ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
Brazilian Journal of Agricultural and Environmental Engineering
v.26, n.10, p.706-712, 2022
Campina Grande, PB – http://www.agriambi.com.br – http://www.scielo.br/rbeaa

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v26n10p706-712

Fruit characteristics of cantaloupe melon in protected environment subjected to irrigation frequencies and substrate volumes[1]

Características de fruto de melão cantaloupe em ambiente protegido sob frequências de irrigação e volumes de substrato

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HIGHLIGHTS:

Higher irrigation frequencies promoted an increase in melon fruit quality.
The higher volumes of substrate used allowed the production of melons with commercial standards.
The mixture of soil, substrate, bovine manure and plant ash makes it possible to produce melons with high quality standards.

ABSTRACT: The objective of this study was to evaluate the effect of irrigation frequencies and substrate volumes on fruit mass, fruit quality and water use efficiency of cantaloupe melon in protected environment. The study was conducted at the Federal University of Rondonópolis, MT, Brazil, from February to August 2021, in randomized block design in a 3 × 4 factorial scheme with four replicates. The substrate volumes used in plastic pots were 5, 10 and 15 dm^3 and the irrigation frequencies were once a day, twice a day, three times a day and once every other day. The characteristics evaluated were fruit mass, pulp thickness, water use efficiency, soluble solids content, and titratable acidity. The irrigation frequencies of once and three times a day showed the best performance for fruit mass and pulp thickness. The water use efficiency was higher for the frequency of three times a day. With the exception of titratable acidity, the substrate volumes of 10 and 15 dm^3 showed the highest performances for all the variables evaluated. As for the soluble solids content, all fruits showed levels that classified them as extra fruits, of high quality and indicated for exportation.

Key words: *Cucumis melo* L., netted, fruit quality, greenhouse

RESUMO: O objetivo deste estudo foi avaliar o efeito de frequências de irrigação e volumes de substratos sobre a massa de frutos, qualidade de frutos e eficiência do uso da água de melão cantaloupe em ambiente protegido. O estudo foi conduzido na Universidade Federal de Rondonópolis, MT, de fevereiro a agosto de 2021, em delineamento de blocos ao acaso em esquema fatorial 3 × 4 com quatro repetições. Os volumes de substrato utilizados nos vasos plásticos foram de 5, 10 e 15 dm^3 e as frequências de irrigação foram uma vez ao dia, duas vezes ao dia, três vezes ao dia e uma vez a cada dois dias. As características avaliadas foram massa de fruto, espessura da polpa, eficiência de uso da água, teor de sólidos solúveis e acidez titulável. As frequências de irrigação de uma e três vezes ao dia apresentaram melhor desempenho para massa de fruto e espessura da polpa. A eficiência do uso da água foi maior para a frequência de três vezes ao dia. Com exceção da acidez titulável, os volumes de substrato de 10 e 15 dm^3 apresentaram os maiores desempenhos para todas as variáveis avaliadas. Quanto ao teor de sólidos solúveis os frutos apresentaram níveis que os classificaram como frutos extra, de alta qualidade e indicados para exportação.

Palavras-chave: *Cucumis melo* L., rendilhado, qualidade de fruto, estufa

• Ref. 261386 – Received 22 Feb, 2022
* Corresponding author - E-mail: sergioplens@bol.com.br
• Accepted 29 May, 2022 • Published 09 Jun, 2022
Editors: Ítalo Herbet Lucena Cavalcante & Carlos Alberto Vieira de Azevedo

Introduction

Melon (*Cucumis melo* L.) is an economically important vegetable in Brazil and its cultivation in the country started in the 1960s. The northeastern region is the main producer of melon in the country, and the cultivation has been conducted under regular field conditions. Although most of the northeastern melon production is of the yellow type, recently there has been an increased interest in the production of noble melons (Vendruscolo et al., 2018).

Cantaloupe melon is a noble fruit option of economic importance and its cultivation can be performed in a protected environment with irrigation system. Through an irrigation schedule, it is possible to manage the frequencies with which irrigation is performed. For Lopes et al. (2020), the use of irrigation frequencies at different times of the day can be advantageous because this management aims to increase the efficiency of water use and to reduce water stress on plants in warmer periods of the day.

Cultivation in a protected environment requires the acquisition of substrate, which can increase production costs and decrease the profitability of the rural producer; however, according to Oliveira Junior et al. (2020), increasing the volume of substrate in cultivation can increase the rate of plant development.

