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Research Article
Drought Effect Simulation on the Growth and Yield Quality of Melon (*Cucumis melo* L.)

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Abstract
Background and Objective: Water is an important factor for the crop growth and development, mainly under the drought condition. The cultivation of *Cucumis melo* requires water both at vegetative and generative phase which are taking role for metabolic and physiological processes. Further, there are reports that melon development requires different volume of water between vegetative and generative phase. The objective of this study was to investigate the amount of water which is required to the different growth phase of melon variety Apollo to simulate the effect of drought on this changing climate. **Materials and Methods:** This study conducted on April, 2015 until June, 2015 in screen house using randomized block design consisting of 9 combinations of treatments and with 3 replications. The treatments include: V1G1 [water supply 100% FC (field capacity) in vegetative and generative phase], V1G2 (water supply 100% FC in vegetative phase, 75% FC in generative phase), V1G3 (water supply 100% FC in vegetative phase, 50% FC in generative phase), V2G1 (water supply 75% FC in vegetative phase, 100% FC in generative phase), V2G2 (water supply 75% FC in vegetative phase, 75% FC in generative phase), V2G3 (water supply 75% FC in vegetative phase, 50% FC in generative phase), V3G1 (water supply 50% FC in vegetative phase, 100% FC in generative phase), V3G2 (water supply 50% FC in vegetative phase, 75% FC in generative phase) and V3G3 (water supply 50% FC in vegetative phase, 50% FC in generative phase. Analysis of the data used in this study is the analysis of variance F-test with a level of 5%. If there is significant effect on the treatment, LSD (least significant difference) is conduct at the level of 5%. **Results:** The results of this study showed that drought simulation to 50% both in vegetative and generative decrease 50% performance of growth of melon. However, on harvest parameters, 25% drought simulation on just vegetative phase increased 1% of yield, 559.33 g from 549.11 g (control). **Conclusion:** While simulating 25% drought only to generative phase, increased the level of sweetness from 14.59-15.98% or increased 9% compare to control.

Key words: *Cucumis melo*, drought phase, field capacity, fruit quality, water deficit

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Melon (*Cucumis melo* L.) is a potential crop because of its economic value as horticultural crop. Alahdadi *et al.*[1] stated that in every 100 g of fresh fruit contains 92.1% water, 0.5% protein, 0.3% fat, 6.2% carbohydrates, 0.5% fiber and 350 IU of vitamin A. In Indonesia consumption of melon fruit reached ±332.698 t/year, however the consumption is less than mango and tomato[2]. In 2010, melon production in Indonesia was only 85.161, hence the national consumption still depends on import about 247.537 t. Cultivation of melon is mainly influenced by an environment factors such as nutrients and water availability. Optimum water supply gives also the optimum metabolism and physiological processes of plants, however in the climate change condition, water availability is in surge. The agriculture with low water input is a challenge to face the water shortage (drought) also for wiser use of resources in the future. Shortage of water either temporarily or permanently affects morphology, physiology and biochemical processes in the plant. Further, water stress can also affect the entire anatomy of plants[3]. Generally, shortage of water on both of vegetative and generative phase effect on the reduction on yield, due to damage of cell and others tissues of plant[4]. Hence, it is important to know the level of water shortage (drought) will effect on the melon yield. Further, it is possible to adjust the cultivation of melon based on water availability. Water stress 40% KL reduced plant height 46%, stem diameter 51%, total plant dry weight 40% and leaf area 45%. By giving 100% KL of water showed a larger diameter stems than 80, 60 and 40% KL[5]. In addition, the treatment of watering of 65% KL has a total dissolved solids higher than the treatment of 55% and 45% KL in melon in the green house[6]. Biglouei *et al.*[7], who stated that dry matter of plant was reduced on the 50% of water surge.

The various responses of fruit growth to soil water availability has been well documented for many fruit. Some scientist stated that irrigation on its full field capacity give an optimum growth both for quantity and quality of fruit harvest. However, other group of scientists found that in water issue, yield does not always relate with quality. As a result of this research, it is necessary to have irrigation management practices which growers can benefit to optimize fruit size and fruit quality. Kirnak *et al.*[6], who stated that optimum growth on vegetative stage (leaves and stem) give positive result on fruit. There is some prove that water conditions can affect internal characteristics of fruit, particularly mild drought stress during ripening can result in beneficial fruit. Surtinah[8], stated that fruit from less irrigated were firmer and stored better fully irrigated one.

