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ORIGINAL ARTICLE

Physiology, biochemistry and yield of melon in a semi-arid region with the application of biostimulants[1]

Fisiologia, bioquímica e produção de melão em região semiárida com aplicação de bioestimulantes

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HIGHLIGHTS:

Application of biostimulants mitigates the harmful effects on melon caused by semi-arid environmental conditions.
'Goldex' melon has higher yield compared to 'McLaren', but produces less fruit per plant.
The studied melon cultivars do not differ in relation to gas exchange variables, with the exception of CO_2 assimilation rate.

ABSTRACT: Regions with semi-arid climates have environmental conditions that result in abiotic stress to plants. The largest melon (*Cucumis melo* L.) production area in Brazil, the state of Rio Grande do Norte, has these climatic characteristics. Use of biostimulants in these production systems can mitigate effects of abiotic stress and increase yield and fruit quality. The objective in this study was to evaluate the physiological and production characteristics of melon, under the application of biostimulants. The biostimulants Acadian®, Folicist® and Nov@® were applied and compared to the control treatment (no biostimulants), in 'Goldex' and 'McLaren' melons. Nov@® led to higher CO_2 assimilation, transpiration and stomatal conductance, as well as ascorbate peroxidase, in 'Goldex' and 'McLaren'. Greater catalase was obtained with the application of Nov@®, while the use of Folicist® resulted in higher malondialdehyde content. The cultivar 'McLaren' exhibited the best physiological and biochemical performance, and 'Goldex' the best yield. Folicist® promotes physiological adaptations to stress without impairing photosynthetic activity. The biostimulants increased yield and number of fruits per plant and promoted physiological adaptations to semi-arid conditions.

Key words: *Cucumis melo* L., antioxidant, bioinputs, antioxidant enzymes

RESUMO: Regiões com climas semiáridos apresentam condições ambientais que resultam em estresses abióticos às plantas. A maior área de produção de melão (*Cucumis melo* L.) do Brasil, o Estado do Rio Grande do Norte, possui essas características climáticas. O uso de bioestimulantes nesses sistemas de produção pode mitigar os efeitos dos estresses abióticos e aumentar a produtividade e a qualidade dos frutos. O objetivo neste estudo foi avaliar as características fisiológicas e de produção do meloeiro, sob aplicação de bioestimulantes. Os bioestimulantes Acadian®, Folicist® e Nov@® foram aplicados e comparados ao tratamento controle (sem bioestimulantes), em melões 'Goldex' e 'McLaren'. Nov@® proporcionou maior assimilação de CO_2, transpiração e condutância estomática, assim como ascorbato peroxidase em 'Goldex' e 'McLaren'. Maior catalase foi obtida pela aplicação de Nov@®, enquanto que o uso de Folicist® resultou em maior teor de malondialdeído. A cultivar McLaren apresentou o melhor desempenho fisiológico e bioquímico e a 'Goldex' o melhor rendimento. Folicist® promove adaptações fisiológicas aos estresses sem prejudicar a atividade fotossintética. Os bioestimulantes aumentaram a produtividade e o número de frutos por planta e promoveram adaptações fisiológicas às condições semiáridas.

Palavras-chave: *Cucumis melo* L., antioxidante, bioinsumos, enzima antioxidante

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INTRODUCTION

Melon (*Cucumis melo* L.) is commonly grown in semi-arid regions due to its adaptation to climatic conditions and the efficient control of fruit fly that result in high-quality fruits (Silva et al., 2021). Despite this, environmental characteristics of the semi-arid region can cause damage to the crop, making it necessary to use agronomic technologies that reduce environmental impacts, adapt to climate change and maintain crop yields (Li et al., 2022), such as the use of biostimulants (Figueiredo et al., 2021; Góes et al., 2021), which are rich in minerals, vitamins, amino acids, polyoligosaccharides, phytohormones and others (Bulgari et al., 2019). On the plant, these products can be applied foliar and via fertigation (Góes et al., 2021).

In plants, biostimulants act on primary metabolism, which is responsible for factors essential to plants, such as photosynthesis, and on secondary metabolism, whose function is to protect plants from biotic and abiotic stress, improving the development of plants exposed to the stress of environmental conditions (Bulgari et al., 2019). In addition to mitigating effects of biotic and abiotic stress on plants, biostimulants reduce dependence on use of chemical fertilizers and pesticides (Mrid et al., 2021).