Therefore, the objective of this study was to evaluate the effect of irrigation frequencies and substrate volumes on fruit mass, fruit quality and water use efficiency of cantaloupe melons in a protected environment, plastic greenhouse.

Material and Methods

The experiment was conducted at the Federal University of Rondonópolis, MT, Brazil (15° 36' 41" S and 56° 03' 53" W, altitude of 165 m) from February to August 2021. According to Köppen's classification, the climate of the region is type Aw (tropical with dry winter), with two well-defined seasons, dry from May to September and rainy from October to April. The greenhouse where the experiment was conducted has an arched metal structure, with a ceiling height of 3.05 m, width of 6.60 m, length of 18.05 m, cover and sides closed with transparent diffuser plastic film (75% transparency) and an evaporative cooling system Pad and Fan, which was programmed to maintain the temperature at 26 ±1 °C and relative air humidity at 65% throughout the experimental period.

In order to reduce the volume of commercial substrate used in vegetable cultivation, avoid the use of chemical fertilizers and prepare a compost with characteristics close to those of an organic product, a mixture containing soil from native forest (Cerrado), commercial substrate, aged bovine manure, plant ash from eucalyptus burning and washed construction sand was used.

For the mixture, 40% of forest soil (Cerrado) was used, classified as Oxisol with a clayey texture, and it had 0.0014 and 0.023 g dm^{-3} of phosphorus and potassium, respectively, a hydrogen potential ($CaCl_2$) of 4.0 and a base saturation of 9.7%. The soil received 15% of vegetable substrate (HT hortaliças, Vida Verde®, Mogi Mirim, SP, Brazil), adapted from EMBRAPA (2019), 25% of aged bovine manure (Mogifertil®, Mogi Mirim, SP, Brazil), adapted from Trani (2014), 3% of eucalyptus ash (Bonfim-Silva et al., 2013) and 17% of washed sand to fill the mixture.

The chemical attributes of the plant ash and the substrate formed from the mixture of soil, commercial substrate, manure, ash, and sand are shown in Table 1.

The experimental design used was randomized blocks in a 3 × 4 factorial scheme, corresponding to three substrate volumes (5, 10, and 15 dm^{-3}) and four irrigation frequencies (once a day, twice a day, three times a day, and once every other day), with four replicates. In each block there were 12 experimental plots, each plot was represented by a perforated plastic pot with capacity of 16 dm^{-3}, and the area occupied by each block was 11.2 m^2 with spacing between pots of 1.0 × 0.5 m.

The cantaloupe melon cultivar used was the Rock Hybrid Cantaloupe (Rock Hybrid Cantaloupe Melon, Isla® Sementes, Porto Alegre, RS, Brazil), lot: 141322, category S2, germination index of 98%, purity of 99% and valid until December 2023. For sowing, on April 07, 2021, five melon seeds were distributed directly into the pots at a depth of 1 cm. At 2 days after emergence (DAE), one plant per pot was thinned, at 7 DAE one more plant per pot was thinned, and at 15 DAE two more plants per pot were thinned, leaving only one plant. For thinning, the less developed plant was selected to be removed (EMBRAPA, 2019).

For nitrogen fertilization, six applications of urea (45% N) were carried out at 15, 30, 45, 53, 58, and 67 DAE. The N dose used in each of the first three applications was 0.059 g dm^{-3}, in the fourth fertilization the dose of 0.1 g dm^{-3} was applied, and in the remaining two fertilizations 0.2 g dm^{-3} was applied. In the first three applications, the urea was diluted in water and applied as a solution, with a volume of 50 mL dm^{-3}; in the remaining applications, the fertilizer was deposited on the substrate and 50 mL dm^{-3} of water was applied on it (Damasceno et al., 2012).

A concentrated liquid fertilizer composed of calcium and boron (Base CaB_2, Base Fertilizers®, Primavera do Leste, MT, Brazil) was used for foliar fertilization. Two applications were made, the first one at 36 DAE and the second at 56 DAE. In each application, the dose used was 1.5 mL L^{-1} of fertilizer and 35 mL of solution per plant. To control pests and diseases of the melon, preventive management was adopted with the application of insecticides and fungicides (EMBRAPA, 2019).

