Universidade Federal Rural do Semi-Árido
Pró-Reitoria de Pesquisa e Pós-Graduação
https://periodicos.ufersa.edu.br/index.php/caatinga
ISSN 1983-2125 (online)

http://dx.doi.org/10.1590/1983-21252024v3712452rc

Scientific Article

# Cultivation of yellow melon subjected to different irrigation levels and application of arbolina® biostimulant

# Cultivo do meloeiro amarelo submetido a diferentes lâminas de irrigação e aplicação do bioestimulante arbolina

Nicolly Q. B. Vieira[1], Welson L. Simões[2]*, José A. B. da Silva[1], Alessandra M. Salviano[3], Jucicléia S. da Silva[2], Marcos B. Braga[4], Miguel J. M. Guimarães[5], Marcelo da S. Martins[6]

[1]Department of Agricultural Engineering, Universidade Federal do Vale do São Francisco, Juazeiro, BA, Brazil. [2]Research Department, Embrapa Semiárido, Petrolina, PE, Brazil. [3]Research Department, Embrapa Solos, Recife, PE, Brazil.[4]Research Department, Embrapa Hortaliças, Brasília, DF, Brazil.[5]Instituto Federal de Educação, Ciência e Tecnologia do Maranhão, São Raimundo das Mangabeiras, MA, Brazil. [6]Universidade Federal do Recôncavo da Bahia, Cruz das Almas, BA, Brazil.

**ABSTRACT** - The objective was to evaluate the physiological and biochemical characteristics during flowering, and the total and marketable fruit yield of yellow melon subjected to different irrigation depths and application of the biostimulant Arbolina®. The experimental design was randomized blocks, in a 2×2×5 factorial arrangement of split-split plots, with four replicates. Plots consisted of 2 forms of biostimulant application (fertigation and spraying), subplots consisted of 2 irrigation depths (40% and 100% of crop evapotranspiration - ETc) and sub-subplots consisted of 5 doses of the biostimulant Arbolina® (0; 0.1; 0.2; 0.4; and 0.8 L ha$^{-1}$). Melon seedlings were transplanted into the soil at a spacing of 2.0 × 0.3 m, with drip irrigation. Basal and topdressing fertilization was performed via fertigation. The variables evaluated were: for total yield and marketable yield, photosynthetic rate, stomatal conductance, internal $CO_2$ concentration, transpiration and leaf temperature, chlorophyll *a* and *b* contents, water use efficiency and relative water content. The biostimulant application by spraying had a better effect on the production process of yellow melon plants, promoting better metabolic efficiency in organ-forming cells, including the process of morphological formation and biochemical constitution of the fruits. It is recommended to use of the biostimulant doses of 0.446 and 0.443 L ha$^{-1}$ combined with the use of 100% of ETc to achieve the highest total and marketable productivity.

**Keywords**: *Cucumis melo* L. Photosynthesis. Water deficit. Irrigation management. Carbon nanoparticles.

**RESUMO** - Objetivou-se avaliar as características fisiológicas e bioquímicas durante a floração, e a produtividades de frutos totais e comerciais de melão amarelo submetidas à
a diferentes lâminas de irrigação e aplicação do bioestimulante Arbolina. O delineamento experimental foi em blocos casualizados, em arranjo fatorial 2×2×5 de parcelas sub-subdivididas, com quatro repetições. As parcelas consistiram de 2 formas de aplicação de bioestimulante (fertirrigação e pulverização), as subparcelas consistiram de 2 lâminas de irrigação (40% e 100% da evapotranspiração da cultura - ETc) e as subsubparcelas consistiram de 5 doses do bioestimulante Arbolina® (0; 0,1; 0,2; 0,4; e 0,8 L ha$^{-1}$). As mudas foram transplantadas para o solo com espaçamento de 2,0 × 0,3 m, com irrigação por gotejamento. As adubações de plantio e cobertura foram realizadas via fertirrigação. As variáveis analisadas foram: produtividade total e comercial, taxa fotossintética, condutância estomática, concentração interna de $CO_2$, transpiração e temperatura foliar, teores de clorofilas *a* e *b*, eficiência do uso de água e conteúdo relativo de água. As variáveis bioquímicas avaliadas foram: teores foliares de carboidratos, amido, e proteínas solúveis totais. A aplicação do bioestimulante por pulverização teve melhor efeito no processo de produção de plantas de melão amarelo, promovendo melhor eficiência metabólica nas células formadoras de órgãos, incluindo o processo de formação morfológica e constituição bioquímica dos frutos. Recomenda-se a utilização do bioestimulante nas doses de 0,446 e 0,443 L ha$^{-1}$ combinadas com a utilização de 100% da ETc para atingir a maior produtividade total e comercial.

**Palavras-chave**: *Cucumis melo* L. Fotossíntese. Déficit hídrico. Manejo da irrigação. Nanopartículas de carbono.

**Conflict of interest:** The authors declare no conflict of interest related to the publication of this manuscript.



**Received for publication in:** January 11, 2024.
**Accepted in:** March 27, 2024.

***Corresponding author:**
<welson.simoes@embrapa.br>

## INTRODUCTION

The Northeast region of Brazil is the largest melon producer in the country, representing more than 90% of the national production (IBGE, 2024). The Sub-middle São Francisco Valley region has great potential for the expansion of irrigated fruit growing, mainly because it has suitable conditions with a hot climate, low relative humidity, and high solar radiation, which are factors that favor the development and production of fruit species (PINTO et al., 2022).

According to Valnir Júnior et al. (2022), understanding the management of irrigation depths for melon crops is essential for the production sustainability of this crop. Excessive irrigation wastes water and electricity, leaches nutrients and provides an environment conducive to the emergence of diseases. Thus, both water excess and water stress will result in losses of melon yield and fruit quality.

According to Melo et al. (2022), high yield is directly related to good physiological performance of plants during all stages of their cycle. The occurrence of harmful abiotic factors, such as water stress, can affect plant development, causing changes in gas exchange and biochemical parameters, resulting in a significant loss of yield.