In melon, the use of biostimulants increased in average mass, number of fruits per plant, yield, pulp firmness, soluble solids and total soluble sugars (Queiroga et al., 2020; Góes et al., 2021). It also promotes benefits to photosynthetic activity and the relative water content of melons (Lima et al., 2020).

However, biochemical changes and gas exchange in melon due to the use of biostimulants may explain the improvement in the agronomic performance of the crop, but research in this regard is still in its infancy. The objective of this study was to evaluate physiological and production characteristics of melon, under the application of biostimulants.

MATERIAL AND METHODS

The experiment was carried out in an area of the company Agrícola Famosa Ltda., located in the municipality of Icapuí, state of Ceará, Brazil, (4° 52’ 13” S and 37° 20’ 18” W, with 16 m altitude), between October and December 2020. The climate of the region is BSh type, characterized by a hot semi-arid climate, with scarce and irregularly distributed rainfall, according to Köppen’s classification. During the experiment no rainfall was recorded, and average temperature, relative humidity of the air, and global radiation were, respectively, 29.9 °C, 54.67% and 1,900.4 J m^{-2}, obtained at a meteorological station installed at the site.

The soil was classified as Entisol (United States, 2014), which corresponds to Neossolo in the Brazilian Soil Classification System (Santos et al., 2018). For characterization of the chemical attributes of the soil, samples were collected at a depth of 0-20 cm and sent to the laboratory for analysis (Table 1).

Table 1. Chemical attributes of soils (0 – 20 cm) in experimental areas, in Icapuí, Ceará state, Brazil

Chemical attributes		
pH	H_2O	6.2
O.M.	g dm^{-3}	12.51
Cu	mg dm^{-3}	2.16
Fe	mg dm^{-3}	113.32
Mn	mg dm^{-3}	17.22
Zn	mg dm^{-3}	5.08
P	mg dm^{-3}	170.04
K	$cmol_c$ dm^{-3}	0.22
Na	$cmol_c$ dm^{-3}	0.02
Ca	$cmol_c$ dm^{-3}	3.05
Mg	$cmol_c$ dm^{-3}	0.70
H+Al	$cmol_c$ dm^{-3}	2.24
SB	$cmol_c$ dm^{-3}	0.97
CEC	pH 7.0	6.23
V	%	64.05

O.M - Organic matter; H+Al - Potencial acidity; SB- Sum of bases; CEC - Cation exchange capacity; V - Base saturation

The experiment was arranged in randomized block design in a 4 × 2 split-plot scheme, with four replicates. Treatments were composed of combinations of three biostimulants plus the control (without biostimulant) and melon cultivars ‘Goldex’ and ‘McLaren’. The dose and method of application of each biostimulant was in accordance with manufacturers’ recommendations for melon. Treatments were: Treatment 1 (Control): without application of biostimulants; Treatment 2 (Acadian®): composed of seaweed extract (*Ascophyllum nodosum*) nutrients, amino acids and carbohydrates, applied at a dose of 4 L ha^{-1}, divided into applications at 10, 20, 30, and 40 days after transplanting, via fertigation; Treatment 3 (Folicist®): composed of acetyl-thioproline, folic acid, glycine-betaine, amino acids and seaweed extract (*Macrocystis integrifolia*), applied at a dose of 4 L ha^{-1}, divided into applications at 25, 30, 35, and 40 days after transplanting, through leaves; and Treatment 4 (Nov@®): composed of phytosaponins, polysaccharides, fulvic acids, amino acids and glycine-betaine, applied at dose of 20 L ha^{-1}, divided into applications at 2, 10, 15, 20, 25, 30, 35, and 40 days after transplanting, via fertigation.

Fruit of ‘Goldex’ melon has a slightly rough yellow rind, belongs to the inodorus group, is non-climacteric and has a larger cultivated area. The cultivar McLaren is of the Galia type, with yellow to orange melons, lacy rind, aromatic, climacteric group and high commercial value. Plots were composed of 4 rows of plants, 12.5 m long and 0.60 m wide, spaced 2.0 m apart. The spacing between plants was 0.40 m. Total number of plants per plot was 124. The plants of the two central rows were used for analysis, disregarding the ends of the plot to avoid effects of treatments applied to neighboring plots. The soil was prepared with one plowing and two harrowing operations, followed by furrowing in rows at a depth of 0.30 m. Basal fertilization was performed with 40 kg ha^{-1} of P_2O_5, 38 kg ha^{-1} of CaO and 20 kg ha^{-1} of S, using single superphosphate, and 10 t ha^{-1} of compost. Ridges were made on fertilizer furrows and were 0.20 m in height and 0.60 m in width.

