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ASPECTOS BIOQUÍMICOS E FLUORESCÊNCIA DA CLOROFILA *A* EM PLANTAS DE MINIMELANCIA HIDROPÔNICA SOB ESTRESSE SALINO*

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1 RESUMO

A salinidade é um dos principais estresses abióticos que induz distúrbios bioquímicos e fisiológicos em diversas culturas. O objetivo do trabalho foi investigar os efeitos da salinidade da solução nutritiva (CEsol) sobre a produção, acúmulo de solutos orgânicos e inorgânicos e fluorescência da clorofila a em plantas de minimelancia cv. Sugar Baby. O delineamento experimental foi o inteiramente casualizado com quatro repetições. As plantas foram cultivadas em sistema hidropônico com cinco níveis de CEsol: 2,5; 3,5; 4,5; 5,5 e 6,5 dS m^{-1}. Foram avaliados: massa do fruto, biomassa da parte aérea, teores de clorofilas *a* e *b*, fluorescência da clorofila a e teores de solutos orgânicos e inorgânicos. A massa do fruto e a biomassa seca da parte aérea foram influenciadas negativamente pela CEsol. Houve redução na concentração de carboidratos solúveis totais, aminoácidos livres, proteínas solúveis e prolina livre com o aumento da CEsol. Os íons sódio, cloreto e razão sódio/potássio aumentaram com a salinidade e os teores de potássio foram reduzidos. O incremento da salinidade aumentou linearmente o teor de clorofila *b* e reduziu linearmente o rendimento quântico da conversão de energia fotoquímica do FSII promovendo um ligeiro aumento no rendimento quântico da perda de energia regulada do FSII.

Palavras-chaves: biomassa, carboidratos, íons tóxicos, estresse abiótico.

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BIOCHEMICAL ASPECTS AND CHLOROPHYLL *A* FLUORESCENCE IN HYDROPONIC MINI WATERMELON PLANTS UNDER SALT STRESS

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2 ABSTRACT

Salinity is one of the main abiotic stresses that induce biochemical and physiological disorders in diverse crops. This study investigated the effects of nutrient solution salinity (ECsol) on production, accumulation of organic and inorganic solutes and chlorophyl *a* fluorescence in mini watermelon plants cv. Sugar Baby. The experimental design was completely randomized with four replications. The plants were grown in a hydroponic system with five levels of ECsol: 2.5; 3.5; 4.5; 5.5 and 6.5 dS m^{-1}. The variables evaluated were the mass of the fruit, the biomass of the aerial parts, contents of chlorophylls *a* and *b*, fluorescence of chlorophyll *a,* and contents of organic and inorganic solutes. The mass of the fruit and dry biomass of the aerial parts was negatively influenced by ECsol. There was a reduction in the concentration of total soluble carbohydrates, free amino acids, soluble proteins and free proline with the increase in ECsol. The sodium, chloride and sodium/potassium ratio increased with ECsol and potassium levels were reduced. The increase in ECsol linearly increased the chlorophyll *b* content and reduced the quantum yield of the photochemical energy conversion of the PSII promoting a slight increase in the quantum yield of the regulated energy loss of the PSII.

Keywords: abiotic stress, biomass, carbohydrates, toxic ions.

3 INTRODUCTION

Watermelon (*Citrullus lanatus L.*) is a species of the Cucurbitaceae family that is highly important to the national economy, as Brazil is the fourth largest watermelon producer in the world (FAOSTAT, 2020). In Brazil, the Northeast Region has stood out over the years as the largest watermelon producer (OLIVEIRA et al., 2016; SOUZA; SILVA, 2021) because of its favorable climatic conditions for cultivation. However, in semiarid regions, irregular rainfall distributions throughout the year, poor water quality from drilled wells or springs with high salt concentrations, degraded soils, and high insolation are frequently found (SILVA JÚNIOR et al., 2017). These factors can accelerate the salinization process of agricultural soils.