Table 1. Chemical attributes of the plant ash and the substrate used for growing of cantaloupe melon, variety Rock Hybrid Cantaloupe

Plant ash							
P	K	Ca	S	Mn	B	Zn	Cu
(g dm^{-3})				(mg dm^{-3})			
9.5	15.4	15.3	8.45	0.0	110	60.0	60.0
Substrate							
OM (g kg^{-1})	pH ($CaCl_2$)	P	K	Ca	Mg	S	V (%)
		(g dm^{-3})					
40.7	6.4	0.44	1.94	0.05	0.04	0.21	90.1
Mn	Cu	Fe	B	Zn			
(mg dm^{-3})							
39.4	0.5	88.0	0.51	7.9			

OM - Organic matter; V - Base saturation; pH - hydrogen potential

The training system was the trellis type, with two horizontal wires arranged at 0.5 m above the edge of the pot and 1.1 m above the first wire. Pruning of the branches was performed between 22 and 51 DAE, according to EMBRAPA (2019).

The flowers of melon can be monoecious, gynoecious or mostly andromonoecious (presence of male and hermaphrodite flowers). Because other researchers are using the greenhouse during the melon cultivation and pesticides for pest control, honeybees (*Apis mellifera*) were not used, so pollination was done manually in the period between 42 and 60 DAE. One fruit per plant was left on the lateral shoots, and pruning was performed after the third leaf posterior to the fruit. Harvesting was initiated at the moment when the occurrence of abscission of the peduncle showing cracking in all its perimeter was observed (EMBRAPA, 2019).

To guarantee the uniformity of the volume of water applied and the periodicity of irrigation frequencies, an automated system was used with an internet controlled home automation device (Sonoff) in a drip irrigation system with a timer for the operation of the water pump.

The volume of water applied by irrigation was the same for all frequencies, but was fractionated. A water meter was also installed next to the automatic drip irrigation system to count the total volume of water applied during the crop cycle and the water consumption per plant (experimental unit). Through the irrigation system drive devices (Sonoff), the electric power consumption by the water pump was also accounted for.

For irrigation performed once a day, the system was turned on at 12:00 pm; for twice a day, the times were set at 7:00 a.m. and 6:00 p.m.; for three times a day, the times were set at 7:20 a.m., 12:20 and 6:20 p.m., and for the frequency of once every other day, the drip irrigation system was turned on at 12:30 p.m. The drip irrigation system was used with the installation of one dripper per pot with a flow rate of 4 L h^{-1}. The flow rate of each dripper was 69.15 mL min^{-1}, and based on this information, the running time of the water pump was adjusted according to the required water flow to be applied in irrigation.

The determination of the volume of water applied in irrigation was performed using evaporation data from a class A pan installed inside the agricultural greenhouse. From the pan evaporation values, adopting a pan coefficient (Kp) of 0.85 and melon crop coefficients of 0.50, 0.80, 1.05 and 0.75, corresponding to the initial, vegetative, fruiting and ripening periods, respectively, the irrigation rates were calculated (Santos et al., 2018).

To evaluate fruit mass, with one fruit per replicate, the individual fruits were weighed on precision scales. Water use efficiency was calculated by dividing the fruit yield per plant, fruit mass, by the volume of water consumed per plant during the growing cycle (Zou et al., 2021).

For fruit quality analyses, with one fruit per replicate, the fruits were halved in the equatorial region. Pulp thickness was measured with a digital caliper (Pantec, 11112AB-150, São Paulo, SP, Brazil). To analyze the soluble solids content (SS), samples of the mesocarp of each fruit were taken and the pulp extract was placed in a refractometer (Biobrix, ATC-103, São Paulo, SP, Brazil), obtaining the values in % (°Brix). The titratable acidity (TA) of the fruits was evaluated by the titration method with a 0.1 N NaOH solution and applying the correction factor (volume of NaOH spent × 0.32), which provides values in grams of citric acid per 100 mL of solution (Chaves Neto & Silva, 2019).

Based on the water storage capacity of the substrate used (field capacity), the available water capacity (AWC) for each volume of substrate used was estimated. The thermal sum or thermal constant is used to obtain the thermal sum of the crop cycle as a function of air temperature, making possible through this information to plan the duration of the cycle and obtain the best sowing times for locations where cultivation is not performed, but climate information is available. To identify the thermal constant (TC) of the melon crop for the site, a thermo-hygrometer was installed inside the greenhouse to monitor air temperature and relative air humidity during the melon cycle, taking daily readings approximately at 3 p.m., according to the fourth methodology proposed by Ometto (1981).