Topdressing fertilizers were applied through fertigation with doses varying according to stage of the crop. Doses of 95 kg ha^{-1} of N, 85 kg ha^{-1} of P_2O_5, 185 kg ha^{-1} of K_2O, 27.5 kg ha^{-1} of CaO, 6 kg ha^{-1} of MgO and 0.85 kg ha^{-1} of B were applied, using potassium nitrate, magnesium nitrate, magnesium sulfate, calcium nitrate, monoammonium phosphate (MAP) and boric acid. Doses were defined based on soil analysis (Table 1).

Irrigation was applied with a drip system, with pressure-compensating drippers spaced 0.30 m apart and an average flow rate of 1.5 L ha^{-1}. A single drip tape was distributed per ridge. Irrigation was daily, and the water depths were determined based on crop evapotranspiration, estimated by multiplying the reference evapotranspiration (ETo) by the crop coefficient (Kc) as a function of the stages of crop development. The irrigation depths applied were 36.94 mm in the initial phase, 81.01 mm in the vegetative phase, 151.54 mm in the fruiting phase and 64.71 mm in the maturation phase.

At 30 days after transplanting, 10 healthy leaves were collected per plot. The material was packed in plastic bags wrapped in aluminum foil, stored on ice and sent to the laboratory. Malondialdehyde (Heath & Packer, 1968), ascorbate peroxidase (Nakano & Asada, 1981), and catalase (Peixoto et al., 1999) were determined.

CO_2 assimilation rate (A - μmol CO_2 m^{-2} s^{-1}), internal CO_2 concentration (Ci - mmol CO_2 mol^{-1} air), transpiration rate (E - mmol H_2O m^{-2} s^{-1}), stomatal conductance (gs - mmol H_2O m^{-2} s^{-1}), vapor pressure deficit (VPD - kPa^{-1}), and water use efficiency (WUE [(μmol CO_2 m^{-2} s^{-1}) (mmol H_2O m^{-2} $s^{-1})^{-1}$]) were determined. Data were obtained using a portable infrared gas analyzer (IRGA, GFS-3,000, Walz, Effeltrich, Germany) with CO_2 content set at 400 ppm and light intensity at 1,200 μmol m^{-2} s^{-1}. Readings were performed between 7 and 9:30 a.m. at 45 days after transplanting.

Melon plants were separated into shoots and fruit to determine dry mass. The tissues were rinsed in distilled water and dried in a forced air circulation oven at 65 °C until reaching constant mass. The cultivars 'Goldex' and 'McLaren' were harvested at 60 and 55 days after transplanting, respectively. Yield was obtained by the mass of fruits harvested. Numbers of fruits per plant was calculated as the ratio between the total number of fruits and the number of plants. Average fruit weight was obtained through the ratio between fruit mass and number of fruits.

The data were subjected to the variance homogeneity test, and analysis of variance was performed; when significant by the F test, means were compared by Tukey's test. Statistical analysis was performed using the SISVAR v.5.3 software (Ferreira, 2019).

RESULTS AND DISCUSSION

The application of biostimulants had an effect on all gas exchange variables evaluated, whereas, among cultivars, there was only a difference for A. There was no interaction between the factors for any gas exchange variable (Table 2).

The biostimulant Acadian® reduced the A of melon plants compared to the other treatments, being lower compared to the control. The A values of plants in the control, Folicist® and Nov@® treatments did not differ from each other (Table 3). The decrease in CO_2 assimilation rate in melon plants under the Acadian® treatment may be related to stomatal conductance of plants, since this physiological attribute is directly related to gs (Pascual et al., 2021).

The biostimulants did not increase the Ci in melon plants compared to the control. However, the internal CO_2 concentration decreased by 32.1 and 60.9% with use of Acadian® and Folicist®, respectively, compared to the control. The lowest stomatal conductance was observed in plants of these treatments (Table 3).