Salinity is an abiotic stress that can result in biochemical and physiological disturbances (POMPEIANO et al., 2016; BAI et al., 2019; SHOUKAT et al., 2019), which in turn affect crop development and productivity. Among the mechanisms used by plants to acclimate to salt stress is osmotic adjustment, which consists of a net increase in the solute content in cells. Inorganic ions are compartmentalized in the vacuole, and organic solutes accumulate in the cytosol. However, the efficiency of this mechanism varies within and between species (Taiz et al., 2017). Among the organic solutes (also called compatible osmolytes or osmoprotectors) evaluated in crops under stress conditions, the following stand out: proline, soluble carbohydrates, soluble proteins and free amino acids (MASTROGIANNIDOU et al., 2016; COVA et al., 2020).

When plants are exposed to high salinity, changes in the functional state of the chloroplast lamellae occur, resulting in changes in the characteristics of the fluorescence signals (WANG et al., 2018). Thus, it is possible to observe the degradation of photosynthetic pigments and a reduction in the net photosynthetic rate (OLIVEIRA et al., 2018; RIBEIRO et al., 2020).

For problems arising from soil and/or water salinity, measures must be taken to reduce their effects on socioeconomically important crops in semiarid regions. Several alternatives can mitigate the deleterious effects of salt, such as pulse irrigation (ZAMORA et al., 2019), foliar application of nitrogen peroxide (SILVA et al., 2019), mulching (LIMA et al., 2020), and hydroponics, which have emerged as alternatives to minimize these effects (Ó et al., 2020).

In this context, the objective of this work was to evaluate the production of fruit, dry biomass, accumulation of organic and inorganic solutes and chlorophyll a fluorescence *in* watermelon plants, cv. Sugar Baby, grown in a *floating* hydroponic system with Furlani nutrient solution. under different levels of water salinity.

4 MATERIALS AND METHODS

The experiment was conducted in a greenhouse belonging to the Graduate Program in Agricultural Engineering at the Federal University of Recôncavo da Bahia, in the municipality of Cruz das Almas, BA, located at 12° 40' 19 "S, 39° 06' 23"W, altitude of 220 m. The experiment was conducted from September to December 2018. According to the Köppen classification, the climate is hot and humid (Af) (ALVARES et al., 2013). During the study, the average maximum and minimum air temperatures in the greenhouse were 36.5 and 19.8 °C, respectively, and the average relative humidity was 51%.

The experimental design was completely randomized, with five treatments and four replicates, for a total of 20 experimental plots. The mini-watermelon cv. Sugar Baby plants were grown in a floating hydroponic system *and* subjected to five levels of electrical conductivity of the nutrient solution (CECol): 2.5 (control), 3.5, 4.5, 5.5 and 6.5 dS m^{-1}. The nutrient solution (NS) was based on the recommendation of Furlani (1999) for fruits (Table 1).

Table 1. Nutrient concentrations in the nutrient solution.

Furlani 's recommendations for fruit												
$N\text{-}NH_4$	$N\text{-}NO_3$	K	P	Here	Mg	S	B	Ass	Faith	Mn	Mo	Zn
Concentrations in mol 1000 L^{-1}												
25.1	152.7	224.9	40.3	153	24	31.2	0.61	0.02	2.16	0.92	0.5	0.25

Source: Fulani (1999)

An electrical conductivity (ECa) of 0.5 dS m $^{-1}$ was used to prepare the SN. In treatments with CEsol greater than 2.5 dS $m^{-1,}$ NaCl was added in an adequate quantity to prepare the solution with the desired CEsol, according to Equation 1, obtained from Richards (1954):

$$Q\ NaCl\ (mg\ L^{-1}) = 640 \times CEa\ (dS\ m^{-1}) \qquad (1)$$

where:

Q is the amount of salt to be dissolved in the water; and

CEa is the electrical conductivity of the desired solution.

After the nutrient solutions were prepared, CEsol was checked and adjusted via a bench conductivity meter.