The objective of this study was to investigate the amount of water which is required to the different growth phase of melon variety Apollo to simulate the effect of drought on this changing climate.

MATERIALS AND METHODS

The study was conducted from April-July 2015 at Tanjung Research Field College of Agricultural Extension, Malang with the altitude ±500 m above of sea level and temperature ranging from 22-33°C. This study using a randomized block design (RBD), consisting of 9 combinations of treatments and repeated 3 times, thus obtained 27 experimental unit. Each treatment was consist of 4 pots contain 5 kg media mixture, 75% soil and 25% manure. Therefore , the experimental units were 108 pots. The treatments include: V1G1 [water supply 100% FC (field capacity) in vegetative and generative phase], V1G2 (water supply 100% FC in vegetative phase, 75% FC in generative phase), V1G3 (water supply 100% FC in vegetative phase, 50% FC in generative phase), V2G1 (water supply 75% FC in vegetative phase, 100% FC in generative phase), V2G2 (water supply 75% FC in vegetative phase, 75% FC in generative phase), V2G3 (water supply 75%) FC in vegetative phase, 50% FC in generative phase), V3G1 (water supply 50% FC in vegetative phase, 100% FC in generative phase), V3G2 (water supply 50% FC in vegetative phase, 75% FC in generative phase) and V3G3 (water supply 50% FC in vegetative phase, 50% FC in generative phase).

Plant growth observation consists of the number of leaves, plant height and diameter of stem. These observations were conducted at 14, 28, 48 and 56 day after transplanting (DAT) by observing the 3 plants samples. The destructive observations include dry weight of leaves, stems, roots and total dry weight of the plant is conducted at the end of the observation. Components of harvest include fruit weight and the sweetness level of the fruit by refractometer (Master Refractometer-Atago, Tokyo Japan). Harvest is conducted 2 times due to various stage of fruit maturation.

Statistical data analysis: Analysis of the data used in this study were recorded and subjected to one-way analysis of variance (ANOVA) at the significant level of 5%. If there is significant effect on the treatment, LSD (least significant difference) is conduct at the level of 5%. Regression analysis is also performed to check the relationship between parameters. Finally, analysis of regression is conducted to determine the influence of parameters to the melons production[9].

RESULTS AND DISCUSSION

Component of growth

Plant length: This parameter shows interesting result that significance is found on each day of observation. Based on Table 1, reduction of watering to 50% both in vegetative and generative significantly decrease ($p = 0.05$) the plant length compare to full irrigation in field capacity (FC). In fact reduction to 75% also give the same effect (plant length reduction) but not as severe as its on 50% reduction. This effect was shown on weekly observation until the end of vegetative stage 56 DAT. Both Yildirim *et al.*[10] and Ozbahce *et al.*[11] stated that plant length and leaves number are the parameters which are most affected by the water surge. This is because the auxin activity which is responsible for the apical shoot and leaves formation is on a low activity because of water surge. Further, Sugito[12] stated that water is important component in plant. Less water resulted on less turgor to the plant and disturbance in plant cell. On the normal cell with water sufficient condition, water maintains the continuous development of sugar synthesis, plant development, maintenance and regulation. Thus, explain the stunted phenomenon on the plant with water surge.

Number of leaves: The study shows that water shortage on generative stage to 50% reduction (V1G3) shows the same result with control (V1G1) as long as there is no water surge in vegetative stage (Table2). On the other hand, water shortage in vegetative stage on 75-50% of field capacity will significantly ($p = 0.05$) reduce the plant height from 14-56 day after transplanting (DAT) observation. This result confirms Yildirim *et al.*[10] and Sengul *et al.*[13], who stated that full of watering from transplanting until harvest, shows higher plant height compare to full watering just on vegetative stage. Li *et al.*[5] stated that it is possible to reduce the water to just 75% of field capacity (FC) without reducing the plant height. Watering of plants with 100% of field capacity results on higher plan than treatment below 100% field capacity[13,14]. Plants with water shortage condition,