Adequate supply of water, combined with the use of new agricultural technologies, has been shown to be a promising strategy for improving the efficiency of metabolic and physiological processes in plants. According to Rosário et al. (2021), the use of biostimulants has been an excellent alternative to increase the photosynthetic rate, improve the mechanisms to dissipate excess energy in the reaction center of photosystem II, and increase the activities of antioxidant enzymes, resulting in plants that are more tolerant to water deficit and, consequently, helping to reduce yield losses.

The biostimulant Arbolina®, produced from renewable raw materials, has stood out for acting as a plant hormone. It is a nanoparticle consisting basically of 70% organic carbon and acts as a transport protein in the plasma membrane of plants (CFQ, 2021). This biostimulant is covered by functional groups that activate important enzymes, acting in several processes of the physiological metabolism of plants, especially in photosynthesis. This promotes better conditions for growth and development, resulting in greater resistance to stress, improved nutrient absorption and, consequently, better quality and yield of crops (SECOM UNB, 2020).

In this context, the objective of the present study was to evaluate the physiological and biochemical characteristics during flowering and the yield of total and marketable fruits of yellow melon subjected to different irrigation depths and application of the biostimulant Arbolina®.

## MATERIALS AND METHODS

The experiment was conducted at the Bebedouro Experimental Field, at Embrapa Semi-Arid Region, in Petrolina, PE, Brazil (9°8'8.9" South, 40°18'33.6" West). According to Köppen's climate classification, the climate of the region is BSwh', with high temperatures and scarce and poorly distributed rainfall, concentrated in the period from November to April, with an average annual rainfall of approximately 418 mm.

The climatic data was collected from a weather station installed near the experiment area. The higher means of the evapotranspiration and temperature were observed in October (Figure 1).

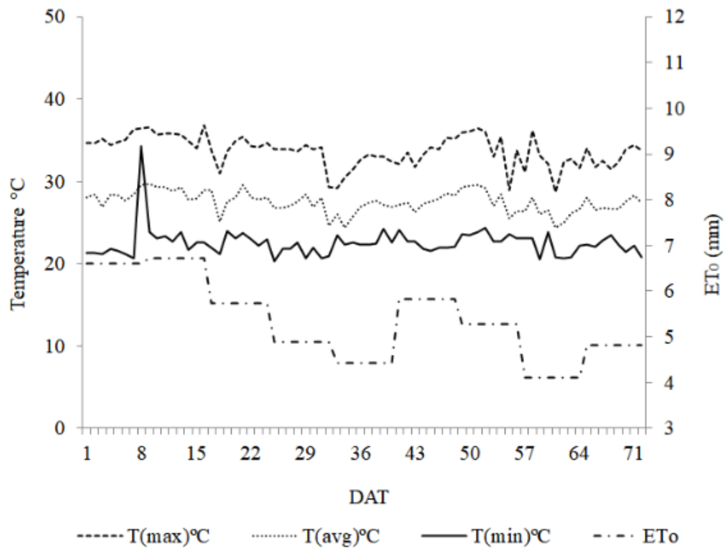


**Figure 1**. Reference evapotranspiration ($ET_0$) and average, maximum and minimum daily temperatures after transplanting (DAT) of yellow melon seedlings, Petrolina, PE, Brazil.

The fertilization was carried out at pre-planting by fertigation, based on the chemical analysis of the soil (Table 1). It was applied 151 kg ha$^{-1}$ of urea, 224 kg ha$^{-1}$ of monoammonium phosphate (MAP), 265 kg ha$^{-1}$ of potassium chloride, 310 kg ha$^{-1}$ of calcium nitrate and 165 kg ha$^{-1}$ of magnesium sulfate. The fertilization was realized twice every week, starting at 20 days after transplanting the yellow melon seedlings. 12 applications were carried out during the melon cycle.

**Table 1**. Chemical analysis of the soil at 0-0.3 m depth of the experimental area cultivated with hybrid yellow melon (cultivar Gladial F1).

| pH | P | $K^+$ | $Ca^{2+}$ | $Mg^{2+}$ | $Na^+$ | Cu | Fe | Mn | Zn |
|---|---|---|---|---|---|---|---|---|---|
| ----- | mg dm$^{-3}$ | -------------- | cmol$_c$ dm$^{-3}$ | -------------- | -------------- | ---------- | mg dm$^{-3}$ | ---------- | ---------- |
| 5.9 | 39.09 | 0.04 | 1.4 | 0.9 | 0.13 | 27 | 59.63 | 32.2 | 45.9 |

The soil of the experimental area was classified as *Argissolo Vermelho-Amarelo Eutrófico* (Ultisol), loamy sand, according to the methodology of Embrapa Semi-Arid (SANTOS et al., 2023), with the physical characteristics of 83.1% sand, 11.9% silt and 4.9% clay and flat relief.

The soil of the experimental area was previously prepared by plowing and harrowing, with pre-planting fertilization directly in the beds. Then, a drip irrigation system was installed, and the soil was covered with silver plastic film (mulching). Cultural practices during the experiment involved, when necessary, spraying to control pests and diseases and cleaning of the area to control invasive plants.

Seeds of hybrid yellow melon (cultivar Gladial F1) were sown in polyethylene trays (200 cultivation cells), previously filled with substrate. After 10 days of sowing, the seedlings were transplanted into the beds of the experimental field, with a spacing of 2.0 m between rows and 0.3 m between plants.

Irrigation was performed with a localized drip system, with drip tapes distributed close to the planting rows, with emitters spaced 0.3 m apart and with average flow rate of 2 L $h^{-1}$. The irrigation depth was based on the determination of evapotranspiration, using the Penman-Monteith method, and on the estimation of the reference evapotranspiration (ETo), using climatic data collected from the weather station installed near the experiment site. The crop coefficient (Kc) recommended in Miranda and Bleicher (2001) was used to determine crop evapotranspiration (ETc).

