Gas exchange in yellow melon (*Cucumis melo*) crop under controlled water deficit (RDI) and application of a biostimulant

Intercambio gaseoso en el cultivo de melón amarillo (*Cucumis melo*) bajo déficit hídrico controlado (RDI) y aplicación de bioestimulantes

Alessandro Carlos Mesquita [1], Welson Lima Simões [2], Luan David Alcantara Campos [1], Marcos Brandão Braga [3], Yuri Rafael Alves Sobral [4]

Originales: *Recepción:* 28/07/2023 - *Aceptación:* 27/06/2024

Abstract

The São Francisco River Valley region in Brazil is a major producer of irrigated melons, facing stresses due to climate change. New strategies for crop management are essential to maintain sustainable cultivation. This study aims to evaluate the characteristics of melons under controlled irrigation deficit (RDI) and the use of a biostimulant. The experiment followed a completely randomized design with sub-subdivided plots. The main plots represented water levels: full irrigation (100% soil water availability - SWA) and deficit levels (80%, 60%, and 40% SWA). The subplots represented biostimulant application (with and without), and the sub-subplots represented collection periods: time I (17 to 26 days after planting - DAP), time II (27 to 36 DAP), and time III (37 to 46 DAP). The variable analyzed was gas exchange. Water restriction affects melons; however, some physiological characteristics show greater tolerance, demonstrating an adaptive response to moderate water deficit (80% SWA), regardless of the evaluation period. This allows for better water use efficiency. The biostimulant applied was not effective in promoting adjustments in the evaluated gas exchanges.

Keywords
Cucumis melo • physiology • irrigation management

1 Universidade do Estado da Bahia. DTCS/III. s/n. São Geraldo. CEP: 48.904-711. Juazeiro. Bahia. * amesquita@uneb.br
2 Embrapa Semiárido. Rodovia BR-428, Km 152. Zona Rural. Caixa Postal 23. CEP: 56302-970. Petrolina. PE.
3 Embrapa Hortaliças, Rodovia BR 060. Km 9 SN. Fazenda Tamandua. CEP: 70351-970 Brasilia. Distrito Federal.
4 Universidade do Estado da Bahia. DTCS/III. s/n. São Geraldo. CEP: 48.904-711. Juazeiro. Bahia. Programa de Pós-Graduação em Agronomia/Horticultura Irrigada. PPGHI.

Resumen

En Brasil, el Valle del Río San Francisco es reconocido como un importante productor de melón bajo riego. Ante el estrés causado por el cambio climático, es crucial emplear nuevas estrategias de gestión del cultivo para garantizar su sostenibilidad. Por lo tanto, el objetivo de este estudio fue evaluar las características del melón bajo déficit de riego controlado (RDI) y la aplicación de bioestimulantes. El experimento se realizó en parcelas subsubdivididas. Las parcelas representaron diferentes niveles de agua: riego completo (100% de disponibilidad de agua del suelo - SWA) y niveles de déficit (80, 60 y 40% SWA). La subparcela consideró el uso de bioestimulante (con y sin), mientras que la subsubparcela abarcó los períodos de recolección: tiempo I (17 días después de la siembra - DDS hasta 26 DDS), tiempo II (27 a 36 DDS) y tiempo III (37 a 46 DDS). Las variables analizadas fueron el intercambio gaseoso. El melón mostró ser afectado por la restricción hídrica; no obstante, ciertas características fisiológicas mostraron ser más tolerantes, exhibiendo una respuesta adaptativa atenuada. Específicamente, la aplicación de déficit hídrico moderado (80% SWA), independientemente de la estación evaluada, permitió un mayor rendimiento en la eficiencia del uso del agua (UEU). Sin embargo, el bioestimulante no demostró ser eficiente para promover ajustes en el intercambio gaseoso.

Palabras clave

Cucumis melo • fisiología • gestión del riego

Introduction

Melon (*Cucumis melo* L.) is appreciated for its sweet flavor, functional and nutritional traits, and significant economic value. It thrives in diverse environments and management practices, particularly in the semi-arid Northeastern Brazil, where it exhibits year-round growth due to its exceptional productivity (5, 24). The climatic conditions of the São Francisco River Valley, characterized by high insolation and low rainfall, are conducive to melon production, fostering high photosynthetic rates and minimal disease incidence, thereby optimizing melon yields in the region (18).

The mid-region of the São Francisco River Valley, notably the Juazeiro-Petrolina area, is a prominent hub for melon production (14). In response to historically limited water resources from the main reservoirs of the São Francisco River, producers in these areas have increasingly adopted agronomic techniques to enhance water use efficiency.

Accurate water management is crucial to meet the crop's water requirements throughout its growth stages, ensuring optimal productivity. Physiological growth analysis serves as a valuable tool for understanding plant responses under varying environmental conditions, enabling comparisons across different cultivation systems (20).

Assessing drought tolerance requires a comprehensive evaluation of multiple physiological variables, such as water potential, stomatal conductance, temperature, and leaf transpiration, which collectively indicate plant performance under water stress (22). Parameters like transpiration, stomatal conductance, and photosynthesis directly influence crop growth, development, and yield, responding to soil water status and climatic variations (9).

Water use efficiency (WUE) metrics in agriculture facilitate the assessment of crop responses to varying water availability conditions. WUE is defined as the ratio of plant biomass production to the volume of irrigation water applied (11, 12).

Climate change exacerbates environmental challenges, particularly in semi-arid regions (8), potentially escalating drought vulnerabilities (7, 16) unless prompt interventions are implemented. Water scarcity in arid and semi-arid regions, such as the mid-region of the São Francisco River Valley, significantly impacts regional development.

Regulated deficit irrigation (RDI) has emerged as a key strategy in irrigation management, aiming to optimize water use efficiency by subjecting fruit trees, including melons, to controlled water stress during specific growth stages (1, 16). RDI entails applying reduced irrigation water at critical plant growth phases, enhancing WUE without compromising yield (3, 13, 14, 26, 27).

Various strategies for applying water deficit alter soil water availability, influencing leaf temperature variations and thereby affecting gas exchange and carbohydrate accumulation (31), ultimately influencing crop growth and productivity (28).

