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Water requirements and fruit development rate of Cantaloupe melons cultivated in summer-autumn

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Abstract

The knowledge regarding the crop water demand and its vegetative development is the basis for any agronomic scientific research. This study determined evapotranspiration, crop coefficient, fruit growth rate, stem, and photosynthetic activities of the melon. The experiment was conducted in a protected environment at the Technical Irrigation Center (CTI) of the Universidade Estadual de Maringá (UEM) in Maringá-Pr. The hybrid used was the melon Cantaloupe Torreon grown vertically. Irrigation was carried out via drip based on accumulated evapotranspiration. Reference evapotranspiration was estimated by the Penman-Monteith-FAO method using data from an automatic weather station, and crop evapotranspiration was measured using constant groundwater lysimeters. Caliper performed measurements of the plant's lap and fruit in formation. The SPAD index measurements occurred on the third leaf of the main stem and the leaf closest to the fruit. The melon's water demand was 388.16 mm. The crop coefficient values obtained were: 0.95, 1.03, and 0.99 for the initial, intermediate, and final stages. The growth rate of the cervix increased from 7 mm to 35th day after transplantation. In 14 days, the equatorial growth of the fruit was 98 mm. The SPAD index registered a maximum of 105 for the third leaf and 112 for the fruit leaf.

Keywords: *Cucumis Melo; evapotranspiration; lysimeter; vegetative growth rate*

Introduction

Researchers estimate that by 2030 the world population will reach 8.6 billion people (ONU, 2019). As important as the increase in food production to meet this demand is the efficient and sustainable use of available resources, water being the main one. According to the Confederation of Agriculture and Livestock of Brazil (CNA), Brazil has 7 million irrigated hectares with great potential for expansion (CNA, 2020).

The proper management of irrigation is essential not only for the rational use of water but also to ensure that the crop's water demand is met in all the different stages of development.

Evapotranspiration is a mean parameter in the interaction between the soil, plant, and atmosphere (Liu et al., 2013). Pereira et al. (2013) consider that crop evapotranspiration is an indispensable element for the water management of different species, representing the amount of water to be replenished to the soil to maintain the plant's development. Therefore, monitoring and quantifying the crop's evapotranspirative demand through lysimetry ensures higher reliability in irrigation management.

The crop coefficient (Kc) makes it possible to perform the irrigation assertively based on the plant's phenological stages. This coefficient is the rate between crop and reference evapotranspiration (Allen, et al., 1998).

From the scientific point of view, the ideal vegetative growth enables the performance of analyses that are fundamental for understanding plant physiology throughout the cycle. Dantas et al. (2016) emphasized the importance of studies concerning fruit growth, as these can define the optimal harvesting point and its useful life in post-harvest. The monitoring of the fruit growth rate aims to identify the main physical and chemical changes in the

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development of these, allowing the proper management and identification of the different phenological phases (Fernandes et al., 2014).

However, the present study aimed to determine the evapotranspirative demand of the melon culture cultivated in the summer-autumn period in the northwest region of Paraná, its crop coefficient, its stem and fruit growth rate, and the quantification of chlorophyll indices in leaves over the cycle.

Materials and Methods

The experiment was conducted at the Irrigation Technical Center, a teaching unit of the Agronomy department of the State University of Maringá, in Maringá-Paraná (Brazil). The experiment was implemented in a protected environment with dimensions: 25 m long, 7 m wide, and 3.5 m height with transparent arc-shaped polyethylene cover (150 µm), and white nylon fabric on its side.

The region's climate, according to the Köppen-Geiger classification, is mesothermal humid with abundant rainfall in summer and dry winter, with an average annual rainfall of 1300 to 1600 mm, an average temperature of 21.8°C, and 66% relative humidity (Montanher & Minaki, 2020).

The soil of the experimental area is classified as Nitossolo Distroférrico vermelho (Santos et al., 2018) with a very clayey texture, possessing 70% of clay in its composition. Soil sampling was performed from 0 to 20 cm depth for chemical analysis, obtaining the following results: pH $CaCl_2$ = 6.1; pH H_2O = 7,4; OM = 25.2 g dm^3; C = 12.57 g dm^3; P = 46.77 mg dm^3; K = 0.55 $cmol_c$ dm^3; Ca^{+2} = 8.06 $cmol_c$ dm^3; Mg^{+2} = 1.96 $cmol_c$ dm^3; $H+Al^{+3}$ = 2.72 $cmol_c$ dm_3; SB = 10.57 $cmol_c$ dm^3; CEC = 17.34 $cmol_c$ dm^3; V (%) = 79.53; Cu = 15.90 mg dm^3; Zn = 9.34 mg dm^3; Fe = 68.97 mg dmv; Mn = 94.61 mg dm^3; $Na^+{}_=$ 32.58 mg dm^3; B = 4.1 mg $dm^{3.}$

Constant level groundwater lysimeters determined the evapotranspiration of the culture (ETc.). On each lysimeter, two melon plants spaced at 0.50 m were transplanted, similar to the experimental environment, and were later tutored with threads attached to the n°12 wire. The daily ETc was obtained by observing the three lysimeters present in the protected environment.