Mini-watermelon seedlings were produced in 0.2 L plastic cups containing coconut fiber and a seed inserted into the substrate at a depth of 0.02 m. Initially, the seedlings were irrigated with a local water supply (EC = 0.50 dS $m^{-1)}$ and, after seven days, with Furlani's (1999) nutrient solution at half strength.

Transplanting was performed when the seedlings presented the first pair of definitive leaves (15 days after sowing). The *floating hydroponic system* consisted of a container containing 10 L of nutrient mixture covered with a Styrofoam (polystyrene) sheet with a hole in the center for plant fixation and reducing evaporation. The SN volume was computed daily with a local water supply, and the nutrient solutions were completely renewed every 10 days. The pH was monitored and maintained at 6.0 ± 0.5 using KOH (1.0 M) or HCl (1.0 M). The system was intermittently aerated for 15 minutes every hour, and an air compressor coupled to a timer was used. A spacing of 0.5 m between plants and 1.0 m between rows was used.

The branches were trained vertically with plastic strings tied to wires located 2.0 m above the ground. The plants were trained with two stems and one fruit on the main stem, as described by Ó et al. (2020).

The variables analyzed were fresh fruit mass; dry biomass of the aerial part; levels of organic solutes (soluble carbohydrates, free proline, free amino acids and soluble proteins); inorganic solutes (sodium - Na^+ and potassium - $K^{+);}$ the sodium/potassium ratio (Na^+ /K^+) and chloride - Cl^-) in the leaves; chlorophyll *a* and *b* contents; and chlorophyll *a fluorescence*.

The determination of the fresh mass of the fruit was carried out at the end of the experimental period. on a semianalytical balance (0.001 g). The determination of the dry mass of the aerial part was performed at the end of the experimental period after drying in an oven at 65 °C until a constant dry mass was reached. Organic solute contents were determined 50 days after transplanting (DAT) in a leaf sample located between the 8th and 10th nodes from the base (leaf adjacent to the fruit). The collected plant material was washed with deionized water, immediately frozen in liquid nitrogen, stored in an ultradeep freezer (-80 °C), lyophilized, and ground in a mortar. Inorganic solute contents were also determined in samples of leaves located between the 8th and 10th nodes, which were dried in an oven at 65 °C and ground in a mill.

To prepare the extract, 0.1 g of lyophilized leaf tissue was macerated with 5 mL of 0.1 M potassium phosphate buffer solution at pH 7.0 containing 0.1 mmol/L $^{\text{EDTA}}$. After maceration, the homogenate was filtered through a fine-mesh nylon cloth and centrifuged at 12,000 × g for 0.25 h. The supernatant was stored in an ultrafast freezer (-80 °C) and used for determination of soluble carbohydrates, free proline, free amino acids, and soluble proteins. All these determinations were performed in a UV–VIS spectrophotometer, model SF200DM (Bel Engineering, Piracicaba, Brazil).

The determination of soluble carbohydrates was performed at 490 nm in a 0.5 mL aliquot of the extract via the phenol–sulfuric acid method, with D-(+)-glucose used as a standard (DUBOIS et al., 1956). Free proline was determined at 520 nm in a 1.0 mL aliquot of the extract using 2.5% ninhydrin in acetic acid (glacial) and 6.0 M phosphoric acid and pure proline as standards (BATES; WALDREN; TEARE 1973). Total free amino acids were determined via the ninhydrin method (570 nm) in a 0.5 mL aliquot of the extract, with pure L-leucine used as a standard (YEMM; COCKING, 1955). The soluble protein content was determined at 595 nm via the dye binding method in a 0.1 mL aliquot of the extract, with pure bovine serum albumin used as a standard (BRADFORD, 1976).