In addition to RDI, another management approach to mitigate regional climatic impacts involves biostimulant application. Biostimulants are formulations-comprising synthetic or natural substances-that promote plant growth and development by enhancing water and nutrient absorption. They influence vital plant processes, augmenting growth attributes like chlorophyll content, leaf area (4), carbohydrate levels, and fruit quality (32).

Therefore, this study aims to evaluate the physiological effects of RDI and biostimulant application on melons throughout their cultivation cycle in a controlled environment.

Material and methods

The research was conducted during November and December in a shaded environment (50% black mesh) at the experimental area of the Department of Technology and Social Sciences (DTCS), Campus III, State University of Bahia (UNEB), located in Juazeiro, BA, Brazil (9°25'09" S, 40°29'13" W, altitude approximately 368 m). The local climate is classified as Bswh, semi-arid, according to the Köppen classification, with an average annual rainfall of 540 mm. The experimental setup utilized 5-L containers filled with Fluvic Neosol soil sampled from the 0-20 cm layer. Chemical analysis of the soil was conducted at the UNEB Water, Soil and Limestone Laboratory (LASAC), with results presented in table 1.

Table 1. Results of the chemical analysis of the soil used in the research.

Tabla 1. Resultados del análisis químico del suelo utilizado en la investigación.

RESULTS											
EC	pH	P	K	Na	Ca	Mg	Al	H+Al	BS	CEC	V
mS cm^{-1}	-	mg dm^{-3}	$cmol_c$ dm^{-3} de TFSA								%
0.9	6.3	25	0.3	0.03	2.8	1.8	0.0	4.0	4.9	9.0	57.7

EC: Electric conductivity; pH: soil pH; P: phosphorus; K: potassium; Ca: calcium; Mg: magnesium; Al: aluminum; H+Al:potential acidity; BS: Bases sum; CEC: cation exchange capacity; V: percentage of base saturation.

EC: conductividad eléctrica; pH: pH del suelo; P: fósforo; K: potasio; Ca: calcio; Mg: magnesio; Al: aluminio; H+Al: acidez potencial; BS: Suma de bases; CEC: capacidad de intercambio catiónico; V: porcentaje de saturación de bases.

The experimental design was completely randomized, consisting of four soil water availability (SWA) levels (40%, 60%, 80%, and 100% SWA) and three water stress application periods (time I: 17 to 26 days after planting (DAP); time II: 27 to 36 DAP; and time III: 37 to 46 DAP), arranged in subdivided plots. Sixteen SWA combinations were tested for each stress period: 100/100/100, 80/80/80, 60/60/60, 40/40/40, 100/80/80, 100/60/60, 100/40/40, 100/100/80, 100/100/60, 100/100/40, 100/80/100, 100/60/100, 100/40/100, 80/100/100, 60/100/100, and 40/100/100% SWA. During non-stress periods, irrigation was adjusted to maintain soil water at field capacity (100% SWA). The subplot factor included the absence or presence of a biostimulant.

The biostimulant (300 mL ha^{-1} concentration), obtained through biological fermentation of organic compounds, was applied twice: six days after transplant and pre-flowering. Each experimental unit provided data, and irrigation depth was calculated for each treatment using graduated cylinders, applied at two-day intervals.

Seedlings of the 'Gold Mine' cultivar, a yellow-type melon belonging to the *inodorus* group, were grown in a greenhouse using commercial substrate in polystyrene trays with 128 cells for germination. At 12 DAP, seedlings were transplanted into 5-liter pots filled with gravel for improved drainage, covered with a fine mesh to prevent soil loss, and filled with soil.

Following a five-day acclimatization period, water deficit treatments commenced at 17 DAP. Biostimulant application was individually administered using a 20-mL syringe in the specified periods. Fertilization was conducted via fertigation three times per week, tailored for the estimated plant population based on a 0.3 x 2.0 m spacing.

During each water stress period, gas exchange parameters including net photosynthesis, leaf transpiration, stomatal conductance, and leaf temperature were analyzed using a portable infrared CO_2 analyzer (IRGA - LiCOR 6400XT) on fully expanded leaves, between 10:00 am and 12:00 pm on sunny days. Water use efficiency (WUE) was calculated as the ratio of photosynthetic rate to transpiration.

Data were subjected to analysis of variance (ANOVA) and significant differences were determined using the Tukey test ($p < 0.05$). Statistical analyses were performed using SISVAR 5.6 software (9).