The results were subjected to normality test, analysis of variance (ANOVA) and Tukey's test ($p \leq 0.001$, 0.01 and 0.05). When the data showed abnormal distribution, data transformations were performed using the square root method. All statistical analyses were performed using the R-Studio statistical software (V.4.1.0). The analysis of correlations between variables was also performed in the interpretation of the results by Pearson's method.

Results and Discussion

The average air temperature and relative air humidity inside the agricultural greenhouse recorded during the period from April 12th to August 10th, 2021, referring to the period from sowing to harvest of the melon fruit, were 30.09 °C and 70.44%, respectively. From the air temperature data collected inside the greenhouse in this period, the thermal constant (TC) of the melon plant was calculated for the city of Rondonópolis, MT, Brazil, adopting a basal temperature (Tb) for the melon crop of 12 °C, as shown in Table 2.

During the whole cycle of the melon plant, 1713.6 °C were accumulated. The average values of relative air humidity inside the agricultural greenhouse for the months of April, May, June, July, and August were 78, 68.5, 72, 63.5, and 70%, respectively.

Table 3 shows the summary of the analysis of variance and results of the comparison test of means for the variables evaluated. There was no significant interaction ($p \leq 0.001$, 0.01 and 0.05) between irrigation frequency and substrate volume for any variable evaluated. It was found that the frequencies of irrigation had significant effect on fruit mass, pulp thickness and water use efficiency. For the volume of substrate used, the

Table 2. Thermal constant for cantaloupe melon, variety Rock Hybrid Cantaloupe

Month	Days	Tm	Tb	DDi	∑ DD month	∑ DD cycle
		(°C)				
April	18	29.7	12	17.7	318.6	318.6
May	31	26.5	12	14.5	449.5	768.1
June	30	26.3	12	14.3	429.0	1197.1
July	31	24.8	12	12.8	396.8	1593.9
August	9	25.3	12	13.3	119.7	1713.6

Tm - Mean air temperature; Tb - Basal temperature; DDi. - Initial degree days; ∑ DD month - Sum of degree days in a month; ∑ DD cycle - Sum of degree days in the cycle

Table 3. Summary of analysis of variance and results of the comparison test of means for the evaluated variables of cantaloupe melon (variety Rock Hybrid Cantaloupe) subjected to different irrigation frequencies and substrate volumes

Source of variation	DF	Mean squares				
		[1]Fruit mass	[1]Pulp thickness	Water use efficiency	[1]Titratable acidity	[1]Soluble solids
Block	3	16.40^{ns}	0.013^{ns}	0.00001^{ns}	0.0018^{ns}	0.110^{ns}
Irrigation frequency (F)	3	85.69**	0.067***	0.00010*	0.0019^{ns}	0.123^{ns}
Substrate volume (V, dm^3)	2	96.19**	0.071***	0.00021**	0.0013^{ns}	0.263*
F x V	6	16.44^{ns}	0.008^{ns}	0.00002^{ns}	0.0036^{ns}	0.019^{ns}
Residual	33	15.73	0.007	0.00002	0.0025	0.059
CV (%)	-	12.92	4.13	25.76	11.95	6.68

Source of variation	Comparison test of means				
	[1]Fruit mass (g plant^{-1})	[1]Pulp thickness (cm)	Water use efficiency (g mL^{-1})	[1]Titratable acidity (g 100 mL^{-1})	[1]Soluble solids (%)
Irrigation frequency (F)					
Once a day	1109.58 a	4.31 ab	0.022 ab	0.19 a	13.56 a
Twice a day	876.66 ab	3.93 bc	0.018 ab	0.17 a	13.40 a
Three times a day	1087.66 a	4.40 a	0.023 a	0.16 a	13.97 a
Once every two days	772.16 b	3.76 c	0.016 b	0.18 a	12.36 a
Substrate volume (V, dm^3)					
5	785.12 b	3.80 b	0.016 b	0.17 a	12.28 b
10	1030.62 a	4.20 a	0.021 a	0.19 a	13.66 ab
15	1068.81 a	4.31 a	0.022 a	0.17 a	14.03 a

***, **, *, ^{ns} - Significant at p ≤ 0.001, 0.01, 0.05 and not significant, respectively, by F test; [1]Square-root-transformed data; DF -Degrees of freedom; CV - Coefficient of variation; Means followed by the same letter in the column did not differ significantly from each other by Tukey test, (p ≤ 0.001, 0.01 and 0.05)

fruit mass, pulp thickness, water use efficiency and soluble solids varied significantly.