Three tenches opening was necessary to install lysimeters. The trenches were circular, where PVC boxes of 310 L capacity, 1.05 m diameter, and 0.65 m depth were buried. Initially, a layer of 0.05 m of gravel type 1 was placed, a geotextile blanket to prevent obstruction of water intake by soil particles. After this process, the boxes were covered by the same soil removed from the box implantation area, following the horizons order (Figure 1).

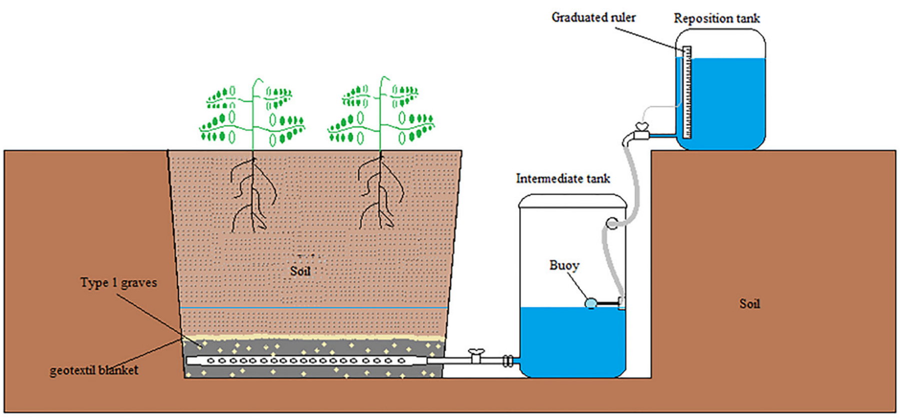

Figure 1. Illustration of the groundwater lysimeter built inside the protected environment.

As the system demands water, it is supplied through the intermediate tank, which is maintained by the tank repositor. In this last tank, a graduated ruler identifies the water consumption by the system, so it is known to Etc.

The irrigation system used was micro drip irrigation composed of 9 self-compensating and self-cleaning drip heads, spaced at 0.25 m, flow rate of 4.8 L h-1, operating at a pressure of 10 mca.

The uniformity coefficient of water distribution in the experimental area was performed as Santos et al. (2018) described, and the Christiansen uniformity coefficient was excellent.

The volume of water evapotranspirated by the system was determined daily (7:30 am). Irrigation was performed every two days, considering the accumulated evapotranspiration.

The reference evapotranspiration (ET_0) was determined by the climatic method with a meteorological station of the brand Campbell, installed inside the protected environment. The calculation of ET0 was obtained through the Penman-Monteith methodology parameterized in the FAO Bulletin 56 (Allen et al., 1998).

Forty-eight beds were built, 3 m long and 0.5 m wide. The seedlings of the hybrid Cantaloupe Torreon were transplanted 22 days after sowing in 0.5 m spacing. Each seedling received five plants, where the three central plants were evaluated.

The plants were tutored vertically by strands attached to two n°12 wires parallel to 0.3 m and 1.80 of the ground surface along each bed. These strands were fixed to 2 meters-high bamboo platforms, placed at the extremities of each bed.

The assessments began five days after transplantation. Lateral prunings were performed periodically, preserving just the central stem. Pollination was performed by hand in the mornings from the tenth to the thirteenth internodes, then thinned, leaving just one fruit per plant. Finally, apical pruning was performed after the 23° internode formation.

The Minolta SPAD 502-Plus tool measured the chlorophyll content in the melon leaves, which is foresight for culture productivity and leaf sanity. The analysis was performed weekly in the morning, assessing the third leaf of the main stem and the closest leaf to the forming fruits.

During the culture development, the lap of the plant diameter, close to the cotyledonary region, and the fruits' equatorial diameter by a digital caliper were measured weekly.

A Microsoft Excel® software chart performed the ETo, Etc, Kc calculi, the fruit growth rate values, stem, and SPAD index.