The highest stomatal conductance (gs) was observed in melon plants in the control and Nov@® treatments (Table 3). The increased opening of the stomata allows plants to capture and accumulate more CO_2 in mesophyll cells (Lima et al., 2020). These results agree with those cited above, since the highest means of A and Ci occurred in melon plants in the control and Nov@® treatments.

The highest transpiration rate was observed in plants treated with Nov@®, which also promoted higher gs (Table 3). These results are related since increase in gs also increases the E of plants (Lima et al., 2020). The results of gs and E in

Table 2. Analysis of variance at 45 DAT for CO_2 assimilation rate (A), internal CO_2 concentration (Ci), transpiration rate (E), stomatal conductance (gs), vapor pressure deficit (VPD) and water use efficiency (WUE) as a result of biostimulants and melon cultivars

S.V.	DF	Mean Square (MS)					
		A	Ci	E	gs	VPD	WUE
Biostimulant (B)	3	105.11**	7,126.93**	1.51*	13,713.54**	42.98**	27.81*
Cultivar (C)	1	127.84*	906.31^{ns}	0.55^{ns}	5,258.25^{ns}	1.29^{ns}	1.19^{ns}
B × C	3	39.94^{ns}	1,067.04^{ns}	0.34^{ns}	2,433.30^{ns}	0.51^{ns}	1.38^{ns}
MS $_{Error1}$		13.54	1,005.59	0.41	1,225.26	3.10	4.43
MS E_{rror2}		22.14	824.79	0.37	3,654.32	3.27	5.37
CV_1 (%)		10.38	38.60	22.62	17.86	11.80	17.55
CV_2 (%)		13.27	34.96	21.68	30.85	12.12	19.54

S.V. - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation; *, **, ns: - Significant at $p \leq 0.05$ and $p \leq 0.01$, and not significant by F test, respectively

Table 3. Means values of CO_2 assimilation rate (A), internal CO_2 concentration (Ci), transpiration rate (E), stomatal conductance (gs), vapor pressure deficit (VPD) and water use efficiency (WUE) of melon due to application of biostimulants at 45 DAT

Biostimulant	A	Ci	E	gs	VPD	WUE
	μmol CO_2 m^{-2} s^{-1}	mmol CO_2 mol^{-1} air	mmol H_2O m^{-2} s^{-1}		kPa	[(μmol CO_2 m^{-2} s^{-1}) (mmol H_2O m^{-2} s^{-1}) $^{-1}$]
Control	37.34 a	110.90 a	2.93 ab	202.96ab	14.55 b	10.50 b
Acadian®	30.06 b	75.27 ab	2.91 ab	160.95 ab	13.28 b	10.50 b
Folicist®	36.78 a	43.28 b	2.23 b	168.30 b	13.53 b	14.45 a
Nov@®	37.68 a	99.12 a	3.26 a	251.66 a	18.29 a	11.98 ab

Means followed by the same letter in the column do not differ according to the Tukey's test ($p \leq 0.05$)

the Nov@® treatment plants explain the vapor pressure deficit, as these physiological variables are directly related to loss of moisture by the plant. The vapor pressure deficit is the driving force of plant transpiration, obtained by the difference in vapor pressure between the interior of the leaf and the external environment (Song et al., 2021). When the vapor pressure deficit is high, there is an increase in transpiration tension of the leaf canopy, causing plants to have a greater consumption of water, and a good part of this is passively transported due to excessive transpiration.

Application of Folicist® promoted less transpiration (2.23 mmol m^{-2} s^{-1}) in the melon plant, decreasing compared to the control (2.93 mmol m^{-2} s^{-1}) and to the biostimulant Nov@® (3.26 mmol m^{-2} s^{-1}) (Table 3). This finding is important since low transpiration reflects less water loss (Figueiredo et al., 2021).

Also in the Folicist® treatment, greater water use efficiency (14.45 [(μmol CO_2 m^{-2} s^{-1}) (mmol H_2O $m^{-2}s^{-1}$) $^{-1}$]) was observed. Compared to the control and to the Acadian® and Nov@® biostimulants, the WUE in plants of this treatment was, on average, 32% (Table 3). The increase in WUE is influenced by the reduction of gs and E in plants when subjected to some type of stress (Dalastra et al., 2014), characteristics observed with the use of the Folicist® biostimulant. The results obtained in this study corroborate findings of Sharma et al. (2019), as the authors previously identified a relationship between decreased stomatal conductance and increased WUE in melon.