Table 1: Length of plant at different level of deficit water

Treatments	Length of plant (cm) in various time observation (DAT)			
	14	28	42	56
V1G1 (100% Veg-Gen)	21.61^{c}	101.56^{cd}	122.17^{d}	123.33^{d}
V1G2 (100% Veg-75% Gen)	21.22^{bc}	100.17^{cd}	115.22^{cd}	116.78^{cd}
V1G3 (100% Veg-50% Gen)	24.33^{c}	102.00^{d}	111.78^{bc}	116.67^{cd}
V2G1 (75% Veg-100% Gen)	22.83^{c}	94.28^{cd}	117.33^{bc}	118.61^{d}
V2G2 (75% Veg-75% Gen)	20.83^{bc}	90.44^{bc}	108.72^{bc}	110.17^{bc}
V2G3 (75% Veg-50% Gen)	17.78^{ab}	91.83^{bc}	105.39^{bc}	107.28^{bc}
V3G1 (50% Veg-100% Gen)	16.94^{ab}	83.00^{ab}	111.94^{bc}	113.17^{bc}
V3G2 (50% Veg-75% Gen)	15.72^{a}	77.33^{a}	10.61^{b}	103.28^{b}
V3G3 (50% Veg-50% Gen)	15.50^{a}	73.28^{a}	90.33^{a}	92.50^{a}
LSD (5%)	4.605	11.215	10.952	10.669
CV (%)	13.54	7.16	5.78	5.54

Figures are accompanied by the same letter in the same column are not significantly different at 5% LSD, DAT: Days after transplanting, veg: Vegetative phase (1-22 DAT), gen: Generative phase (23-65 DAT)

Table 2: Number of leaves at different level of deficit water

Treatments	Number of leaves (sheet) in various time observation (DAT)			
	14	28	42	56
V1G1 (100% Veg-Gen)	4.00^{b}	13.67^{de}	16.78^{c}	17.78^{b}
V1G2 (100% Veg-75% Gen)	4.00^{b}	13.33^{cd}	16.67^{c}	17.67^{b}
V1G3 (100% Veg-50% Gen)	4.67^{c}	14.33^{e}	15.78^{bc}	16.89^{b}
V2G1 (75% Veg-100% Gen)	4.00^{b}	12.33^{cd}	16.00^{c}	16.89^{b}
V2G2 (75% Veg-75% Gen)	3.67^{ab}	11.67^{bc}	14.11^{ab}	15.33^{a}
V2G3 (75% Veg-50% Gen)	4.00^{b}	12.67^{cd}	14.00^{ab}	15.22^{a}
V3G1 (50% Veg-100% Gen)	3.67^{ab}	11.00^{ab}	15.89^{c}	16.89^{b}
V3G2 (50% Veg-75% Gen)	4.00^{b}	10.33^{ab}	13.78^{a}	14.78^{a}
V3G3 (50% Veg-50% Gen)	3.33^{a}	9.67^{a}	13.00^{a}	14.33^{a}
LSD (5%)	0.564	1.998	1.508	1.506
CV (%)	8.31	9.53	5.77	5.37

Figures are accompanied by the same letter in the same column are not significantly different at 5% LSD, DAT: Days after transplanting, veg: Vegetative phase (1-22 DAT), gen: Generative phase (23-65 DAT)

Table 3: Diameter of stem at different level of deficit water

Treatments	Diameter of stem (mm) in various time observation (DAT) 14	28	42	56
V1G1 (100% Veg-Gen)	4.69[d]	5.25[c]	5.36	5.38
V1G2 (100% Veg-75% Gen)	4.92[de]	5.27[c]	5.25	5.36
V1G3 (100% Veg-50% Gen)	5.15[e]	5.06[c]	5.12	5.14
V2G1 (75% Veg-100% Gen)	4.81[d]	5.37[c]	5.14	5.25
V2G2 (75% Veg-75% Gen)	4.26[c]	5.04[bc]	4.7	4.72
V2G3 (75% Veg-50% Gen)	4.15[bc]	5.04[bc]	4.83	4.94
V3G1 (50% Veg-100% Gen)	3.81[a]	4.61[ab]	4.8	4.82
V3G2 (50% Veg-75% Gen)	3.92[ab]	4.58[a]	4.82	4.83
V3G3 (50% Veg-50% Gen)	4.04[ab]	4.74[ab]	4.7	4.82
LSD (5%)	0.32	0.448	ns	ns
CV (%)	4.2	5.18	5.47	6.05

Figures are accompanied by the same letter in the same column are not significantly different at 5% LSD, DAT: Days after transplanting, veg: Vegetative phase (1-22 DAT), gen: Generative phase (23-65 DAT)

Table 4: Dry weight of leaves, stem, root and total dry weight at different level of deficit water