The experiment was conducted in a randomized block design, in split-split plots in a 2×2×5 factorial arrangement, with four replicates. Plots consisted of two forms of biostimulant application (fertigation and spraying), subplots consisted of two the irrigation depth as a function of ETc (40% and 100% ETc), and sub-subplots consisted of the application of five doses of Arbolina® biostimulant at a concentration of 400 g $L^{-1}$ (0, 0.1, 0.2, 0.4 and 0.8 L $ha^{-1}$).

The plant biostimulant used (Arbolina®) is composed of carbon nanoparticles [Carbon Dots (C-Dots), 67.4%], nitrogen (11.6%) and oxygen (21%). The doses were applied at the flowering stage of the crop, 35 days after transplanting (DAT).

During this period of the experiment, at 40 DAT, the relative water content (RWC) was determined in mature leaf discs, following the methodology of Marenco et al. (2013). Plant samples collected were dried in an air circulation oven at 60 °C to constant weight to determine shoot dry weight (%).

Chlorophyll *a* and chlorophyll *b* contents were determined at 40 DAT by non-destructive measurement on leaves, using a portable device (ClorofiLOG CFL 1030, Falker®).

Gas exchange was determined at 40 DAT, between 8:00 and 10:00 a.m. on a cloud-free day, in physiologically mature leaves exposed to the sun. The gas exchange variables evaluated were: photosynthetic rate (A), stomatal conductance (gs), internal $CO_2$ concentration (Ci), leaf transpiration (E), leaf temperature ($T_L$) and water use efficiency (WUE). Photosynthetic rate measurements were made with an infrared gas analyzer (Infra-Red Gas Analyzer - Licor Li 6400), at a fixed radiation of 1350 μmol $s^{-1}$. WUE was calculated by the ratio of A to E (A/E).

Leaves were collected at 40 DAT for biochemical analyses. Starch and sucrose contents were determined after maceration of 0.8 g of leaf tissue in liquid nitrogen. This material was then centrifuged, and 4 mL of the supernatant was collected to prepare the extract. Starch contents were determined in 100 μL of the extract, following the methodology described by Dubois et al. (1956).

To determine the carbohydrate and total soluble protein contents, 1 g of leaf tissue was macerated in liquid nitrogen, and then 4 mL of 0.1 M monobasic potassium phosphate buffer were added. Carbohydrate and amino acid contents were determined in 500 μL of the extract, following the methodologies described by Dubois et al. (1956) and Yemm and Cocking (1955), respectively. Total soluble protein contents were determined in 100 μL of the extract, following the methodology of Bradford (1976). Proline contents were determined in 1 mL of the extract, following the methodology described by Bates, Waldren and Teare (1973).

The total and marketable yields of the evaluated plants of each treatment were quantified at harvest.

The data obtained were subjected to analysis of variance using the F test ($p<0.05$). Effects of quantitative factors were evaluated by regression analysis, testing linear and quadratic models ($p<0.05$). Equations with the coefficient of determination ($R^2$) less than 0.5 were not considered. Means of biostimulant application were compared using Tukey test ($p<0.05$). All statistical analyses were performed using the Sisvar 7.7 computer program (FERREIRA, 2011).

## RESULTS AND DISCUSSION

The form of biostimulant application had a significant effect on internal $CO_2$ concentration (Ci), leaf temperature ($T_L$) and water use efficiency (WUE) (Table 2). The application of biostimulant by fertigation resulted in increments in Ci and WUE, but in lower $T_L$. The irrigation depth had a significant effect on relative water content (RWC), and the highest RWC was found for the 100% ETc depth.

The application of the biostimulant by spraying resulted in a higher T L (34.14 °C) 2). Thus, the increase in leaf temperature due to this form of cultivation, during the flowering period, may have caused some negative effects on the plant's metabolism, with a direct effect on photosynthetic activity, such as a reduction in the amount of $CO_2$ available for this activity, since that increasing temperature in mesophyll cells tends to reduce their solubility, thus decreasing the carboxylation efficiency of the enzyme ribulose 1,5-bisphosphate carboxylase oxygenase (RuBisCO).

The increase in leaf temperature after spraying the biostimulant also resulted in a lower WUE (Table 2) for the metabolic processes of yellow melon plants. However, the application of biostimulant by fertigation significantly increased WUE, denoting that the plants showed greater efficiency in the access of $CO_2$ molecules by mesophyll cells, i.e., they had greater $CO_2$ assimilation with lower loss of water to the external environment.

**Table 2**. Internal $CO_2$ concentration (*Ci*), leaf temperature ($T_L$), water use efficiency (WUE) as a function of forms of biostimulant application, and relative water content (RWC) as a function of irrigation depth, in hybrid yellow melon plants (cultivar Gladial F1).

| | Treatment | *Ci* (umol m$^{-2}$ s$^{-1}$) | $T_L$ (ºC) | WUE [(umol m$^{-2}$ s$^{-1}$) (mmol $H_2O$ m$^{-2}$ s$^{-1}$)$^{-1}$] | RWC (%) |
|---|---|---|---|---|---|
| Form of application | Fertigation | 191.62 a | 32.70 b | 4.35 a | 83.70 a |
| | Spraying | 179.71 b | 34.17 a | 3.95 b | 83.86 a |
| Irrigation depth | 40% ETc | 186.15 a | 33.48 a | 4.17 a | 80.16 b |
| | 100% ETc | 185.19 a | 33.39 a | 4.14 a | 87.39 a |

According to Pacheco, Lazzarini and Alvarenga (2021), stomatal movements regulate the entry of atmospheric $CO_2$ into the leaf for immediate use of $CO_2$ by chloroplasts, through the process of photosynthesis. The exit of water via transpiration is controlled during photosynthesis, thus resulting in better efficiency of this process.