Another characteristic that explains the higher WUE in Folicist® treatment plants is the increase in number of fruits per plant. This biostimulant promotes better fruit setting; therefore, there is an increase in sinks for the partition of photoassimilates, requiring plants to spend more energy and, consequently, favoring an increase in WUE (Ferraz et al., 2012).

The results obtained in the gas exchange variables attest to the beneficial effects of Folicist® on the physiological attributes of the melon plant. This biostimulant favors activation of the defense mechanisms of the plant exposed to stress, without deleterious effects on the photosynthetic activity.

Means of Ci, gs, E, VPD and WUE did not differ between cultivars 'Goldex' and 'McLaren' (Table 2). However, 'McLaren' (37.46 μmol m^{-2} s^{-1}) had a higher CO_2 assimilation rate compared to 'Goldex' (33.47 μmol m^{-2} s^{-1}). This result demonstrates greater photosynthetic capacity of the cultivar 'McLaren'.

Biostimulants and cultivars had individual effects on malondialdehyde (MDA) content, while for ascorbate peroxidase (APX) and catalase (CAT) there was an interaction between the factors (Table 4).

MDA in melon increased with application of biostimulants. Compared to the control, Folicist® increased MDA content (Table 5).

MDA content is an indicator of lipid peroxidation (Panfili et al., 2019) that reflects the degree of damage to plant cell membranes caused by oxidative activity. Several factors can influence an increase in lipid peroxidation, since reactive oxygen species (ROS) also act as a signal, responding, at first, not to damage caused, but as an indication of damage, indicating the need for actions that minimize oxidative activity (Alves et al., 2021). This result may be linked to initial damage due to absorption of the biostimulant by membranes, since the collection of leaves was carried out one day after the application, so there was not enough time for its action. The method of application of the biostimulant may have had an influence, considering that Folicist® was applied to the foliage, which provides faster contact of the product with the membranes.

Table 4. Analysis of variance at 30 DAT for malondialdehyde (MDA), ascorbate peroxidase (APX) and catalase (CAT) submitted to biostimulants and melon cultivars

S.V.	DF	Mean square (MS)		
		MDA	APX	CAT
Biostimulant (B)	3	38.18**	14,520.82**	207,195.63**
Cultivar (C)	1	32.46*	11,068.86**	140,668.71**
B × C	3	13.43^{ns}	3,626.06**	236,692.74**
MS $_{\text{Error1}}$		3.38	46.00	2,021.84
MS $_{\text{Error2}}$		7.03	50.66	759.36
CV_1 (%)		11.31	4.90	6.34
CV_2 (%)		16.32	5.14	3.89

S.V. - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation; *,**, ns - Significant at p ≤ 0.05 and at p ≤ 0.01 and not significant by F test

Table 5. Malondialdehyde (MDA) and ascorbate peroxidase (APX) of melon as a function of biostimulants and cultivars at 30 DAT

Biostimulant	Malondialdehyde (nmol G MF $^{-1}$)
Control®	13.94 b
Acadian®	15.94 b
Folicist®	19.21 a
Nov@®	15.92 b
Cultivar	
'Goldex'	17.26 a
'McLaren'	15.24 b

Ascorbate peroxidase (mmol of ascorbic acid min $^{-1}$ g $^{-1}$ FM)				
Cultivar	Biostimulant			
	Control	Acadian®	Folicist®	Nov@®
Goldex	135.28 bA	80.51 dB	106.82 cB	156.69 aB
McLaren	124.16 bB	132.49 bA	126.69 bA	244.74 aA

Means followed by the same uppercase letter in the lowercase column and letter in the line do not differ according to the Tukey's test (p ≤ 0.05)

The low internal CO_2 concentration observed in the Folicist® treatment plants (Table 3) may also have influenced the higher MDA content obtained in this treatment (Table 5). Low Ci limits rates of Calvin cycle reactions and $NADP^+$ generation, increasing charges on electron transport in the photosynthetic system, in which photosystems I and II, in the thylakoid membrane, are the main sites of ROS generation (Hasanuzzaman et al., 2021).

The cultivar 'Goldex' had a higher content of malondialdehyde (Table 5). The adaptation and resistance of melon varieties to environmental conditions may have influenced MDA contents. Plants adapted to stress conditions may, or may not, have increased levels of ROS and antioxidant enzymes; however, lipid oxidation and malondialdehyde contents were reduced in these situations (Alché, 2019). Production of ROS can cause harmful effects on plants, requiring maintenance of redox homeostasis. For this, the plant needs to activate antioxidant defense systems, which include ascorbate peroxidase and catalase (Hasanuzzaman et al., 2021).