Results and discussion

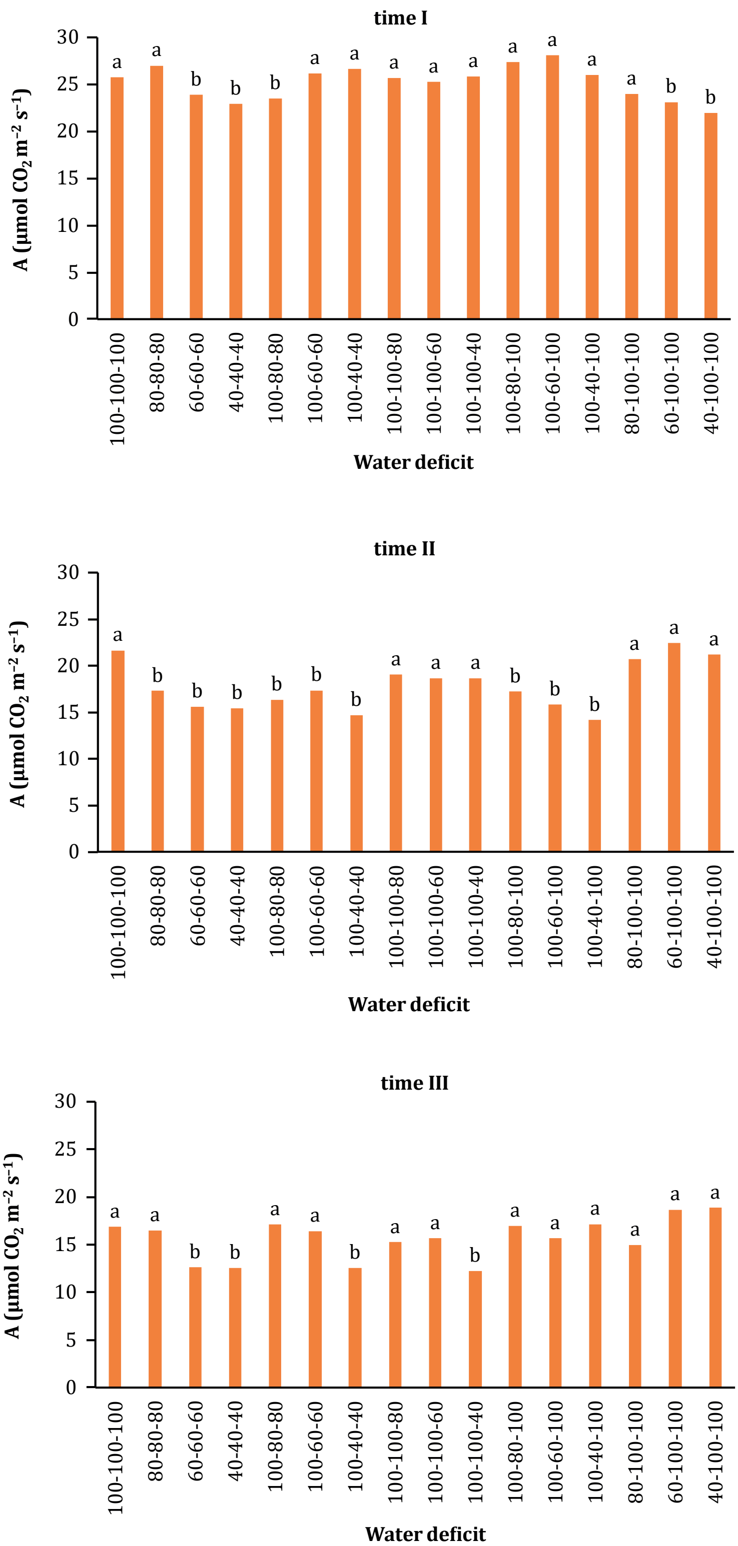
Despite previous studies (4, 29) demonstrating that biostimulants enhance plant metabolism and structure by improving water and nutrient absorption and tolerance to water stress, the analysis of variance in this study revealed no significant interaction between treatments or exclusive differences in evaluated physiological variables compared to RDI. The lack of biostimulant effects on physiological variables may be attributed to the cultivation period, which coincided with the hottest time of the year, likely impacting plant physiological and biochemical characteristics. Nonetheless, there is limited literature discussing the biostimulant's influence on gas exchange parameters.

The analysis of photosynthesis data indicated statistical significance ($p < 0.01$) and a significant interaction between time and water deficit levels. Figure 1 (page 18), illustrates the impact of water deficit on photosynthesis levels, represented by *A - net assimilation rate* of CO_2 *(μmol* CO_2 m^{-2} s^{-1}*)*. Plants irrigated at 100% SWA during times I, II, and III exhibited minimal reductions in photosynthetic activity. Moderate and severe water deficits (60% and 40% SWA) at any time resulted in significantly lower photosynthetic activity. As noted by Vendruscolo *et al.* (2017), adequate irrigation enhances internal CO_2 concentration in plants; however, water availability directly limits photosynthesis, with high CO_2 concentrations correlating with increased stomatal conductance (gs). Thus, stomatal closure primarily restricts photosynthesis, as reduced stomatal apertures hinder CO_2 diffusion, a phenomenon observed in this study.

At times I and III, using 80% SWA showed statistical similarity ($p < 0.05$) to the control, indicating no decrease in carbon assimilation or photosynthetic capacity under moderate water deficit. This finding aligns with previous research (23), which evaluated gas exchange in melon plants under different irrigation frequencies, and Ferrerira (2011), which examined water stress in sesame plants, supporting our results by reporting reduced photosynthetic activity with decreased irrigation frequency.

Stomatal conductance (gs) data (figure 2, page 19), analyzed via ANOVA, revealed a significant interaction between time and water deficit levels. Examination across time periods indicated a decline in leaf surface water vapor conductance over time (I, II, and III), correlating with the photosynthesis data (figure 1, page 18), where photosynthetic levels decreased correspondingly. During time I, treatments maintaining 100% SWA exhibited the highest averages. The treatment with 80% SWA statistically mirrored ($p < 0.05$) the control, allowing higher water vapor conductance and photosynthesis levels (27.01 $\mu mol.m^2.s^{-1}$). Maximum and minimum gs values per time period were as follows: 100% SWA (0.544 $mol.m^2.s^{-1}$) and 40% SWA (0.264 $mol.m^2.s^{-1}$).

Time II showed a similar pattern to time I, with highest conductance values in non-stressed plants and lowest in stressed plants: 100% SWA (0.381 $mol.m^2.s^{-1}$) and 40% SWA (0.162 $mol.m^2.s^{-1}$), respectively. This aligns with findings by Vendruscolo *et al.* (2017), who reported increased gs with higher water availability in eggplants. However, during time III, no significant differences in water deficit levels were observed. As noted by Melo *et al.* (2014), studying gas exchanges aids in understanding melon responses to soil water deficits and quantifying species' acclimation to adverse conditions. Reductions in gs throughout the phenological cycle reflect photosynthetic adjustments, as melon development (15 DAP: vegetative, 30 DAP: flowering, 45 DAP: fruiting) increases leaf area and stomatal density, enhancing gas exchange efficiency. Without this efficiency, both melon types risk excessive water loss, potentially leading to dehydration and hindered growth.