Treatments	Dry weight (g plant^{-1}) Leaves	Stem	Root	Total dry weight
V1G1 (100% Veg-Gen)	12.22[e]	5.26[d]	0.18	17.90[d]
V1G2 (100% Veg-75% Gen)	10.07[cd]	4.73[cd]	0.18	16.93[cd]
V1G3 (100% Veg-50% Gen)	8.50[bc]	4.13[b]	0.17	13.80[bc]
V2G1 (75% Veg-100% Gen)	11.22[de]	5.08[d]	0.19	17.60[cd]
V2G2 (75% Veg-75% Gen)	8.93[bc]	3.89[b]	0.14	13.20[ab]
V2G3 (75% Veg-50% Gen)	7.66[ab]	3.80[b]	0.14	11.67[ab]
V3G1 (50% Veg-100% Gen)	10.66[de]	4.89[d]	0.16	16.40[cd]
V3G2 (50% Veg-75% Gen)	8.54[bc]	4.18[bc]	0.11	14.00[bc]
V3G3 (50% Veg-50% Gen)	6.39[a]	2.72[a]	0.10	9.37[a]
LSD (5%)	17.841	0.5809	ns	3.987
CV (%)	11.02%	7.81%	21.80%	15.84%

Figures are accompanied by the same letter in the same column are not significantly different at 5% LSD, ns: Non significance. veg: Vegetative phase (1-22 DAT), gen: Generative phase (23-65 DAT)

experience less auxin activities which also reduce the development of vegetative organs such as leaves and stem elongation. Contrary, optimal water conditions promotes auxin activity and increase the formation of vegetative organs of the plant[15].

Stem diameter: Contrary to Li *et al.*[5], that various level of irrigation results on different stem diameter, in this study water surge both in vegetative and generative do not show significant different. In the Table 3, the end of vegetative stage 56 DAT (V3G3) showed that all level of watering treatment do not give significant impact to the stem diameter. On the early growth 14 and 28 DAT shows that sufficient water on 100 and 75% FC show bigger stem diameter of stem. However, on the late vegetative stage water level treatments do not show significant effect on stem diameter. This confirmed Kirnak *et al.*[6], that water sufficiency only give the significant effect on early vegetative growth. Hence, on the stem diameter water reduction to 50% from FC do not give significant reduction to stem diameter.

Plant dry weight: Dry weight of melon shows interesting result. On leaves, the plant dry matters are determined mostly by the amount of irrigation on the generative stage. This explained by the V1G1, V2G2 and V3G1 treatments which expose to 100% irrigation on generative stage. Those treatments showed the best leaves, stem and total dry matter on compare to other treatments. On the other hand, reduction of irrigation on generative stage upto 50% FC results on reduction of dry weight on leaves, stem and total dry weight. Generally, the irrigation surges to 50% of field capacity reduce total plant dry weight (Table 4). This is because the formation of plant biomass determined by plant's photosynthesis rate. When there is insufficient water condition, plant will experience the reduction of photosynthesis rate. Moreover, the stomata will close and the process of photosynthesis is inhibited. Further, as explained by Yativ *et al.*[16], the plants on the limited of water supply condition will face senescence rapidly due to chlorophyll degradation. Further according to Febrio *et al.*[4], when the cells condition expose to continuous water stress, the cell contents will be detached from the walls that cause damage to cells and eventually chlorosis.

Table 5: Fresh weight of fruit and sweetness level at different level of deficit water

Treatments	Weight of fruit (g)	Sweetness level (brix)
V1G1 (100% Veg-Gen)	549.11[d]	14.59[ab]
V1G2 (100% Veg-75% Gen)	505.33[c]	15.98[c]
V1G3 (100% Veg-50% Gen)	470.33[bc]	14.67[ab]
V2G1 (75% Veg-100% Gen)	559.33[d]	14.33[ab]
V2G2 (75% Veg-75% Gen)	472.67[bc]	15.06[b]
V2G3 (75% Veg-50% Gen)	459.89[ab]	14.44[ab]
V3G1 (50% Veg-100% Gen)	507.22[c]	14.16[a]
V3G2 (50% Veg-75% Gen)	455.22[ab]	14.78[ab]
V3G3 (50% Veg-50% Gen)	424.33[a]	14.22[a]
LSD (5%)	40.391	0.72
CV (%)	4.77	2.83

Figures are accompanied by the same letter in the same column are not significantly different at 5% LSD, DAT: Days after transplanting, veg: Vegetative phase (1-22 DAT), gen: Generative phase (23-65 DAT)