Considering only the irrigation depth factor (Table 2), the RWC was higher in plants subjected to the highest soil water availability (100% ETc), consequently resulting in higher cell turgor for the yellow melon plants evaluated. The reduction of RWC in plants under water deficit can be attributed to a lower soil water availability, which tends to disfavor the absorption of water by plants. In addition, the reduction in soil water availability can cause a drop in the water potential of plants, affecting $CO_2$ exchange and their metabolic processes, including the photosynthetic rate (SILVA et al., 2013).

Silva et al. (2015) evaluated RWC in leaves of papaya plants subjected to water deficit and found that RWC in leaves was higher in plants under conditions of higher water availability (RWC of 79%), compared to that of plants under water deficit (RWC of 58%), which corroborates the result found in the present study. However, Santos et al. (2017) found higher RWC in melon plants under water stress and attributed this result to reductions in other physiological variables, such as transpiration and stomatal conductance, which may have affected the water status of the leaves in the treatments, especially in plants in treatments with a longer interval between irrigations.

The interaction between the forms of biostimulant application versus irrigation depths had a significant effect on leaf transpiration (Figure 2). Spraying of biostimulant in combination with the application of an irrigation depth corresponding to 100% ETc increased leaf transpiration by 16% when compared to the application of the biostimulant via fertigation in plants that received the same irrigation depth. The other interactions did not cause significant difference.

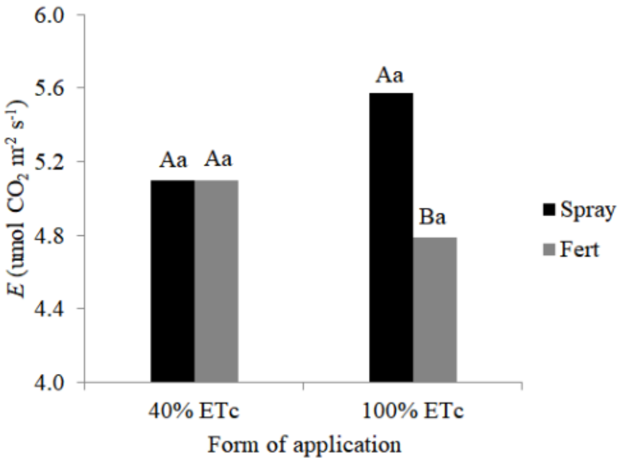


**Figure 2**. Leaf transpiration (*E*) of hybrid yellow melon plants (cultivar Gladial F1) as a function of the factors forms of biostimulant application and irrigation depth. Uppercase letters compare forms of application for the same irrigation depth. Lowercase letters compare irrigation depths for the same form of application.

According to the results of Figure 2, spraying of the biostimulant probably promoted better efficiency of the mechanisms involved in the leaf transpiration process, including a better efficiency of stomatal opening to regulate the internal temperature of leaf tissue cells. Table 2 shows that, when the biostimulant was sprayed, there was an increase in leaf temperature, which induced an increase in leaf transpiration in order to compensate for the increase in temperature.

According to Morais, Rossi and Higa (2017), the increase in leaf transpiration is a strategy of plants to decrease leaf temperature, thus avoiding damage due to the exaggerated heating of the photosynthetic apparatus. The process of evaporation of water molecules by plants causes a significant loss of heat and is one of the most important strategies in plants to regulate temperature and prevent damage to the photosynthetic apparatus.

The biostimulant dose factor had a significant effect on chlorophyll *a* and *b* contents in the yellow melon plants evaluated (Figure 3). Biostimulant doses of 0.500 and 0.398 L ha$^{-1}$ resulted in the highest contents of chlorophyll *a* (40.85) and chlorophyll *b* (22.0), respectively.

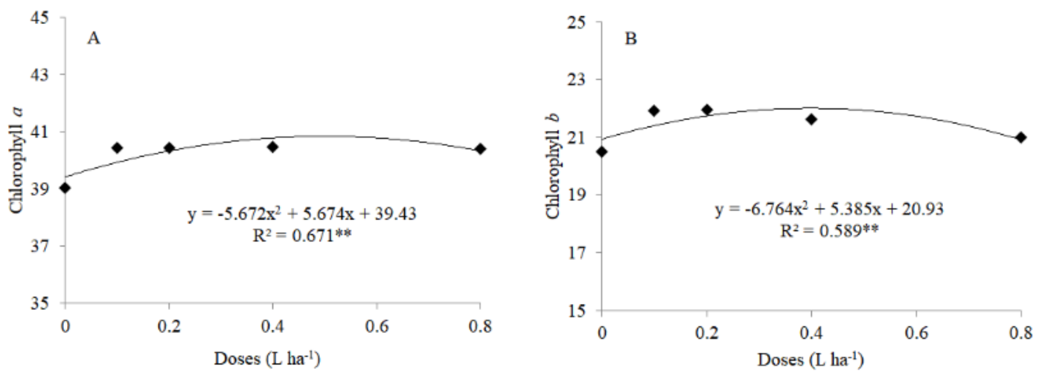


**Figure 3**. Contents of chlorophyll *a* (A) and chlorophyll *b* (B) in hybrid yellow melon plants (cultivar Gladial F1) as a function of the biostimulant dose factor. ** = significant at 1% probability level.

These results indicate that increasing the dose of biostimulant (Arbolina®) up to 0.500 and 0.398 L ha$^{-1}$ resulted in higher biosynthesis of chlorophylls *a* and *b*, respectively, increasing their contents in leaf cell chloroplasts. This increase can result in improved photosynthetic activity and, consequently, in a better production of sugars, favoring plant growth.

Results similar were also found by Li et al. (2021), who reported that, with the presence of C-Dots, the chlorophyll content increased by 64.53% in relation to the control treatment. However, Kuang et al. (2023), applied C-Dots during the flowering stage of Chinese cabbage plants, found a significant anti-aging effect, which increased the maximum fluorescence dose, slowing down chlorophyll degradation, maintaining the homeostasis of the metabolism of reactive oxygen species, and increasing carbohydrate content.