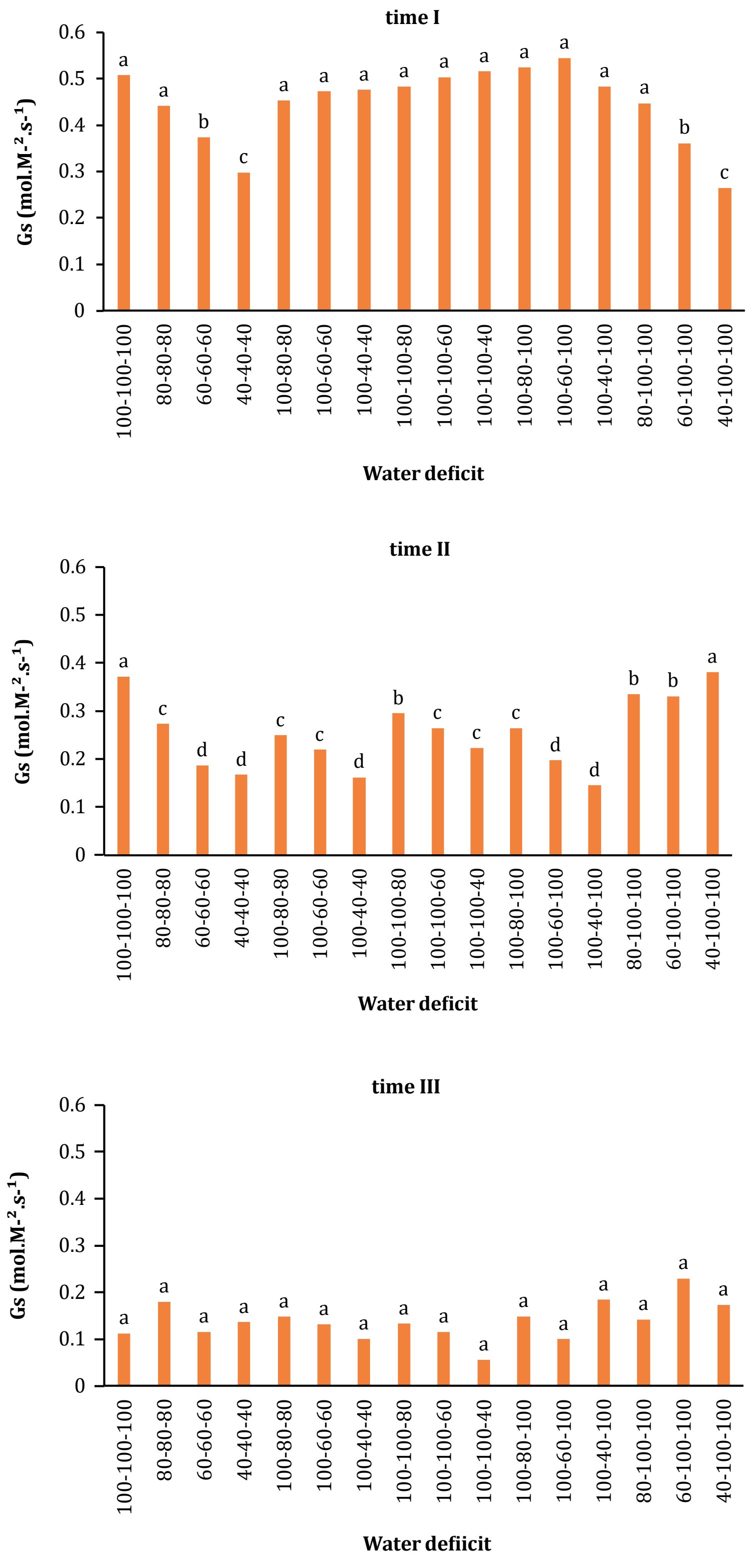


Means followed by the same letters do not differ at 5% probability level by Tukey's test.

Medias seguidas de letras iguales no difieren al nivel de probabilidad del 5% por la prueba de Tukey.

Figure 1. Changes in A - net assimilation rate CO_2 (µmol CO_2 m^{-2} s^{-1}) observed at different times (time I: 17 to 26 DAP; time II: 27 to 36 DAP; and time III: 37 to 46 DAP) in relation to the interaction with water deficit levels.

Figura 1. Cambios en A - tasa de asimilación neta de CO_2 (µmol CO2 m^{-2} s^{-1}) observados en diferentes momentos (Tiempo I: 17 a 26 días después de la siembra - DAP; Tiempo II: 27 a 36 DAP y Tiempo III: 37 hasta 46 DAP) en relación con la interacción con los niveles de agua.



Means followed by the same letters do not differ at 5% probability level by Tukey's test.

Medias seguidas por letras iguales no difieren al nivel de probabilidad del 5% por la prueba de Tukey.

Figure 2. Changes in stomatal conductance - (gs) (mol m^{-2} s^{-1}) at different times (time I: 17 to 26 DAP; time II: 27 to 36 DAP; and time III: 37 to 46 DAP) in relation to the interaction with water deficit levels.

Figura 2. Cambios en (gs) - conductancia estomática (mol m^{-2} s^{-1}) en diferentes tiempos (Tiempo I: 17 a 26 días después de la siembra - DAP; Tiempo II: 27 a 36 DAP y Tiempo III: 37 a 46 DAP) en relación con la interacción de los niveles de déficit hídrico.

Post the fourth week under RDI, temporal variations significantly decreased compared to controls (17), showing stress-induced reductions in gs due to lowered leaf water potential. Figure 3 (page 21), depicts leaf transpiration levels.

According to Lamaoui *et al.* (2018a), stomatal closure results from reduced osmotic-water potential. Results also indicated melon's limited ability to maintain adequate leaf water potential, a trait some cultivars manage due to biochemical characteristics that sustain photoassimilate transport from shoots to roots, enabling enhanced water absorption (25).

For the variable transpiration, there was a double-factor interaction for times and levels of water deficit (figure 3, page 21).

At time I, plants under 100% SWA exhibited higher transpiration rates, while those under moderate deficit (80% SWA) were statistically similar ($p < 0.05$) to the control. There was a slight reduction of 3.79% in maximum transpiration capacity compared to the control treatment. By time II, plants irrigated at 100% SWA continued to display higher transpiration rates, whereas those under water stress exhibited significant reductions. Specifically, the moderate deficit treatment (80% SWA) showed approximately a 20.89% decrease in transpiration compared to its own performance at time I. Time III data indicated a decline in transpiration rates as plants matured, though the pattern observed in previous periods persisted. Water deficit consistently resulted in decreased transpiration rates, with non-stressed treatments exhibiting the highest rates. Notably, the moderate deficit treatment (80/80/80) did not significantly differ at the 5% probability level from the control. Previous studies (unpublished data) on melon physiology under varying irrigation levels suggest that applying an 80% deficit does not reduce transpiration rates.