Results and Discussion

The temperature gradually decreased during the experiment due to the seasons' change. The mean temperature of the protected environment during the culture cycle was 21.6°C (Figure 2). The minimum recorded temperature was 5.6°C, the maximum, 37 °C. Relative humidity varied between 43% and 94%, but the mean was 64% during the culture cycle.

The total water production demand was 388.16 mm during the 98 days in a protected environment (Figure 3).

Twenty-two days passed between seeding and transplantation, summing up 120 days under meteorological conditions of the end of summer and autumn beginning in the Maringá municipality.

The energy increase, promoted by the temperature rise during the first days (Figure 2), increased evapotranspiration during the first 20 days too, as highlighted by Figure 3. In the same period, the plant was beginning its vegetative growth, and soil water was the main responsible for the evapotranspiration values observed.

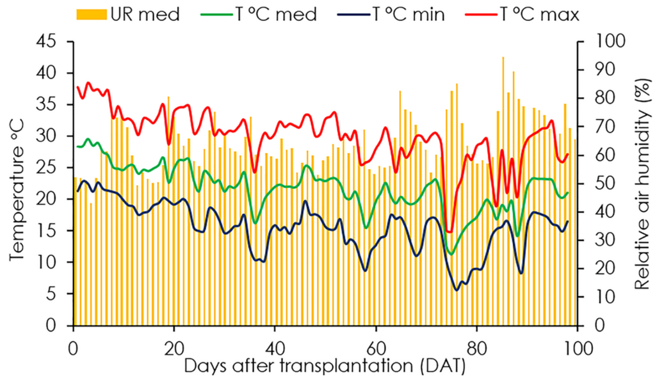

Figure 2. Mean relative humidity, maximum, mean, and minimum temperature of the protected environment during the melon production cycle in Maringá-PR as days after transplantation (DAT).

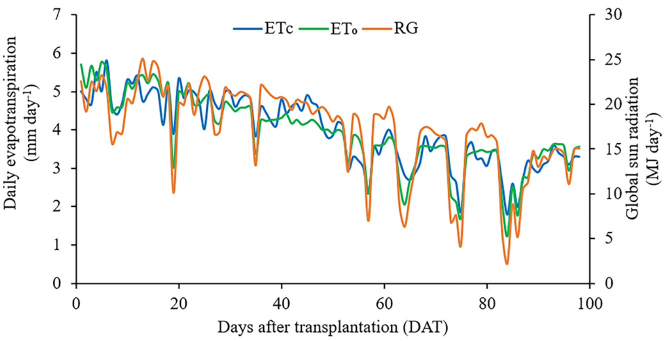

Figure 3. Daily reference evapotranspiration (ET_0), melon culture evapotranspiration (Etc), and global sun radiation (RG) of Cantaloupe melon produced in a controlled environment, Maringá-PR.

Lozano et al. (2017) observed lower water demand than observed in the present experience (295 mm) in melons under protected environment during the spring-summer period, but their global solar radiation and temperature were constant during the culture cycle.

The global sun radiation rates decreased during the days due to season change. Radiation incidence directly influences temperature, which, on the other hand, contributes to evapotranspiration variations. Figure 3 points out how the evapotranspiration observed variations resembled the solar radiation modifications.

The mean cantaloupe melon crop coefficients (Kc) were calculated based on the Etc and ETo data. These results were higher than the recommendations of the FAO bulletin 56 (120 days cycle) in all phenological stages, as displayed in Table 1.

Table 1. Crop coefficient (Kc) and water volume used in the *Cantaloupe* melon production under protected environment, Maringá-PR.

Stage	Culture coefficient		Water volume (mm)	
	measured	FAO	measured	FAO
Initial	0.95	0.5	75.13	37.56
Intermediate	1.03	0.85	265.99	226.09
Final	1.99	0.6	47.04	28.22

Based on the FAO data, watering management is insufficient to meet the melon water demand in the studied area. Therefore, it is crucial to point out the relevance of regional research on the culture coefficient. Moreover, according to Table 1, the water deficit promoted by the FAO values represents 49% of the culture water demand on the initial stage, 85% on the intermediate stage, and 60% on the final stage.

Da Silva Cavalcanti et al. (2015) describe that melon production under water deficit reduces the culture development, causing low productivity and jeopardizing nutrient assimilation.

Factors such as climate, soil type, plants' physiological conditions, soil cover, or cultivars variety influence Kc intensely, promoting discrete values from those published by FAO (Lorenzoni et al., 2019; Barion Alves Andrean et al., 2021). Allen et al. (1998) describe that frequent soil humidification by irrigation or daily rainfalls can significantly increase Kc values.