There was no interaction between the forms of application and the doses of the biostimulant for RWC, with a significant effect only of the doses applied by spraying (Figure 4). The biostimulant applied at a dose of 0.411 L ha$^{-1}$ by fertigation improved the plants efficiency in maintaining turgid cells, as the RWC had an increase of 85%. This pattern was not found for spray application, which showed no significant difference as the biostimulant dose increased.

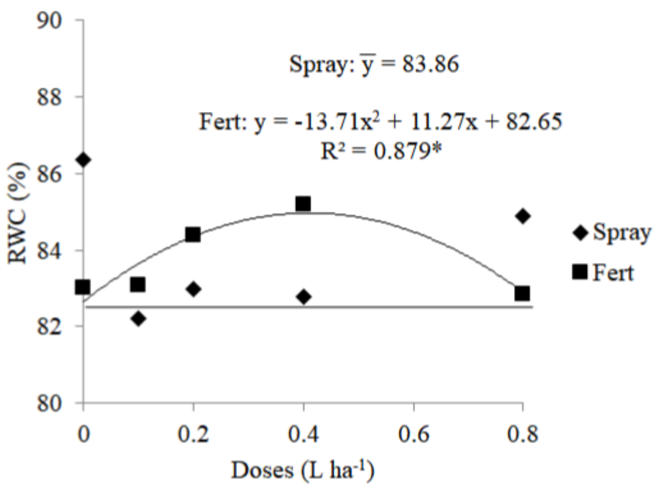


**Figure 4**. Relative water content (RWC) in hybrid yellow melon plants (cultivar Gladial F1) as a function of the factors form of application and biostimulant dose. * = significant at 5% probability level.

The plants treated with biostimulant applied via fertigation showed polynomial behavior for RWC; the same did not occur with the application by spraying. The increase in the biostimulant dose up to the limit of 0.411 L ha$^{-1}$ allowed greater use of water in the plants, for fertigated treatments, and thus promoting lower water losses by transpiration.

However, RWC is considered one of the best criteria to evaluate the water status of plants, as it is directly involved in the metabolic activity in plant tissues. Reductions in RWC result in loss of cell turgor, which indirectly affects cell expansion and consequently results in reduced growth in plants (TAIZ et al., 2017).

According to Secom Unb (2020), an important action of the biostimulant Arbolina® is to cause reduction in leaf transpiration, contributing to a more efficient water consumption by plants and, therefore, to a significant saving in the volume of water used for irrigation.

Starch content in leaves was significantly affected by the interaction between the form of biostimulant application and the irrigation depth, as well as by the interaction between the application form and the biostimulant dose (Figure 5).

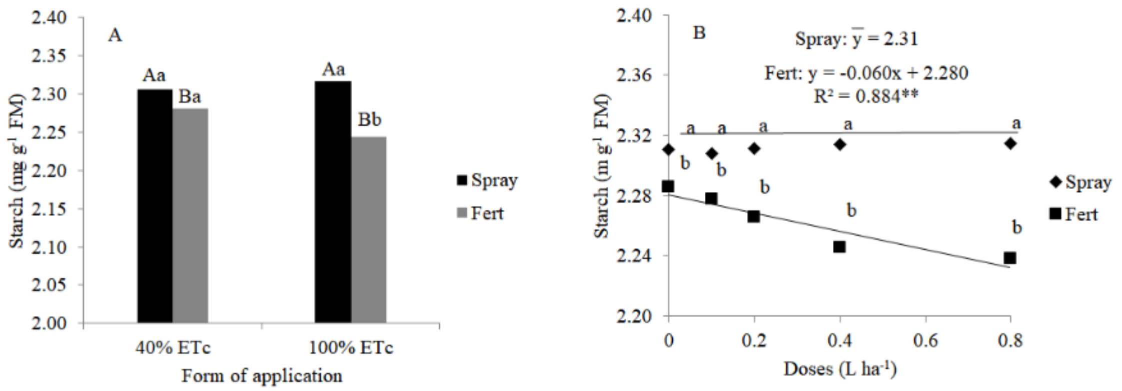


**Figure 5**. Starch content in hybrid yellow melon plants (cultivar Gladial F1) as a function of interactions of form of biostimulant application with irrigation depth (A) and with biostimulant dose (B). ** = significant at 1% probability level. Uppercase letters compare forms of application for the same irrigation depth, while lowercase letters compare irrigation depths for the same form of application (A). Lowercase letters compare, vertically, forms of application for the same dose of biostimulant.

The comparison of biostimulant application forms, considering each irrigation depth, showed that the biostimulant spraying resulted in higher starch contents in yellow melon leaves. Considering the 100% ETc depth, the plants showed higher starch content when subjected to biostimulant spraying (Figure 5A).

The interaction between the form of application and the dose of biostimulant (Figure 5B) showed that the increase in biostimulant dose did not significantly affect starch content, which averaged 2.31 mg $g^{-1}$. However, the biofertilizer application by fertigation decreased the starch content as the dose of biostimulant increased.

Thus, it possible to infer that increasing the biostimulant dose, applied by fertigation, reduces the starch content stored in melon leaves. This phenomenon is common for some species due to a significant demand for carbohydrates for flower and fruit production.

Similar results were reported by Araújo, Nascimento and Sousa (2017) in *Schizolobium amazonicum* leaves. They attributed this result to decreased photosynthetic rate and increased starch degradation by the enzymes α-amylase and β-amylase, forming new sugars. Thus, the reduction in starch content found in the present study may be due to the synthesis of new sugars for better development and quality of yellow melon flowers and fruits. However, it is important to highlight that the melon mesocarp contains little starch reserve, possibly being less than 1%, in contrast to most fruit species, which store considerable amounts of starch in the fruit to later convert them into sugars (FINGER; VIEIRA, 2002).