The result observed for fruit mass between irrigation frequencies showed that when the volume of water applied is divided into two equal parts and added at the beginning and end of the day, it probably results in a loss of part of the water through percolation, since the pots were perforated at the base to avoid flooding the substrate. For the irrigation frequency of once a day, at noon, greater fruit mass was obtained probably because the highest rate of evapotranspiration occurs at times of the day when the air is less humid and temperatures are higher, resulting in greater absorption of water by the roots, which consequently absorb more nutrients for the plants, because according to Lehane (1981), the simultaneous occurrence of high temperatures and low relative humidity of the air leads to a higher rate of potential evapotranspiration.

The fruit mass obtained for the frequency of once every other day represented a 29.71% reduction in fruit mass when compared to the average between the frequencies of once and three times a day, which was 1098.62 g plant^{-1}. This average fruit mass meets the marketing standard for melon fruits, because according to Medeiros et al. (2011), the masses of commercial fruits vary from 1000 to 1500 g fruit^{-1} and larger fruits are devalued in the foreign market, but appreciated in the domestic market. However, the average observed in this research is lower than that observed by Lozano et al. (2018), who found in cantaloupe melon fruits average fruit mass of 1243 g plant^{-1}.

The results observed in this research for irrigation frequencies of once and three times a day can be attributed to the adequate water content in the substrate, made possible by the irrigation management, which consisted of more frequent applications of water. On the other hand, it is also observed that the frequency of irrigation of once every two days may have provided a lower availability of easily absorbable water for melon plants between irrigation periods, due to the greater variation in the volume of water available in the substrate between field capacity and the permanent wilting point, which resulted in a reduction in the mass of fruit per plant. According to Freitas et al. (2010), plant development may be affected depending on the intensity of water deficit, because this has effects on stomatal opening, photosynthetic process and plant growth.

The substrate volumes of 10 and 15 dm^3 led to the highest performance of fruit mass, with an average of 1049.71 g plant^{-1}, and did not differ from each other. The lowest performance was observed for the volume of 5 dm^3, which corresponded to a 25.20% reduction in fruit mass when compared to the average of the two largest substrate volumes. The volume of substrate used affected the development of the plants, which resulted in a reduction in fruit mass. This result demonstrates that, among the three volumes of substrate used in this research, the two largest volumes were the most adequate for fruit yield. Similar results were observed by Bezerra & Aquino (2003), who evaluated substrate volumes in the production of melon seedlings and obtained higher dry mass measurements for the two largest substrate volumes used.

This fact can be explained by the greater availability of area occupied by the root system, which resulted in greater availability of water and nutrients for the plants, enabling greater development of the plant and fruit.

The highest average pulp thickness among the irrigation frequencies was observed for the water application performed three times a day, with an average of 4.40 cm of thickness. When irrigating once every two days, the pulp thickness was 3.76 cm, which corresponds to a reduction of 14.55% in pulp gain for melon fruits.

The average pulp thickness observed in this study is higher than that obtained by Rangel et al. (2018), who evaluated the performance of cantaloupe melon in a greenhouse and observed an average of 3.45 cm.

These results show that when irrigation management is adopted with a fractional addition of water, the probability of occurrence of water deficit or loss of water by percolation decreases, thus the fractional addition of water allows the maintenance of micropores with sufficient water for the absorption of nutrients by the plants, because according to Silva et al. (2017), it is evident that the movement of nutrients from the soil towards the root depends on the presence of water. The greater absorption of water and nutrients by the melon allows the plant to produce fruits of larger size and thicker pulp, since it is possible to produce a greater volume of photoassimilates. Greater thickness of the pulp is desirable, because it indicates that the fruit has a greater edible part and greater mass, which also indicates that these fruits are of better quality.

In the present study, as a statistical difference was observed for pulp thickness among irrigation frequencies and among the substrate volumes used, it was noted that the distribution of the irrigation depth at a higher frequency and larger substrate volumes are more suitable for the production of cantaloupe melon fruits with thicker pulp.