To determine the Na^+, K^+ and Cl^- contents, aqueous extracts were prepared as described by Jones Júnior (2001), with slight modifications. The Na+ and K+ contents were determined via a flame photometer, model B462 (Micronal SA, São Paulo, Brazil), and the Cl^- contents were determined via spectrophotometry at 480 nm according to methodologies proposed by Faithfull (2002) and Gaines, Parker and Gascho (1984), respectively.

a and *b* Concentration indices and chlorophyll *a fluorescence* were measured on the same leaves used for solute analysis at 50 DAT. The chlorophyll concentration indices were obtained via the electronic chlorophyll content meter model ClorofiLOG CFL1030 (Falker Automação Agrícola Ltda, Porto Alegre, RS), and the values are expressed in the ICF (Falker chlorophyll index).

Chlorophyll a fluorescence *was* measured via an OS5p portable modulated fluorometer (Opti-Sciences, Hudson, USA). In leaves adapted for 30 min in the dark, the minimum fluorescence (F_0), maximum fluorescence (F_m) and potential quantum yield of photosystem II-PSII (F_v/F_m) were measured according to the saturation pulse method (SCHREIBER; BILGER; NEUBAUER, 1995). In leaves adapted to light, the yields of the competitive pathways of de-excitation of the energy absorbed in PSII were evaluated: the quantum yield of the photochemical energy conversion of PSII ($Y_{II)}$ and the quantum yields of regulated (Y NPQ) and unregulated ($Y_{NO)}$ dissipation of nonphotochemical energy in PSII, according to Kramer et al. (2004) and Klughammer and Schreiber (2008).

The data were subjected to analysis of variance (ANOVA) via the F test. In the case of a significant effect, the salinity levels were subjected to polynomial regression analysis (linear and quadratic) to obtain the model best suited to the data. Statistical analysis was performed via the SISVAR statistical software, version 5.6 (FERREIRA, 2019).

5 RESULTS AND DISCUSSION

Salinity significantly affected all the studied variables except the chlorophyll *an index (*Cl*a*), minimum fluorescence (F_0), maximum fluorescence (F_m), potential quantum yield of photosystem II (F_v/F_m) and the quantum yield of unregulated energy dissipation in PSII (Y_{NO}) (Table 2).

Table 2. Summary of Fisher's test (F) and observed means for the studied variables

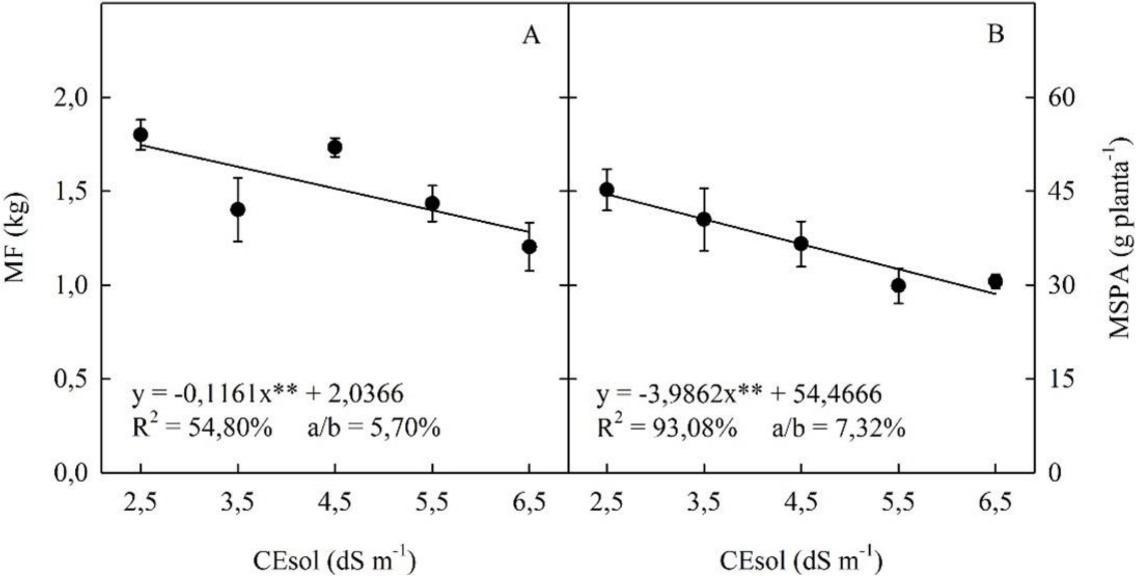
	F Test								
FV	MF	MSPA	CH	PL	AA	PS	In the $^+$	K $^+$	Na $^+$/K $^+$
Salinity	**	**	**	*	*	*	**	**	**
Linear	**	**	**	**	**	**	**	**	**
Quadratic	ns	ns	ns	ns	ns	ns	ns	ns	ns
Average	1.51	36.52	575.9	0.62	99.72	33.99	13.36	37,37	0.42
CV %	14.8	18.6	15.5	18.6	12.1	12.8	31.1	17.0	42.7
FV	Cl $^-$	Cl *a*	Cl *b*	F $_0$	F $_m$	F $_v$ / F $_m$	Y $_{II}$	Y $_{NPQ}$	Y $_{NO}$
Salinity	*	ns	**	ns	ns	ns	*	**	ns
Linear	**	ns	**	ns	ns	ns	**	**	ns
Quadratic	ns	ns	ns	ns	ns	ns	ns	**	ns
Average	58.4	39.7	19.7	261.3	1,119.0	0.76	0.27	0.53	0.19
CV %	8.2	3.3	12.5	4.9	3.9	2.0	9.8	5.5	8.4