In 'Goldex' cultivar, the use of the biostimulant Nov@® increased ascorbate peroxidase by 15.8% compared to the control, while Folicist® and Acadian® reduced it by 21 and 40.4%, respectively, compared to melon plants not treated with biostimulant (Table 5). In 'McLaren', the highest average was observed in plants treated with Nov@®, responsible for an increase compared to the control, while the other treatments did not differ from each other (Table 5). When comparing the behavior of cultivars, in each treatment, ascorbate peroxidase was higher in 'McLaren' when biostimulants were used and, in the control treatment, the highest average was obtained in 'Goldex'.

The biostimulants Folicist® and Nov@® reduced catalase in 'Goldex' compared to the control (Table 6). In 'McLaren', all treatments differed from each other. Application of Acadian® and Folicist® increased catalase compared to control plants, and Nov@® decreased it. Among cultivars, catalase was higher in 'Goldex' in all treatments, with the exception of Folicist®, in which the highest average was observed in the cultivar 'McLaren' (Table 6).

Ascorbate peroxide and catalase metabolize reactive oxygen species and control their potential impacts on metabolic activity and cellular functions (Anjum et al., 2016). The increased activity of these enzymes in plants is an adaptation mechanism, preventing tissue damage by reducing hydrogen peroxide content of cellular metabolism (Gill & Tuteja, 2010). The melon plant has a high capacity to activate protective mechanisms against oxidative damage (Keling et al., 2017). The antioxidant activity of ascorbate peroxidase and catalase in melon may vary depending on composition of the biostimulant and on the cultivars.

Plant response to application of biostimulants is influenced by dose, mode and time of application, composition of biomolecules and/or microorganisms (Baltazar et al., 2021). According to the same authors, the heterogeneous composition of the products is a factor that hinders the understanding of some results, such as those obtained in this study. It is important to expand studies in order to understand the influence of biostimulants on plant and molecular physiology, seeking to elucidate mechanisms of action as well as efficiency in relation to the final result of production (Petroppoulos, 2020).

Number of fruits per plant (NF) and total yield (TY) were influenced by biostimulants and cultivars, while FDM differed between biostimulants (Table 7). For the average fruit weight (AFW) and the shoot dry mass (SDM), there was an interaction between the factors (Table 7).

Biostimulants promoted an increase in fruit dry mass of melon plants compared to the control. The highest average in fruit dry mass was observed in the Folicist® treatment, with an increase in fruit dry mass compared to the control (Table 8).

For shoot dry mass, there was a significant interaction between biostimulants and cultivars. Only the Nov@® biostimulant differed from the other treatments for the cultivar 'Goldex', with an increase in shoot dry mass compared to the control (Table 9), while in 'McLaren' no difference was observed between treatments (Table 9). When comparing this variable within each treatment, a significant effect was observed only for the biostimulant Acadian®, with a higher mean dry mass in 'McLaren'.

For average fruit weight, there was a significant interaction between treatment and cultivars. The application of the biostimulant Nov@® promoted higher average weight in the cultivar 'Goldex'; in 'McLaren', there was no difference between treatments (Table 10). Among cultivars, a higher average fruit weight was observed for 'Goldex' in all treatments. The average fruit weight in all treatments, including the control, was within the expected range for the cultivars 'Goldex' (1.5 to 2.5 kg per fruit) and 'McLaren' (1.0 to 1.5 kg per fruit), according to Topseed Premium and Bayer Seminis, respectively.

Table 6. Antioxidant activity of catalase enzymes in melon cultivars as a function of biostimulant application at 30 DAT

Cultivar	Catalase (U mg^{-1} protein)			
	Biostimulant			
	Control®	Acadian®	Folicist®	Nov@®
Goldex	943.47 a A	976.31 aA	357.75 cB	824.60 bA
McLaren	573.12 cB	839.95 aB	712.87 bA	445.77 dB

Means followed by the same uppercase letter in the lowercase column and letter in the line do not differ according to the Tukey's test ($p \leq 0.05$)

Table 8. Fruit dry mass of melon plants according to the application of biostimulants