Research by Elmaghrabi *et al.* (2017), on the Sancho melon cultivar suggested that this response might be attributed to melon metabolism, which can maintain efficient photosynthesis with reduced stomatal opening and lower intercellular CO_2 levels without compromising water use efficiency (WUE). Under optimal water conditions, melons exhibit higher transpiration rates correlated with stomatal conductance (gs), as stomata serve as the primary avenue for water loss, essential for water and mineral absorption, CO_2 uptake for photosynthesis, growth, and plant cooling (23). According to Lamaoui *et al.* (2018a), melon's high gs under normal conditions results from increased stomatal aperture, leading to higher transpiration rates. Conversely, under stress conditions, both transpiration rates and gs decrease. The authors noted that adequate irrigation induces stomatal opening, enhancing melon photosynthetic rates and mitigating stress effects.

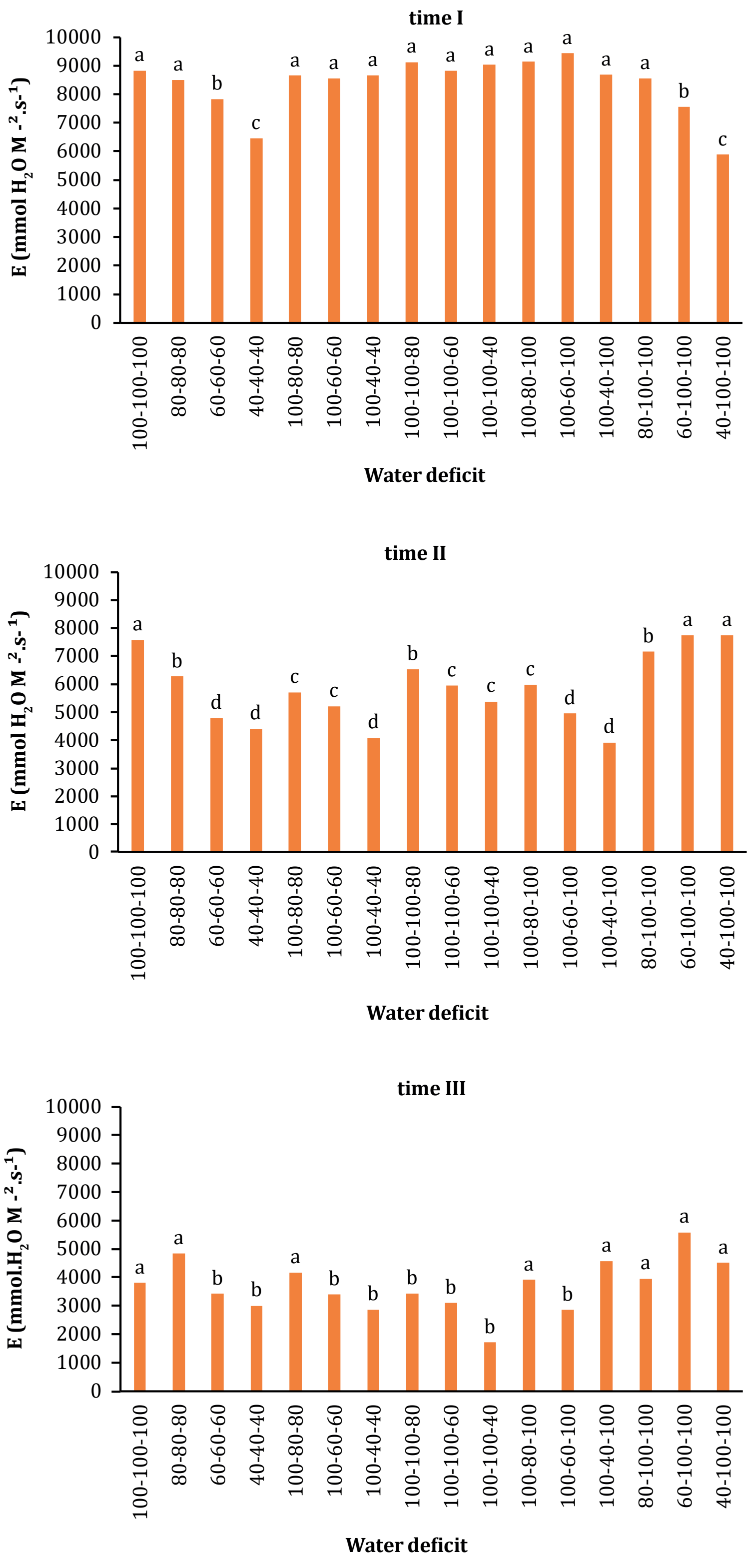
Reducing irrigation by 50% compared to conventional methods led to reduced transpiration rates primarily due to stomatal closure, a phenomenon observed in various plant species. According to Lamaoui *et al.* (2018b), hormonal signaling in shoot long-distance signaling and hydraulic conductivity control explain changes in stomatal activity.

Significant interaction effects were observed in leaf temperature results (figure 4, page 22).

Analysis across time periods (I, II, and III) indicated a gradual increase in leaf temperature over time, driven by rising ambient temperatures typical of November and December, the study period. During times I and II, most treatments receiving 100% SWA showed lower leaf temperatures compared to water deficit treatments (60% and 40% SWA). Notably, plants under 80% SWA did not exhibit increased leaf temperatures, contrasting with other stressed treatments and statistically equating to the control ($p < 0.05$). Similar findings were reported by Vieira *et al.* (2019), in studies on melon plants subjected to various water stress levels, where conductance and transpiration closely influenced leaf cooling. Water deficit indirectly raises leaf temperature by limiting cooling mechanisms through chemical signaling that prompts stomatal closure.

The WUE graph (figure 5, page 23) illustrates how WUE is directly influenced by water deficit.