*, ** - significant at the 1% and 5% probability levels, respectively; ns - not significant.

FV - source of variation, CV - coefficient of variation (expressed as a percentage), MF - fresh fruit mass (kg), MSPA - shoot dry mass (g plant $^{-1}$), CH - soluble carbohydrates (μmol g $^{-1}$ DM), PL - free proline (μmol g $^{-1}$ DM), AA - soluble amino acids (μmol g $^{-1}$ DM), PS - soluble protein (mg g $^{-1}$ DM), Na $^+$ - sodium content in the leaf (mmol g $^{-1}$ DM), K $^+$ - potassium content in the leaf (mmol g $^{-1}$ DM), Na $^+$ / K $^+$ - sodium potassium ratio, Cl $^-$ - chloride content in the leaf (mmol g $^{-1}$ DM), Cl *a* - content of chlorophyll *a,* Cl *b* - content of chlorophyll *b*, F $_0$ - minimum fluorescence, F m - maximum fluorescence, F $_v$ / F $_m$ - potential quantum yield of photosystem II, Y $_{II}$ - quantum yield of photochemical energy conversion of PSII, Y $_{NPQ}$ - quantum yield of regulated dissipation and Y $_{NO}$ - quantum yield of unregulated energy dissipation in PSII.

The increase in salinity in the nutrient solution linearly reduced the MF (Figure 1A) and MSPA (Figure 1B) of the watermelon plants, with reductions of 5.70 and 7.32%, respectively, per unit increase in the salinity of the nutrient mixture. When comparing the plants in the CEsol = 6.5 dS m^{-1} treatment with those in the control treatment (CSsol = 2.5 dS m $^{-1}$), a reduction of 26.60% in the fresh mass of the fruit and 35.83% in the dry biomass was observed.

Figure 1. Fruit fresh mass - MF (A) and shoot dry mass - MSPA (B) of mini watermelon cv. Sugar Baby plants grown in a *floating hydroponic system* in a greenhouse under different electrical conductivities of the nutrient solution (CEsol). The vertical bars represent standard errors (n = 4).