Table 3 presents the results of the triple interaction between the biostimulant application form, irrigation depth and biostimulant dose on the contents of carbohydrates and total soluble proteins. The difference between the contents of total soluble proteins stands out for the biostimulant dose of 0.8 L $ha^{-1}$, in the application by spraying, for which water stress led to the lowest value.

Regarding the carbohydrate content in yellow melon leaves, a quadratic fit was found for the application of biostimulant by fertigation combined with the irrigation depth of 40% ETc (Table 3), according to which the biostimulant dose of 0.483 L $ha^{-1}$ resulted in a maximum carbohydrate content of 8.82 mg $g^{-1}$. However, a linear fit was found for the application by fertigation combined with irrigation depth of 100% ETc, denoting that the increase in biostimulant dose reduced carbohydrate content. Thus, a greater water availability to yellow melon plants reduces the effect of increasing doses of biostimulant on the carbohydrate biosynthesis process. The water restriction in the treatments increased the concentration of carbohydrates in yellow melon leaves as the biostimulant dose was increased. Oliveira (2023) attributed the increase in carbohydrate contents in *Parkia pendula* plants to an osmotic adjustment mechanism.

However, plants subjected to reduced water levels may show decreased cell expansion due to a lower water content in their tissues, so they may have higher contents of sugars. Another hypothesis to explain the results may be that water stress induced yellow melon plants to increase the dynamics of activation of carbohydrate synthesis pathways for osmotic adjustment.

Thus, yellow melon plants under water stress conditions tended to increase the carbohydrate content in their leaves, compared to plants without water stress, probably due to the reduction of water content in the cells.

**Table 3**. Total soluble carbohydrate and protein contents in hybrid yellow melon leaves (cultivar Gladial F1) as a function of the triple interaction between form of biostimulant application [spraying (S) and fertigation (F)], irrigation depth [40% ETc (40%) and 100% ETc (100%)] and biostimulant dose.

| Treatment | Biostimulant dose (L ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | 0 | 0.1 | 0.2 | 0.4 | 0.8 |
| | Carbohydrate content (mg g$^{-1}$) | | | | |
| S 40% | 8.74 Aa | 8.72 Aa | 8.74 Aa | 8.68 Ba | 9.16 Aa |
| F 40% | 8.65 Ab | 8.69 Ab | 8.79 Aa | 8.79 Aa | 8.75 Ba |
| S 100% | 8.78 Aa | 8.74 Ba | 8.73 Aa | 8.63 Aa | 8.68 Ab |
| F 100% | 8.79 Aa | 8.89 Aa | 8.77 Aa | 8.69 Ab | 8.65 Aa |
| | Total soluble protein content (mg g$^{-1}$) | | | | |
| S 40% | 33.21 Aa | 27.84 Aa | 26.21 Ba | 27.54 Ba | 25.95 Ab |
| F 40% | 27.01 Bb | 27.80 Aa | 32.76 Aa | 32.19 Aa | 26.31 Aa |
| S 100% | 32.95 Aa | 33.59 Aa | 27.04 Aa | 34.86 Aa | 36.69 Aa |
| F 100% | 35.54 Aa | 34.01 Aa | 27.19 Aa | 22.60 Bb | 30.37 Ba |

| Treatment | Equation | $R^2$ | Ymax | DoseR |
|---|---|---|---|---|
| | Carbohydrate content (mg g$^{-1}$) | | | |
| S 40% | - | ns | - | - |
| F 40% | $y= -0.717x^2 + 0.692x + 8.648$ | 0.900* | 8.82 | 0.483 |
| S 100% | - | ns | - | - |
| F 100% | $y = -0.236x + 8.831$ | 0.703** | - | - |
| | Total soluble protein content (mg g$^{-1}$) | | | |
| S 40% | - | ns | - | - |
| F 40% | $y = -39.11x^2 + 30.85x + 26.60$ | 0.861** | 32.68 | 0.394 |
| S 100% | - | ns | - | - |
| F 100% | - | ns | - | - |

Means followed by uppercase letters in columns compare forms of application for the irrigation depth of 40% ETc; means followed by bold-italic uppercase letters compare forms of application for the irrigation depth of 100% ETc. Means followed by lowercase letters in columns compare irrigation depths for the spraying application; Means followed by lowercase letters in bold-italics in columns compare irrigation depths for the fertigation application. ns = not significant; ** and * = significant at 1% and 5% probability levels, respectively.

According to Souza et al. (2013), plants under water deficit, in general, tend to increase the carbohydrate content as this effect is directly related to the osmotic adjustment process of these plants, reducing their osmotic potentials in order to keep the plant hydrated and, consequently, delay the dehydration of its tissues.

Regarding the total soluble protein content, a quadratic fit was also found for the biostimulant application by fertigation, combined with a depth of 40% ETc (Table 3), at which the biostimulant dose of 0.394 L ha$^{-1}$ promoted a maximum content of 32.68 mg g$^{-1}$ of total soluble proteins.

These results may be associated with the action of the C-Dots present in the applied biostimulant. Thus, a possible intensification of the protein synthesis process (which is an activity directly correlated with the increase in protein concentration) can be attributed to the application of this biostimulant. According to Kou et al. (2021), the increase of nanomaterials, such as C-Dots, can promote plant growth by stimulating protein metabolism; therefore, the increase in the concentration of C-Dots may result in an increase in the contents of total soluble proteins in plants. These authors evaluated the use of C-Dots for tomato plants and found higher contents of total soluble proteins in plants subjected to different concentrations of C-Dots than in control plants.

The variables total yield (TY) and marketable yield (MY) of yellow melon fruits were significantly affected by the biostimulant doses and spraying application. It was observed that, at irrigation depths of 40 and 100% ETc (Figure 6), the biostimulant doses of 0.533 and 0.446 L ha$^{-1}$ resulted in maximum TY of 2.41 and 3.28 kg plant$^{-1}$, respectively. For MY, the doses of 0.483 and 0.443 L ha$^{-1}$ resulted in maximum values of 2.28 and 3.19 kg plant$^{-1}$, for the depths of 40 and 100% ETc, respectively. No significant effect was found in the treatments with the application of biostimulant by fertigation, which had overall means of 2.31 and 2.14 kg plant$^{-1}$ (TY) and 1.89 and 1.98 kg plant$^{-1}$ (MY) for the depths of 40 and 100% ETc, respectively.