Full irrigation (100/100/100) resulted in lower WUE compared to treatments subjected to higher water stress levels. Comparing the WUE of the 40/40/40 treatment with the control, there was a 14.7% increase, while the 60/60/60 treatment showed a 25.2% superiority in WUE over the control. Similar results were reported by Al-Mefleh *et al.* (2012) and Nascimento *et al.* (2011), in studies on melon subjected to varying irrigation depths (50%, 75%, 100%, and 125% ETc), highlighting that lower irrigation levels generally lead to higher WUE values.



Means followed by the same letters do not differ at 5% probability level by Tukey's test.

Medias seguidas de letras iguales no difieren al nivel de probabilidad del 5% según la prueba de Tukey.

Figure 3. Changes in transpiration - (E) (mmol H_2O m^{-2} s^{-1}) at different times (time I: 17 to 26 DAP; time II: 27 to 36 DAP; and time III: 37 to 46 DAP) in relation to the interaction with water deficit levels.

Figura 3. Cambios en transpiración - (E) (mmol H_2O m^{-2} $s^{-1)}$ en diferentes tiempos (Tiempo I: 17 a 26 días después de la siembra - DAP; Tiempo II: 27 a 36 DAP y Tiempo III: 37 a 46 DAP) al interactuar con los niveles de déficit hídrico.

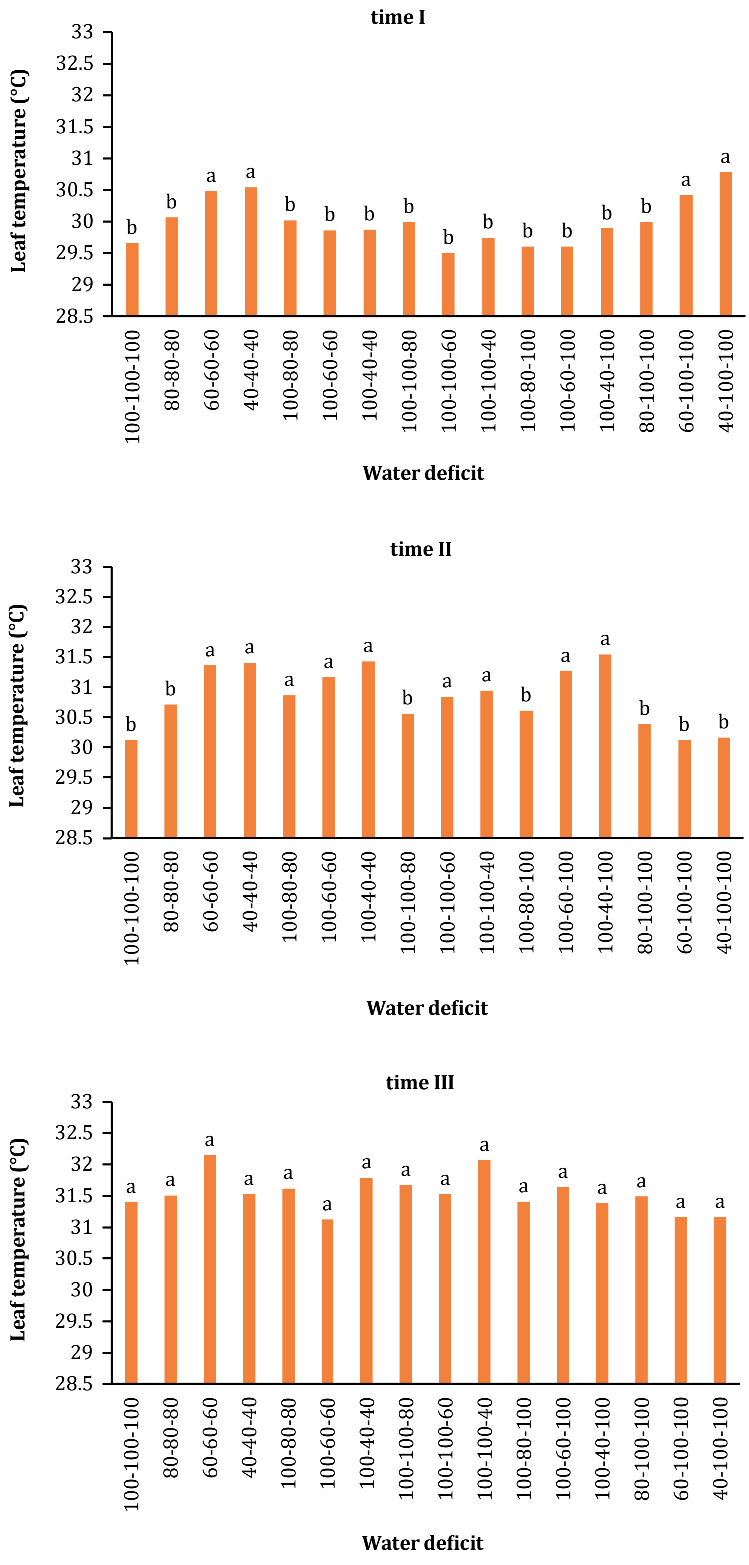


Figure 4. Changes in leaf temperature (°C) at different times (time I: 17 to 26 DAP; time II: 27 to 36 DAP; and time III: 37 to 46 DAP) in relation to the interaction with water deficit levels.

Figura 4. Cambios en la temperatura foliar (°C) en diferentes momentos (Tiempo I: 17 a 26 días después de la siembra - DAP; Tiempo II: 27 a 36 DAP y Tiempo III: 37 a 46 DAP) al interactuar con los niveles de déficit hídrico.

Means followed by the same letters do not differ at 5% probability level by Tukey's test.

Medias seguidas de letras iguales no difieren al nivel de probabilidad del 5% según la prueba de Tukey.