Component of yield

Fruit weight: The most interesting phenomenon is on the harvest parameters (Table 5). On the fruit weight parameter, the best result shows on V1G1 (100% FC both in vegetative and generative stage) and V2G1 (reduction to 75% FC only in vegetative stage). It is suspected that the optimum irrigation on the generative stage is the important factor to determine the yield (fruit weight). On the other hand, the surge of water on 50 and 75% in generative stage significantly ($p = 0.05$) reduce the harvest. Ibrahim[17] showed that melon cultivars on water stress treatment reduced its fruit weight, length and flesh thickness. Hence, highest yield is achieved in non-stress plant.

The results also showed that although during the vegetative stage water supply is 100% FC, weight is decreased if there is a stress in generative stage. Yildirim *et al.*[10] stated that the difference of irrigation during the generative stage period affects growth of stem and affect the yield of fruit both size and weight of fruit.

Fruit quality: Unlike the fresh fruit weight, the fruit quality from its sugar content parameter show that 100% FC in generative stage does not show the highest sugar content. The highest sugar content is surprisingly occurred on the reduction to 75% FC on generative stage. Altering the irrigation to 75% FC in vegetative and generative stage, show similar result with 100% FC. While irrigation reduction on 50% FC during vegetative and generative stages was reduce the sugar content of melon.

Li *et al.*[5] stated that irrigation level is related with the thickness of fruit, total soluble solids (TSS), soluble sugars (SS), vitamin C (Vc), soluble protein (SP) and the content of free amino acids (FAA). Further stated that irrigation with 75% FC is the optimum irrigation schedule for melon which is growing in the green house. In ripening stage, the fruit weight does not related with fruit sweetness. This finding confirmed research by Kirnak *et al.*[6], who show that fruit sugar content is affected positively by less water. In our case, although the sugar content was not influenced by the water treatments, a tendency of this parameter to improve as the amount of water decreased was observed. The results suspected that the decrease in moisture content create minor decrease in photosynthate production, further activated sugar translocation and reduced competition for photosynthates.

Other researchers like Msaakpa and Obasi[18] came out with explanation that in the slight water deficit, quantities of assimilate were transported to fruit from other part of plant as an addition to sugar formed from starch hydrolysis. Further, on the slight water stress, respiration rate in fruit is higher than fully irrigated melon which resulted on higher sugar content in fruit[19].

Growth and yield relationship: Regression analysis also performed in this study to confirm the relationship between growth parameters and harvest parameters. This analysis was performed to see how the yield can be predicted by growth parameters in melon. From the research shows that fruit weight can be predicted by number of leaves, dry weight of leaves, stem and total dry weight of plants in all treatments. Regard to the analysis of regression, number of leaves, dry weight of leaves, stems and total dry weight of the plant significantly affect weight of melon fruit (Fig. 1). Further, this study confirms.

This phenomenon is due to fact that optimum water condition in vegetative stage produce more assimilates to translocate to the fruit during fruit grow[20]. At the beginning of the vegetative stage, the leaf is the organ which contributed most to the total biomass, (80%). The stem is important contribution to the whole plant, right after and followed by fruit in the middle until harvesting stage[21].

Leaf dry matter contribution to the total aerial biomass could be due to photosynthate translocation to sinks. Bilgin *et al.*[22] stated that high fruit development affects to decreasing leaf biomass. Further Yativ *et al.*[16] stated that the fruit number is the factor determining the allocation of resources between vegetative and reproductive organs, hence large sinks of fruit grow at the expense of leaf formation. The relationship grown in protected environments relevated that more than 10 leaves are required for normal development of a fruit. Nerson[23], the percentages of off-shape fruits increased with decreasing leaf number and their means were 71, 48, 30 and 2% for 4, 8,16 and ultimited leaves/plant, respectively.