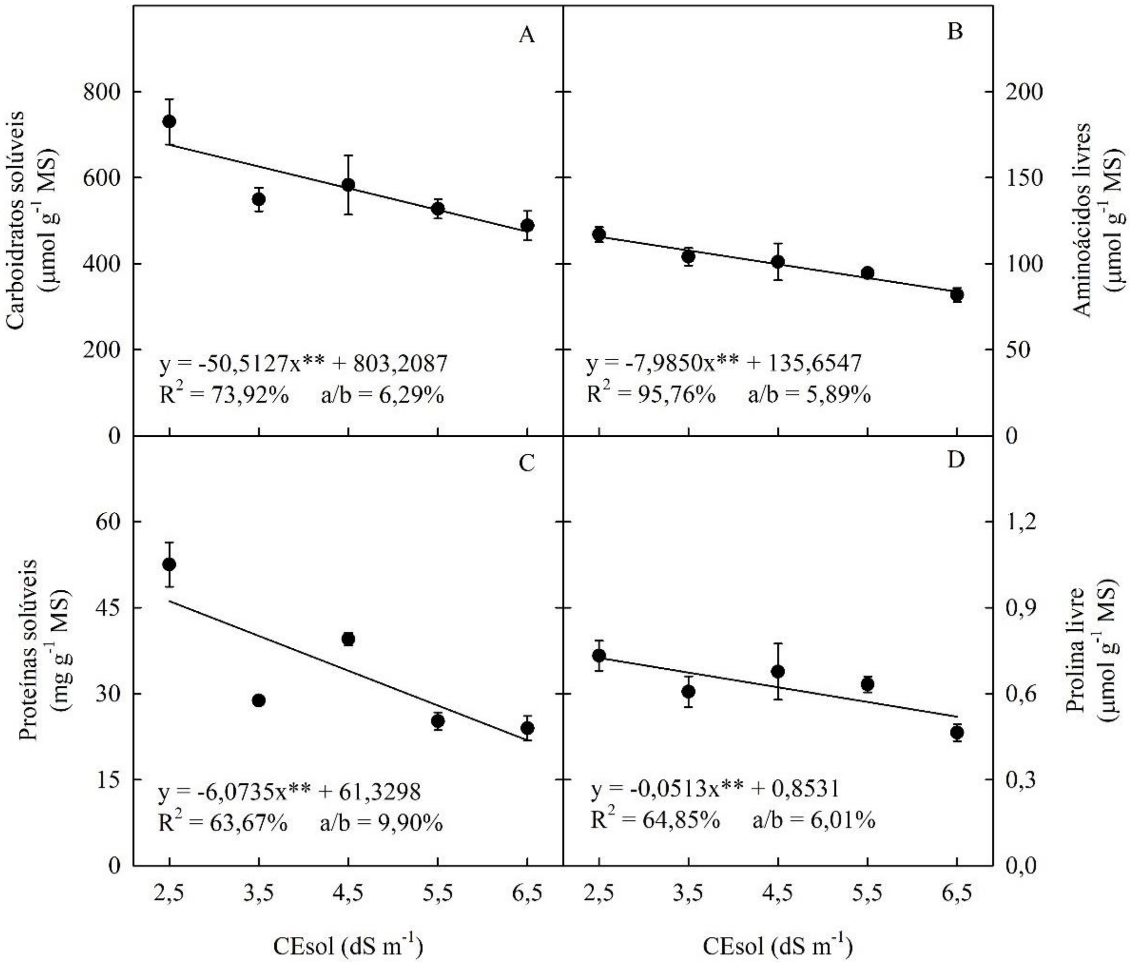


In general, plants respond to salinity by reducing growth, i.e., dry biomass production, as a result of osmotic and ionic disturbances. However, damage depends on the salt concentration and composition, the physiological stage of the plant, and the plant species (MASTROGIANNIDOU et al., 2016). The reduction in biomass in response to salinity can also be attributed to the diversion of energy from growth to acclimatization, for example, the exclusion of toxic ions Na+ and Cl^- and the synthesis of compatible solutes (MUNNS; TESTER, 2008).