The results of TY and MY show that the biostimulant spraying had a better effect on the production process of yellow melon plants, promoting better metabolic efficiency in organ-forming cells, including the process of morphological formation and biochemical constitution of the fruits. In addition, these results indicate that the nutrients absorbed by the plants during growth were used, resulting in higher production potential, since nutrients favor the plants during the development and reproduction stages.

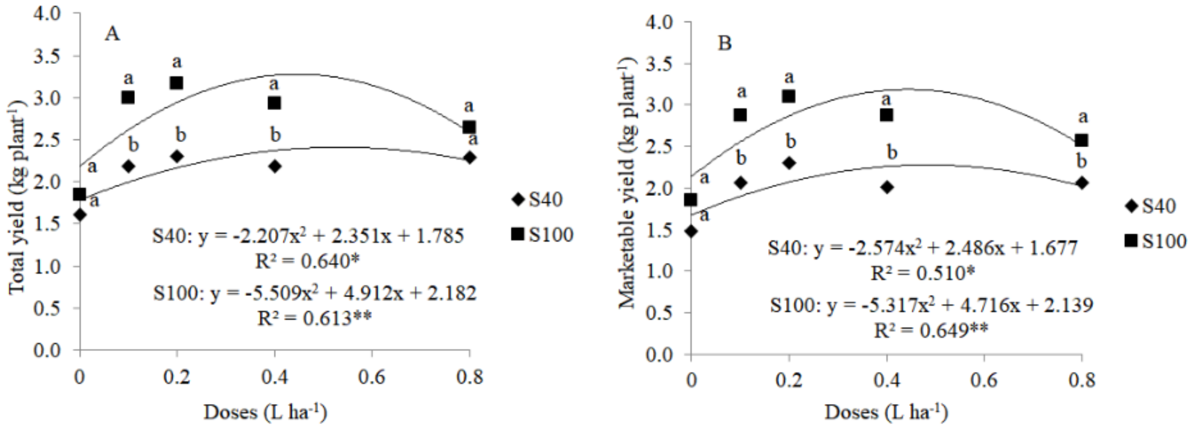


**Figure 6**. Total (A) and marketable (B) yields of hybrid yellow melon (cultivar Gladial F1) as a function of biostimulant doses applied by spraying and irrigation depths of 40% and 100% ETc. ** and * = significant at 1% and 5% probability levels, respectively.

Silva et al. (2014) evaluated the production of melon plants subjected to the application of nitrogen and potassium doses and found that the increase in these nutrients resulted in average yields of 1.54 and 1.38 kg $plant^{-1}$, respectively; these results were lower than those obtained in the present study with the application of the biostimulant Arbolina®.

Busato et al. (2021) subjected strawberry plants to different doses of the same biostimulant used in the present study and found a significant increase of 41% in production when compared to the control treatment, which proves the efficient action of the product.

However, it should be noted that, although the models (linear and quadratic) did not fit to the treatment with the application of biostimulant by fertigation, the means found are similar to those reported by other studies, such as Yuri, Resende and Costa (2020).

## CONCLUSIONS

The biostimulant application by spraying had a better effect on the production process of yellow melon plants, promoting better metabolic efficiency in organ-forming cells, including the process of morphological formation and biochemical constitution of the fruits. It is recommended to use of the biostimulant doses of 0.446 and 0.443 L $ha^{-1}$ combined with the use of 100% of ETc to achieve the highest total and marketable productivity. The biostimulant application by fertigation did not alter the yield, but the application of 0.483 and 0.394 L $ha^{-1}$ of the biostimulant Arbolina®, combined with an irrigation depth of 40% of the ETc, resulted in higher contents of carbohydrates and total soluble proteins, respectively, in yellow melon plants Gladial. Biostimulant dose of 0.411 L $ha^{-1}$ applied by fertigation resulted in higher relative water content in melon plants. Application of biostimulant doses of 0.500 and 0.398 L $ha^{-1}$ resulted in higher contents of chlorophylls *a* and *b* in the yellow melon plants evaluated.

## REFERENCES

ARAÚJO, B. A. E.; NASCIMENTO, V. R.; SOUSA, K. P. Amido, açúcares redutores e não redutores, sacarose e glicina-betaína em plantas jovens de paricá acometidas à dosagens de alumínio. In*:* II CONGRESSO INTERNACIONAL DAS CIÊNCIAS AGRÁRIAS, 2017, Natal. **Anais...** Natal: IFRN , 2017. p. 1-5.

BATES, L. S.; WALDREN, R. P.; TEARE, J. D. Rapid determination of free proline for water-stress studies. **Plant and Soil**, 39: 205-207, 1973.

BRASFORD, M. M. A rapid and sensitive method for quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. **Analytical Biochemistry**, 72: 248-254, 1976.

BUSATO, J. G. et al. Estímulo ao crescimento de morangueiro a partir da adição de nanocomposto de carbono (arbolina). **Revista Multidisciplinar de Educação e Meio Ambiente**, 2: 1-1, 2021.

CFQ - Conselho Federal Químico. **Notícias: Químicos criam biofertilizante vegetal nanotecnológico**. 2021. Disponível em: <http://cfq.org.br/noticia/quimicos-criam-bio fertilizante-vegetal-nanotecnologico/>. Acesso em: 15 mar. 2024.

DUBOIS, M. et al. Colorimetric method for determination of sugars and related substances. **Analytical Chemistry**, 28: 350 -356, 1956.

FERREIRA, D. F. SISVAR: a computer statistical analysis system. **Ciências e Agrotecnologia**, 35: 1039-1042, 2011.