Different Kc values can be measured in the same region during different times of the year, as observed by Lozano et al. (2017), who obtained the following Kc values: 0.87, 1.15, and 0.64 for the Cantaloupe melon culture under a protected environment in the Maringá-Pr municipality in summer. In this form, even during different times of the year, the values presented by FAO seem to be insufficient to promote adequate water availability.

Fruits' production period is inserted in the intermediate stage, characterized by increasing vegetative architecture and nutrients' absorption (Oliveira et al., 2016). Figure 4 displays the transversal fruit diameter and plant lap growths.

After the female flowers' fecundation (begun on the 20th DAT), the fruits displayed a 22 mm diameter at the 28th DAT. After 14 days (42nd DAT), the fruits displayed a significant 98 mm diameter increase. A research performed by Gao et al. (1999) also highlighted an expressive melon mass growth on the 15th day after pollination.

The plant lap displayed an accelerated 7 mm diameter growth up to the 35th DAT. This initial vegetative development stage is marked by new branches formation, leaves expansion, and stem elongation. The plant's lap growth stabilized from the 40th DAT as the fruit was ripening.

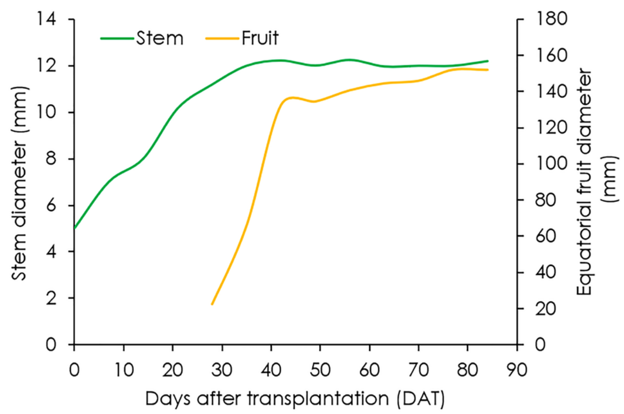

Figure 4. Periodic measure of the plant lap and fruit diameters as millimeters in the Cantaloupe melon production cycle under a protected environment in the Maringá- Pr municipality.

A leaves' intense photosynthetic activity marks the vegetative melon development and its reproductive period. This dynamic varies according to the leaf's position on the plant, playing a crucial role in maintaining the culture cycle.

Figure 5 displays the chlorophyll index variations measured on the melon leaves until their senescence.

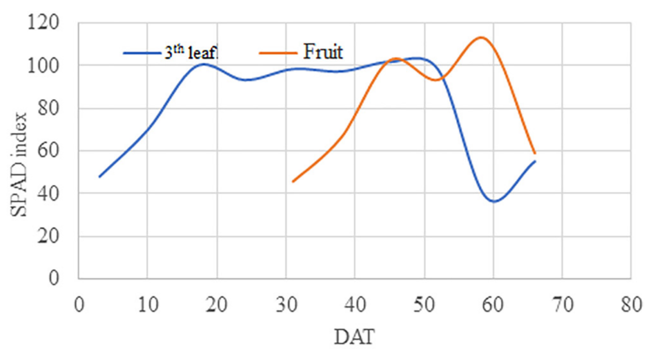

Figure 5. SPAD index of the third leaf and reproductive leaf of the Cantaloupe melon.

The third leaf began its growth and expansion process from the first week after transplantation on, with a gradual photosynthesis increase. During 17 days, the leaf ends its growth process, acting at its full potential, displaying SPAD index variations from 93 to 105. These rates continue until 52 DAT, as the leaf begins its senescence, reducing its activity.

The leaf near the forming fruit displayed a remarkable SPAD index increase from the 30th DAT until the 45th day. The following days displayed variations that lasted until the 60th DAT when the highest 112 SPAD index was recorded. Nevertheless, the activity period of this leaf was shorter than the third leaf.

Conclusions

The culture coefficient was higher than published by FAO, being: 0.95; 1.03, and 0.99 for the initial, intermediate, and final stages under the Northeastern Paraná State soil and climate conditions.

The plant lap diameter growth stabilized as the fruit diameter increased (35 DAT), and the fruit growth peaked from 28 to 42 DAT.

Vegetative leaves have a longer photosynthesis time than reproductive leaves. As a result, the latter enter senescence as it increases its photosynthesis activities to supply the fruit's nutritional demands.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.