In mini-watermelons grown with coconut fiber in a greenhouse, Ó et al. (2020) reported a similar result, with a 4.28% decrease in MF per unit increase in CEsol. Additionally, Oliveira et al. (2015) reported that the reduction in MSPA in plants under salt stress may be due to a decrease in photosynthetic efficiency during plant growth. This decrease in CO2 fixation $_{\text{may}}$ be the result of enzymatic impairment caused by ionic toxicity, with a reduction in the formation of carbon skeletons for biomass formation (PEREIRA et al., 2020). This reduction was also reported by Ekbic et al. (2017) and Silva Júnior et al. (2017) in watermelons subjected to salinity.

The increase in CEsol linearly reduced the CH, AA, PS and PL contents, respectively, by 6.29, 5.89, 9.90 and 6.61% per unit increase in CEsol (Figure 2). Among the organic solutes evaluated, PS was relatively more affected by the increase in salinity than were the other solutes evaluated.

Figure 2. Soluble carbohydrate (CH) (A), free amino acid (AA) (B), soluble protein (PS) (C) and free proline (PL) (D) contents in the leaves of mini watermelon cv. Sugar Baby plants grown in a *floating* hydroponic system 50 days after transplanting in a greenhouse under different electrical conductivities of the nutrient solution (CEol). The vertical bars represent standard errors (n = 4).



According to Silva et al. (2010), plants perform osmoregulation to tolerate some abiotic stress, with the accumulation of soluble carbohydrates being an important indicator of this mechanism. In the present study, the results suggest that the mini watermelon cultivar Sugar Baby did not undergo osmotic adjustment, a behavior reflected by a reduction in the accumulation of this compound.

Alternatively, these decreases may be related to the position of the leaf used for the determinations, since the samples were collected from leaves adjacent to the forming fruits. The direction of solute translocation is always from the producing organ (source leaf) to the consuming organ (sink fruit), whenever there is demand. Thus, it is possible that the translocation of organic solutes to the fruit was prioritized, to the detriment of their accumulation in the leaf (SOUZA et al., 2013).