FINGER, F. L.; VIEIRA, G. Fisiologia pós-colheita de frutos tropicais e subtropicais. In: Zambolim, L. (Ed.) **Manejo integrado: fruteiras tropicais-doenças e pragas**. Viçosa, MG: UFV, 2002. v. 1, p. 1-30.

IBGE - Instituto Brasileiro de Geografia e Estatística. **Produção Agrícola Municipal**. Disponível em: http://www.sidra.ibge.gov.br. Acesso em: 11 mar. 2024.

KOU, E. et al. Regulation Mechanisms of Carbon Dots in the Development of Lettuce and Tomato. **ACS Sustainable**

**Chemistry and Engineering**, 9: 944-953, 2021.

KUANG, L. et al. The roles of Salvia miltiorrhiza-derived carbon dots involving in maintaining quality by delaying senescence of postharvest flowering Chinese cabbage. **Food Chemistry**, 404: 134704, 2023.

LI, Y. et al. Carbon dots as light converter for plant photosynthesis: Augmenting light coverage and quantum yield effect. **Journal of Hazardous Materials**, 410: 1-11, 2021.

MELO, T. S. et al. Déficit hídrico e recuperação pós-estresse do metabolismo fisiológico em arroz-evidência do efeito priming. **South American Journal of Basic Education, Technical and Technological**, 9: 91-107, 2022.

MIRANDA, F. R. de; BLEICHER, E. **Evapotranspiração e coeficientes de cultivo e de irrigação para a cultura do melão (Cucumis melo L.) na região litorânea do Ceará**. 1. ed. Fortaleza, CE: Embrapa Agroindústria Tropical, 2001. 17 p. (Boletim de Pesquisa e Desenvolvimento, 2).

MORAIS, R. R. D.; ROSSI, L. M. B.; HIGA, R. C. V. Trocas gasosas de plantas jovens de taxi-branco submetidas à variação de temperatura foliar e suspensão da irrigação. **Ciência Florestal**, 27: 97-104, 2017.

OLIVEIRA, T. B. D. **Respostas ecofisiológicas e bioquímicas de plantas jovens de *Parkia pêndula* (Willd.) Benth. ex Walp Urb. submetidas à deficiência hídrica**. 2023. 79 f. Dissertação (Mestrado em Ciências Florestais: Área de concentração em Ciências Florestais) - Universidade Federal Rural da Amazônia, Belém, 2023.

PACHECO, F.; LAZZARINI, L. E.; ALVARENGA, I. Metabolismo relacionado com a fisiologia dos estômatos. **Enciclopédia Biosfera**, 18: 186-206. 2021.

PINTO, J. M. et al. **Cultivo de melão em fileiras duplas com irrigação por gotejamento**. Petrolina, PE: Embrapa, 2022. ISSN 1808-9976. *E-book*. Disponível em: https://ainfo.cnptia.embrapa.br/digital/bitstream/item/241584/1/Melao-fileiras-duplas-irrigacao-gotejamento.pdf. Acesso em: 4 ago. 2023.

ROSÁRIO, R. V. et al. Increased soybean tolerance to water deficiency through biostimulant based on fulvic acids and *Ascophyllum nodosum* (L.) seaweed extract. **Plant Physiology and Biochemistry**, 158: 228-243, 2021.

SANTOS, F. A. S. et al. Tempo ótimo de imersão de discos foliares para quantificação do teor relativo de água em folhas de melão. In: ENCONTRO INTERNACIONAL DE PRODUÇÃO CIENTÍFICA, 2017. **Anais…** Maringá: UNICESUMAR , 2017. p. 1-6.

SANTOS, H. G. et al. **Proposta de atualização da 5ª edição do Sistema Brasileiro de Classificação de Solos: ano 2023**. 1. ed. Rio de Janeiro, RJ: Embrapa Solos, 2023. 143 p. (Documentos, 238)

SECOM UNB. **Desenvolvido na UnB, unicórnio brasileiro tem potencial para revolucionar agronegócio**. 2020. Artigo em Hypertexto. Disponível em: https://noticias.unb.br/117-pesquisa/4628-desenvolvido-na-unb-unicorniobrasileiro-tem-potencial-para-revolucionar-agronegocio. Acesso em: 11 abr. 2023.

SILVA, K. R. S. et al. Compostos nitrogenados em plantas jovens de mamoeiro sob deficiência hídrica. **Enciclopédia Biosfera**, 11: 771-786, 2015.

SILVA, M. D. A. et al. Respostas fisiológicas de cultivares de cana-de-açúcar submetidas à deficiência hídrica e a reidratação. **Revista Caatinga**, 26: 28-35, 2013.

SILVA, M. D. C. et al. Características produtivas e qualitativas de melão rendilhado adubado com nitrogênio e potássio. **Revista Brasileira de Engenharia Agrícola e Ambiental**, 18: 581-587, 2014.

SOUZA, L. C. et al. Osmorreguladores em plantas de sorgo sob suspensão hídrica e diferentes níveis de silício. **Revista Brasileira de Milho e Sorgo**, 12: 240-249, 2013.

TAIZ, L. et al. A. **Fisiologia e desenvolvimento vegetal**. 6 ed . Porto Alegre, RS: Artmed, 2017. 858 p.

VALNIR JÚNIOR, M. et al. Qualidade e vida útil pós-colheita dos frutos de melão submetidos a diferentes lâminas de irrigação. **Research, Society and Development**, 11: e1211225091 2022.

YEMM, E. W.; COCKING, E. F. The determination of amino acids with ninhydrin. **Analyst**, 80: 209-213, 1955.

YURI, E.; RESENDE, G. M.; COSTA, N. D. Características produtivas de genótipos de melão amarelo e pele de sapo em duas épocas de plantio no submédio do vale do São Francisco. **Revista Brasileira de Agricultura Irrigada**, 14: 3897-3905, 2020.