Lester *et al.*[24] confirmed the importance of the loss in AI (acid invertase) activity and the increase in sucrose phosphate

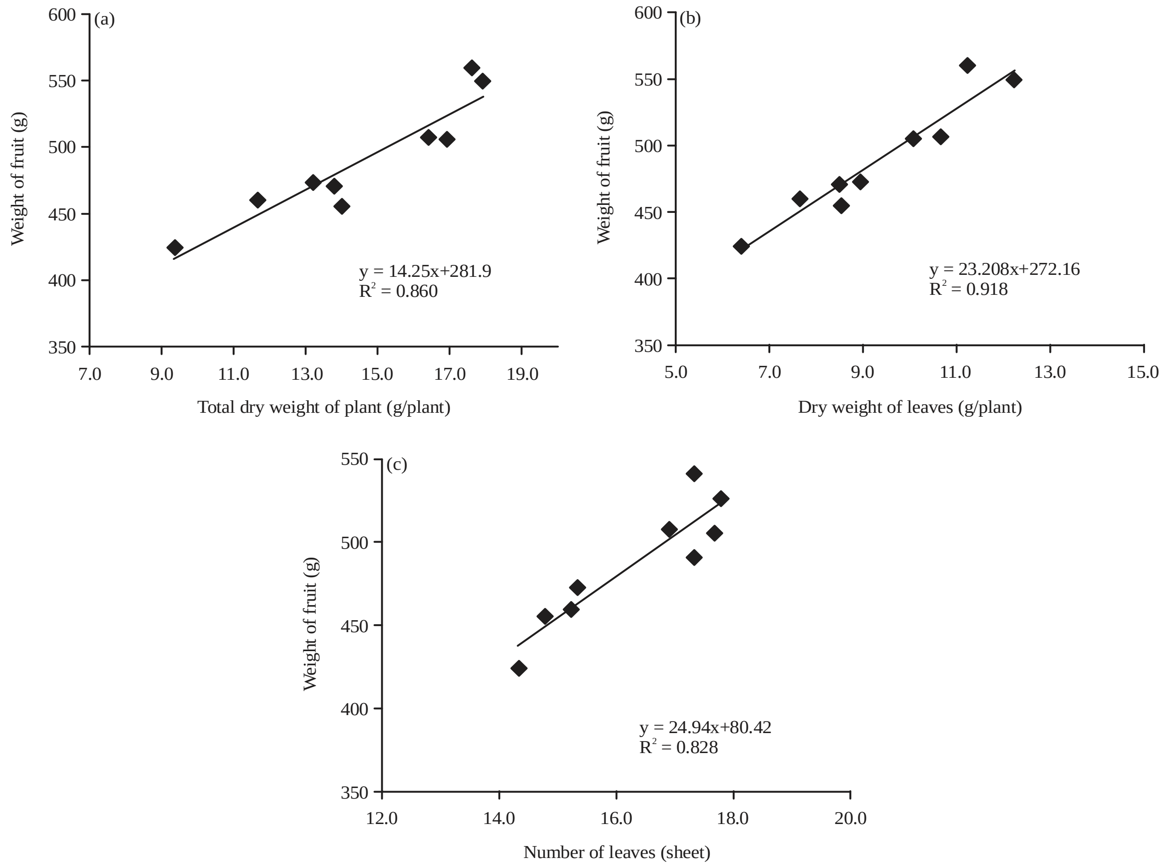

Fig. 1(a-c): Relationship analysis of regression between (a) Total dry weight, (b) Dry weight of leaves and (c) Number of leaves with weight of fruit

synthase (SPS) activity in two sweet melon cultivars and emphasized particularly the necessity for SPS activity to be higher than that of AI. Also, Burger *et al.*[20] indicated that sucrose accumulation in the developing fruits of melon began only when AI activity declined to less than an experimentally determined threshold value and continued until removal of the fruit from the plant. In addition, the activities of sucrose phosphate synthase, sucrose synthase and neutral invertase were all positively correlated with sucrose accumulation among the genotypes. Eifediyi *et al.*[25] reported that sugar composition in watermelon, as in all cucurbit fruits, includes sucrose, fructose and glucose. It was indicated that, within the genus *Citrullus*, there are genotypes that accumulate a high percentage of sucrose in fruits, while others accumulate glucose and fructose.

CONCLUSION

The effect of water stress in melon shows different phenomenon in vegetative and generative stage. Reducing the water availability to 50% in vegetative stage is generally giving negative effect to the growth and yield of melon. The fresh weight of melon is determined mainly to the optimum water availability (100% of field capacity). On the other hand, the best fruit quality of melon obtain by reducing the water availability to just 75% of field capacity.

SIGNIFICANCE STATEMENTS

This study will help the researcher to uncover the critical areas of the amount of water volume that is proper for the growth phase of melon (Apollo variety), so the water can be used efficiently and optimally. Thus, a new theory about the production of melon with Apollo variety could be done under conditions of water constraints by regulating the amount of watering based on the plant growth phase.

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