The substrate volumes of 10 and 15 dm^3 showed the best performance for melon pulp thickness, with averages of 4.20 and 4.31 cm, respectively, with no difference between them. These results are superior to those obtained by Vargas et al. (2008), who in a study on the quality of netted melon as a function of the cultivation system, observed an average of 37.80 mm (3.70 cm) of pulp thickness in melons whose plants were grown in substrate and an average of 34.56 mm (3.45 cm) of pulp thickness in plants grown in soil.

Among the volumes of substrate used in this study (5, 10 and 15 dm^3), there was probably a greater root volume for plants grown in 10 and 15 dm^3 compared to those grown in 5 dm^3. This fact occurred because the larger volumes of substrate had a larger area for exploration by the plant's root system, a greater volume of water stored in the pot, and a greater availability of nutrients for the plants. Thus, the plants grown in 10 and 15 dm^3 had greater vegetative development, which in turn allowed them to produce fruits with greater thickness of pulp, since the amount of nutrients available to the plants as a function of the volume of substrate allowed greater fruit yield in these substrate volumes. Also, according to Souza et al. (2001), the larger volume of substrate promotes greater availability of water and nutrients, as well as greater growth and expansion of the root system.

Water use efficiency of cantaloupe melon was affected by the frequency of irrigation and the volume of substrate used. When the irrigation rate was applied three times a day, the highest water use efficiency was obtained for fruit mass gain, averaging 0.023 g mL^{-1}. The lowest average water use efficiency was observed for the frequency of irrigation performed once every two days, with an average of 0.016 g mL^{-1}, corresponding to 69.56% of the average obtained for the frequency of three times a day, or a reduction of 30.43% in water use efficiency. Statistically, the frequencies of irrigation corresponding to once, twice and three times a day are the most efficient in the use of water, showing that the increase in the frequency with which irrigation is performed results in an increase in the efficiency of water use.

Similar results were also observed by Sousa et al. (2000), when evaluating the efficiency of water use in melon cultivation under different irrigation frequencies, showing higher water use efficiency for higher irrigation frequencies (once and twice a day). These same authors emphasize that more frequent water applications allow better distribution of water and maintenance of soil moisture at optimum levels throughout the crop cycle, and may also reduce water losses by drainage and the occurrence of periods of crop water stress, thus resulting in better vegetative and productive performance of the crop.

The values obtained in this study for water use efficiency correspond to the application of 100% water use defined from the evapotranspiration data of the crop. However, authors such as Ezzo et al. (2020) state that water use corresponding to 75% of crop evapotranspiration promotes increases in water use efficiency, pulp thickness, soluble solids content, and pulp firmness of cantaloupe melon fruits. This can be explained by the fact that plants tend to absorb as much water as possible from the soil when water deficit begins as a survival mechanism.

For water use efficiency between substrate volumes, the highest performance was observed for the volumes of 10 and 15 dm^3, with averages of 0.021 and 0.022 g mL^{-1}, respectively. The higher water use efficiency observed for substrate volumes of 10 and 15 dm^3 may be related to the volume of water corresponding to the available water capacity (AWC) that each substrate volume had. For the 5 dm^3 substrate volume the AWC was 1.4 L, while for the 10 and 15 dm^3 volumes the AWC was 2.8 and 4.2 L, respectively.

Although there is a limit on the water storage capacity of the substrate used, the substrate volumes of 10 and 15 dm^3 evidently had a greater volume of water available to the plants as a whole, which made it possible to provide a greater amount of nutrients for absorption by the roots.

The titratable acidity content of the pulp did not differ between treatments for both irrigation frequency and substrate volume. The average values observed were 0.18 g 100 mL^{-1} between irrigation frequencies and 0.17 g 100 mL^{-1} between substrate volumes. These values are higher than those obtained by Vargas et al. (2021), who observed titratable acidity of 0.11 g 100mL^{-1} of pulp of netted melon grown in a protected environment.

The values obtained for titratable acidity in this study are in agreement with the amounts of citric acid generally observed in melons, which range from 0.05 to 0.35 g of citric acid per 100 mL of juice (Costa et al., 2004).

The soluble solids content of fruits was not significantly influenced by the irrigation frequencies. The average soluble solids content among the irrigation frequencies was 13.48%, which is higher than that observed by Irineu et al. (2018), who obtained an average value of 9.75% for soluble solids content in a study on the agronomic performance of cantaloupe melon under different irrigation levels.

