAS on the growth rate, development, and fruit maturity of GMP melon.

In general, melon fruits belong to the climacteric group, which are fruits that experience a surge in respiration rate and ethylene production that gradually increases after harvest. This causes the fruits to continue ripening even after being harvested (Paul & Pandey, 2014). The indicator of skin color change in fruits is quite effective in determining the harvest maturity age. The change in skin color of the fruit serves as an indicator of the maturity level for fruit consumption, and it is widely used for various types of fruits. However, GMP melon fruits cannot be consumed directly because their content causes a bitter taste. Generally, GMP melon fruits, after harvest, are immediately used as raw materials for the industry. In Figure 4, it can be seen that ripe GMP melons turned orange in color, as seen in the 50% field capacity group, and they had a round shape with prominent turbinate structures at the apical part. GMP melon fruits that had not changed color to orange, such as in the submergence group, were not mature enough to produce optimum quality, characterized by their green color and incomplete turbinate structure.

Drought stress and waterlogging are environmental factors that have a significant impact on fruit formation in plants. According to the study by (Fernandes et al., 2018), drought conditions can result in a decrease in cell turgor pressure, inhibit nutrient transportation and absorption, and trigger plant defense mechanisms that can affect fruit conditions. This is supported by the statement by (Gargallo-Garriga et al., 2014) that under drought conditions, the reproductive phase, including the initiation of flowers, flowering phase, and fruit formation phase, will decrease. Based on this study, it can be observed that under dry conditions, melon plants undergo fruiting phases more quickly and can sustain their fruits during and after stress is applied. This may be due to the various adaptation mechanisms of melon plants. One of them is the reproductive mechanism, which responds to drought to ensure offspring's survival in an unstable environment. Additionally, it may also be due to hormonal processes that trigger the production of plant hormones such as auxin and gibberellin, which play a role in regulating plant growth and development, including fruit formation, thus stimulating fruit development.

CONCLUSIONS

The study demonstrated that different water management treatments had variable effects on the growth and physiological traits of GMP melon plants. A 100% field capacity increased stem diameter, while a 50% field capacity improved the root-to-shoot ratio but reduced chlorophyll content. In contrast, an 8 cm submergence condition reduced stem diameter and the root-to-shoot ratio but increased chlorophyll levels. Neither treatment significantly impacted plant height, leaf number, biomass, carotenoid, or proline levels. Regarding fruit characteristics, a 50% field capacity increased fresh fruit weight, while a 2 cm submergence reduced fresh fruit weight and water content. However, neither treatment influenced the total fruit count per plant.

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