Biostimulant	Fruit dry mass (g per plant)
Control®	191.19 b
Acadian®	235.78 ab
Folicist®	308.44 a
Nov@®	260.99 ab

Means followed by the same letter in the column are do not differ according to the Tukey's test ($p \leq 0.05$)

Table 9. Shoot dry mass of cultivars melon according to the application of biostimulants

Cultivar	Shoot dry mass (g per plant)			
	Biostimulant			
	Control®	Acadian®	Folicist®	Nov@®
Goldex	86.50 bA	92.35 bB	93.54 bA	130.26 aA
McLaren	99.21 aA	129.13 aA	108.62 aA	124.25 aA

Means followed by the same uppercase letter in the lowercase column and letter in the line do not differ according to the Tukey's test ($p \leq 0.05$)

Table 7. Summary of analysis of variance for number of fruits per plant (NF), average fruit weight (AFW), total yield (TY), fruit dry mass (FDM) and shoot dry mass (SDM) submitted to biostimulants and melon cultivars

S.V.	DF	Mean square (MS)				
		NF	AFW	TY	FDM	SDM
Biostimulant (B)	3	0.52**	21,128.22 ^{ns}	167.15**	19,184.90*	1741.5*
Cultivar (C)	1	0.69**	5,159,242.91**	20,81.73**	4,641.42^{ns}	1,655.56**
B × C	3	0.11^{ns}	56,299.26*	1.40^{ns}	2,089.55^{ns}	584.94*
MS$_{\text{Error1}}$		0.07	14,081.40	21.93	4236.68	438.03
MS$_{\text{Error2}}$		0.10	11,056.69	28.85	2094.50	163.75
CV$_1$ (%)		13.18	7.35	11.55	26.13	19.40
CV$_2$ (%)		15.07	6.51	13.25	18.37	11.86

S.V. - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation; *,**, ns - Significant at $p \leq 0.05$ and at $p \leq 0.01$ and not significant by F test

Table 10. Average fruit weight of melon cultivars as a function of biostimulant application

Cultivar	Average fruit weight (kg)			
	Biostimulant			
	Control®	Acadian®	Folicist®	Nov@®
Goldex	1.99 abA	1.92 bA	1.97 bA	2.19 aA
McLaren	1.30 aB	1.14 aB	1.17 aB	1.24 aB

Means followed by the same uppercase letter in the lowercase column and letter in the line do not differ according to the Tukey's test ($p \leq 0.05$)

Biostimulants increased number of fruits per plant (Table 11) and total yield (Table 11) of the melon plant. Among cultivars, greater number of fruits per plant was observed in the cultivar 'McLaren', while the highest total yield was found in cultivar 'Goldex' (Table 10).

All evaluated biostimulants increased total yield compared to the control. On average, the biostimulants increased total yield by similar values compared to the control. Total yield between biostimulants did not differ (Table 11). The increase in total yield can be explained by the action of biostimulants on plant roots, as they promote expansion of the melon root system, favoring water absorption and nutrient reserve in the vacuole (Lima et al., 2021).

When evaluating doses and timing of biostimulant application, Queiroga et al. (2020) observed gains compared to the control treatment, in number of fruits per plant and in total yield. The results found in this research corroborate theirs, highlighting the importance of biostimulants in increasing melon yield.

Despite producing less fruit per plant, 'Goldex' melon had higher yield than 'McLaren' melon (Table 11). These results attest to the differences in production characteristics between cultivars, especially with regard to average fruit weight, a factor that helps explain the difference in yield.

Table 11. Average number of fruits per plant and total yield of melon cultivars as a function of biostimulant application

Biostimulant	Fruits per plant	Total yield (t ha^{-1})
Control®	1.74 b	33.99 b
Acadian®	2.08 ab	41.58 a
Folicist®	2.36 a	41.66 a
Nov@®	2.06 ab	41.88 a
Cultivar		
Goldex	1.91 b	48.59 a
McLaren	2.21 a	32.46 b

Means followed by the same letter in the columns are not significantly different at $p \leq 0.01$ by the Tukey's test

CONCLUSIONS

1. Application of biostimulant increase total yield and number of fruits per melon plant.

2. The biostimulant Folicist® promotes physiological adaptations in melon plants to stress conditions without causing damage to their photosynthetic activity.

3. Activity of ascorbate peroxidase and catalase varies according to composition of biostimulants and melon cultivars used.

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