Differences in soluble solids content were observed only between the volumes of substrate evaluated, showing that there is a correlation between the amount of nutrients available to the plants and the concentration of soluble solids in the fruit. The highest average of soluble solids was observed in fruits from plants grown in 15 dm^3 of substrate, not different from value obtained with the volume of 10 dm^3. The lowest

Table 4. Pearson's correlation coefficients (r) of melon, variety Rock Hybrid Cantaloupe, subjected to different irrigation frequencies and substrate volumes

	Water use efficiency (g mL^{-1})	Fruit mass (g plant^{-1})	Pulp thickness (cm)	Soluble solids (%)	Titratable acidity (g 100mL^{-1})
Water use efficiency (g mL^{-1})	1				
Fruit mass (g plant^{-1})	0.93	1			
Pulp thickness (cm)	0.84	0.91	1		
Soluble solids (%)	0.50	0.40	0.39	1	
Titratable acidity (g 100mL^{-1})	0.01	0.08	0.06	0.21	1

Pearson's correlation coefficient (r) close to 0 indicates that there is no relationship between the two variables

content of soluble solids was observed in fruits grown in 5 dm^3 of substrate, with an average of 12.28% of soluble solids. The average soluble solids observed for the 5 dm^3 volume corresponds to a reduction of 12.47% compared to the 15 dm^3 volume.

These results show that larger volumes of substrate give greater availability of water and nutrients to plants, enabling greater vegetative development, which will result in increased soluble solids content in the fruit. The cultivation of melon with only one fruit per plant, as it is the case of this study, also contributes to the increase of soluble solids content in melon fruits. This technique allows the photoassimilates to concentrate in a single fruit, instead of being diluted among several fruits.

The fact that the cultivation of only one fruit of melon per plant allows the production with a high content of soluble solids is corroborated by Queiroga et al. (2008), who found higher soluble solids values in melon plants with only one fruit compared to plants that had two fruits. These same authors state that the higher soluble solids content observed in plants with only one fruit can be attributed to the greater availability of leaf area per fruit, which increases the contribution of photoassimilates to the fruits. In a study on the effects of main stem pruning and fruit thinning of melon, Ferreira et al. (2018) also observed that early fruit thinning led to an increase in soluble solids content of fruit compared to later fruit thinning.

Larger substrate volumes are desirable in vegetable cultivation, as these provide greater availability of water and nutrients for the plants, resulting in greater vegetative growth, conferring increased fruit mass and quality. Another important factor for the production of melon fruits with high levels of soluble solids is the correct management of fertilization, because the availability of elements such as nitrogen and potassium at adequate levels is essential to increase the content of soluble solids in the fruit.

Fruit classification is of fundamental importance in the commercialization step, once satisfactory presentation of the product provides a greater attraction to consumers. According to Gayet (1994), melon fruits with soluble solids contents lower than 9 °Brix are not marketable, fruits with contents between 9 and 12 °Brix are marketable, and fruits with values above 12 °Brix are considered "extra". Therefore, for the conditions of the present study, melon fruits for both irrigation frequencies and substrate volumes were classified as "extra" fruits.

The highest correlation was observed between fruit mass and water use efficiency (0.93), suggesting that the adoption of the irrigation frequency that promotes better use of water will result in an increase in melon fruit mass. There were also strong correlations between pulp thickness and water use efficiency (0.84) and fruit mass (0.91), as shown in Table 4.

These results indicate that the irrigation frequencies that showed the highest performance for water use efficiency promote the highest fruit mass and also lead to thicker pulp fruits, which are more acceptable to the consumer market.

Conclusions

1. Irrigation frequencies of once and three times a day, together with substrate volumes of 10 and 15 dm^3, promote higher fruit mass of melon, greater pulp thickness and higher water use efficiency.

2. Irrigation frequencies do not alter titratable acidity and soluble solids of melon fruits.

3. The use of substrate volumes of 10 and 15 dm^3 in the cultivation of cantaloupe melon produces fruits with higher pulp thickness, greater fruit mass, and higher water use efficiency.

4. The frequency of irrigation of once every two days associated with the volume of 5 dm^3 of substrate is not recommended for the cultivation of melons in protected environment.

Acknowledgements

The authors thank the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES - 001) for the scholarship that made this study possible.

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