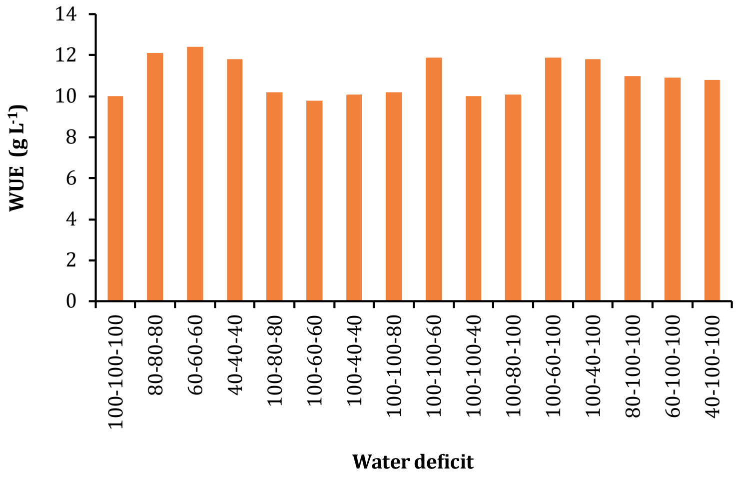


Figure 5. Variation in water use efficiency (WUE) of melon plants in relation to different water deficits.

Figura 5. Variación en la eficiencia del uso del agua (WUE) de las plantas de melón en interacción con diferentes déficits hídricos.

Conclusion

Water restriction impacts melon plants, but certain physiological traits exhibit greater tolerance and adaptive responses, notably under moderate water deficit (80% SWA), irrespective of the season. Consequently, this approach enhances water use efficiency (WUE).

However, the biostimulant applied during the cultivation period does not effectively induce adjustments in gas exchange.

References

1. Ahmadi-Mirabad, A.; Lotfi, M.; Roozban, M. R. 2014. Growth, yield, yield component sand water-use efficiency in irrigated cantaloupe sunder fulland deficit irrigation. Electronic Journal of Biology. 10(3): 79-84.
2. Al-Mefleh, N. K.; Samarah, N.; Zaitoun, S.; Al-Ghzawi, A. A. 2012. Effect of irrigation levels on fruit characteristics, total fruit yield and water use efficiency of melon under drip irrigation system. Journal of Food, Agriculture & Environment. 10(2): 540-545. https://www.researchgate.net/publication/233859372
3. Bassoi, L. H.; Gonçalves, S. O.; Santos, A. R. L.; Silva, J. A.; Lima, A. C. M. 2011. Influência de manejos de irrigação sobre aspectos de ecofisiologia e de produção da videira cv. Syrah/Paulsen 1103. Irriga. 16(4): 395-402. DOI: 10.15809/irriga.2011v16n4p395
4. Batista, G. S.; Silva, J. L.; Rocha, D. N. S.; Souza, A. R. E.; Araújo, J. F.; Mesquita, A. C. 2019. Crescimento inicial do meloeiro em função da aplicação de biofertilizantes no cultivo orgânico. Revista Brasileira de Agropecuária Sustentável. 9(2): 24-32. DOI: 10.21206/rbas.v9i2.3072
5. Bigaran Aliotte, J. T.; Ramos de Oliveira, A. L. 2022. Multicriteria decision analysis for fruits and vegetables routes based on the food miles concept. Revista de la Facultad de Ciencias Agrarias. Universidad Nacional de Cuyo. Mendoza. Argentina. 54(1): 97-108. DOI: https://doi.org/10.48162/rev.39.069
6. Elmaghrabi, A. M.; Rogers, H. J.; Francis, D.; Ochatt, S. J. 2017. PEG induces high expression of the cell cycle checkpoint gene WEE1 in embryogenic callus of *Medicago truncatula*: Potential link between cell cycle checkpoint regulation and osmotic stress. Front. Plant Sci. 8: 1479.
7. FAO - A agricultura irrigada pode contribuir no aumento da produção de alimentos no Brasil. 2018. http://www.fao.org/brasil/noticias/detail-events/pt/c/1110333/. (Access: 10 may. 2021).
8. Faria, L. N.; Soares, A. A.; Donato, S. L. R. 2016. Irrigação com déficit hídrico controlado na cultura da mangueira no semiárido baiano. Engenharia Agrícola, Jaboticabal. 36(3): 387-398.

9. Feitosa, S. S.: Albuquerque, M. B.; Oliveira, A. P. 2016. Fisiologia do *Sesamum indicum* L. sob estresse hídrico e aplicação de ácido salicílico. Irriga, Botucatu. 21(4): 711-723. DOI: 10.15809/irriga.2016v21n4p711-723
10. Ferreira, D. F. 2011. Sisvar: um sistema computacional de análise estatística. Ciência e Agrotecnologia. 35(6), 1039-1042. DOI: 10.1590/S1413-70542011000600001
11. Frizzone, J. A.; Souza, F.; Lima, S. C. R. V. 2015. Manejo de Irrigação: quando, quanto e como irrigar. Curso de capacitação. Brasília: Agencia Nacional das Águas-ANA. 62 p.
12. Ghrab, M.; Ayadi, M.; Gargouri, K.; Chartzoulakis, K.; Gharsallaoui, M.; Bentaher, H.; Psarras, G.; Mimoun, M. B.; Masmoudi, M. M.; Mechlia, N. B. 2014. Long-term effects of partial rootzone drying (PRD) on yield, oil composition and quality of olive tree (cv. Chemlali) irrigated with saline water in arid land. Journal of Food Composition and Analysis. 36(1): 90-97. DOI: 10.1016/j.jfca.2014.05.005
13. Hortifruit-Anuário Brasileiro de Horti & Fruti. 2020. In: Melão, p. 88. http:// www.editoragazeta.com.br/sitewp/wpcontent/uploads/2020/05/HORTIFRUTI_2020. (Acces: 10 may. 2021).
14. Lacerda, F. H. D.; Pereira, F. H. F.; da Silva Neves, D.; da Costa Borges, F. Q.; Júnior, J. E. C. 2012. Aplicação exógena de prolina na redução do estresse salino em meloeiro. Revista Verde de Agroecologia e Desenvolvimento Sustentável. 7(3): 218-227.
15. Lamaoui, M.; Chakhchar, A.; Kharrassi, E. L.; Wahbi, Y. S.; Modafar, C. E. 2018a. Morphological, physiological, and biochemical responses to water stress in melon (*Cucumis melo*) subjected to regulated deficit irrigation (RDI) and partial rootzone drying (PRD). J. Crop Sci. Biotechnol. 21: 407-416. DOI: 10.1007/s12892-018-0122-0
16. Lamaoui, M.; Jemo, M.; Datla, R.; Bekkaoui, F. 2018b. Heat and drought stresses in crops and approaches for their mitigation. Frontiers and Chemistry. 6(26): 1-14. DOI: 10.3389/fchem.2018.00026
17. Lima, D. S.; Simões, W. L.; Silva, J. A. B.; Amorim, M. N.; Salviano, A. M.; Costa, N. D. 2020. Pele de sapo' melon grown under different irrigation depths and bioestimulant rates in the Semi-arid region of Brazil. Comunicata Scientiae. 11: e3303. DOI: 10.14295/CS.v11i0.330
18. Melo, A. S.; Dias, V. G.; Dutra, W. F.; Dutra, A. F.; Sá, F. V. S.; Brito, M. E. B.; Viégas, P. R. A. 2020. Physiology and yield of piel de sapo melon (*Cucumis Melo* L.) under water deficit in semi-arid region, Brazil. Bioscience Journal. 36(4): 1251-1260. DOI: 10.14393/BJ-v36n4a2020-48168
19. Melo, D. M.; Charlo, H. C. O.; Castoldi, R.; Braz, L. T. 2014. Dinâmica do crescimento do meloeiro rendilhado 'Fantasy' cultivado em substrato sob ambiente protegido. Revista Biotemas. 27(2): 19-29. DOI: 10.5007/2175-7925.2014v27n2p19
20. Melo, J. M. M.; Marinho, L. B.; Vargens, F. N.; Sousa Filho, J. R.; Deon, M. D.; Melo, A. M. Y. 2017. Crescimento de meloeiro submetido ao estresse hídrico com e sem micorrização no Vale do Submédio São Francisco. Revista Brasileira de Agricultura Irrigada-RBAI. 11(2): 1261 -1270. DOI: 10.7127/rbai.v11n200595
21. Nascimento, S. P.; Bastos, E. A.; Araújo, E. C. E.; Filho, F. R. F.; Silva, E. M. 2011. Tolerância ao déficit hídrico em genótipos de feijão-caupi. Revista Brasileira de Engenharia Agrícola e Ambiental. 15(8): 853-860. DOI: 10.1590/S1415-43662011000800013
22. Pereira filho, J. V.; Bezerra, F. M. L.; Chagas, K. L.; Silva, T. C.; Pereira, C. C. M. S. 2015. Trocas gasosas e fitomassa seca da cultura do meloeiro irrigado por gotejamento nas condições semiáridas do nordeste. Revista Brasileira de Agricultura Irrigada. 9(3): 171-182. DOI: 10.7127/rbai.v9n300286
23. Pires, M. M. M. L.; Santos, H. A.; Santos, D. F.; Vasconcelos, A. S.; Aragão, C. A. 2013. Produção do meloeiro submetido a diferentes manejos de água com o uso de manta de tecido não tecido. Horticultura Brasileira. 31: 304-10. DOI: 10.1590/S0102-05362013000200021
24. Rewald, B.; Raveh, E.; Gendler, T.; Ephrath, J. E.; Rachmilevitch, S. 2012. Phenotypic plasticity and water flux rates of Citrus root orders under salinity. Journal of Experimental Botany. 63(7): 2717-2727.
25. Romero-Conde, A.; Kusakabe, A.; Melgar, J. C. 2014. Physiological responses of citrus to partial rootzone drying irrigation. Scientia Horticulturae. 169(1): 234-38. DOI: 10.1016/j.scienta.2014.02.022
26. Sampaio, A. H. R.; Filho, M. A. C.; Coelho, E. F.; Daniel, R. 2014. Indicadores fisiológicos da lima ácida tahiti submetida à irrigação deficitária com secamento parcial de raiz. Irriga, Botucatu. 19(2): 292-301. DOI: 10.15809/irriga.2014v19n2p292
27. Santos, A. R.; Donato, S. R. L.; Coelho, E. F.; Junior, P. R. F. C.; Castro, I. N. 2016. Irrigation deficit strategies on physiological and productive parameters of 'Tommy Atkins' mango. Revista Caatinga. 29(1): 173-182. DOI: 10.1590/1983-21252016v29n120rc
28. Silva, F. G.; Dutra, A. F.; Oliveira, I. M.; Filgueira, L. M. B.; Melo, A. S. 2015. Trocas gasosas e fluorescência da clorofila em plantas de berinjela sob lâminas de irrigação. Revista Brasileira de Engenharia Agrícola e Ambiental. 19(10): 946-952. DOI: 10.1590/1807-1929/agriambi.v19n10p946-952
29. Vendruscolo, E. P.; Martins, A. P. B.; Seleguini, A. 2016. Promoção no desenvolvimento de mudas olerícolas com uso de bioestimulante. Journal of Agronomic Sciences, Umuarama. 5(2): 73-82.

30. Vendruscolo, E. P.; Rabelo, R. S.; Campos, L. F. C.; Martins, A. P. B.; Semensato, L. R.; Seleguini A. 2017. Alterações físico-químicas em frutos de melão rendilhado sob aplicação de bioestimulante. Revista colombiana de ciencias hortícolas. 11(2): 459-463. DOI: 10.17584/rcch.2017v11i2.7413
31. Vieira, D. A.; Mesquita, A. C.; Marinho, L. B.; Souza, V.; Aidar, S. T.; Carvalho, M. M. P. 2019. Gas exchanges of melon under water stress in the Submedium region of the São Francisco River Valley. Acta Scientarum Agronomy. 41(13): e42686. DOI: 10.4025/actasciagron.v41i1.42686
32. Vieira, D. A.; Carvalho, M. M. P.; Rodrigues, B. A.; Marinho, L. B.; Mesquita, A. C. 2020. Metabolic behavior in the allocation of biomass of melon cultivars under water deficit conditions. Research, Society and Development. 9(7): 1-19. DOI: 10.33448/rsd-v9i8.5128