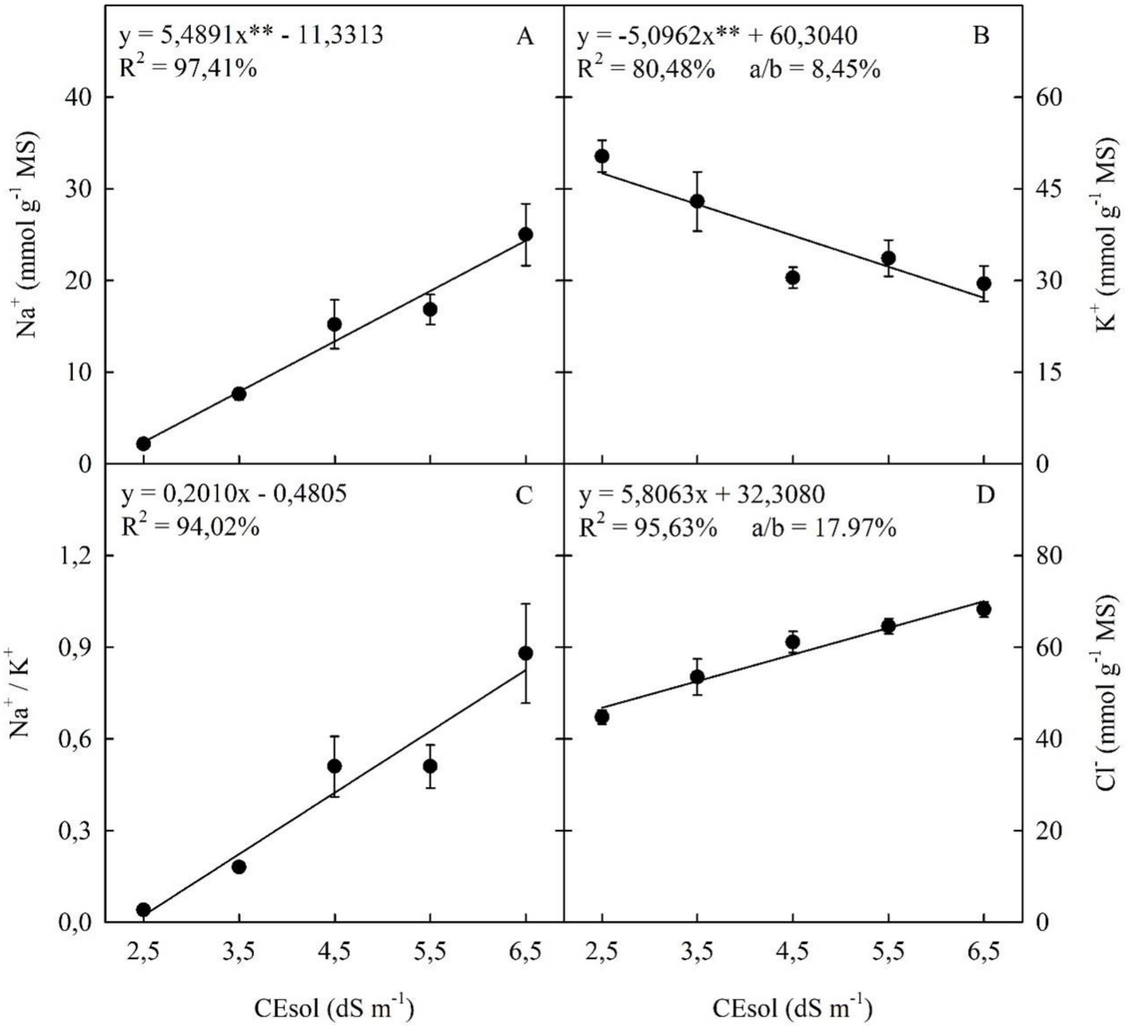
In this context, Lins et al. (2013) reported that in watermelon trees, fruits after pollination are considered the main sinks, which leads to changes in the source–sink relationship during the development phase, influencing the formation of photoassimilates.

In this study, salinity reduced the AA content in the leaves (Figure 2B), which may be associated with the inhibition of its biosynthesis or increased degradation (SILVA et al., 2008). Low-molecular-weight organic solutes frequently accumulate in plants under salt stress (COVA et al., 2016; 2020; MENEZES et al., 2017). In contrast, the data from this study revealed that salt stress reduced the PS content (Figure 2C), a phenomenon also reported by Gondim et al. (2011), in which the authors emphasized that under high salinity, the PS content of some plants decreased. Different stress conditions often alter the rates of amino acid biosynthesis and degradation, increasing or decreasing amino acid availability for protein synthesis or secondary metabolite production (BATISTA-SILVA et al., 2019). Thus, the data suggest that the salt-induced reduction in PS was a result of reduced protein synthesis due to decreased amino acid content (Figure 2B).

proline accumulation is believed to facilitate osmoregulation under saline stress (PARIDA; DAS, 2005). However, in the present study, the leaf proline content decreased linearly with increasing salinity (Figure 2D), indicating that this amino acid did not play an osmoregulatory role in mini watermelon cv. Sugar Baby plants.

The $^{Na+}$ concentration and the $Na^{+/}K^{+}$ ratio increased 10.18- and 37.54-fold, respectively, when the 2.5 and 6.5 dS m $^{-1}$ treatments were compared (Figure 3A and 3C). Similarly, the Cl^{-} values increased 1.50 times compared with those of the control treatment (Cols = 2.5 dS m^{-1}) with the nutrient solution with the highest salinity (6.5 dS m^{-1}), representing an increase of 17.97% per unit increase in the salinity of the nutrient solution (Figure 3D).

Figure 3. Na^+ (A), K^+ (B), Na^+/K^+ ratio (C), and Cl^- (D) contents as a function of the electrical conductivities of the nutrient solution (Cols) in leaves of mini-watermelon cv. Sugar Baby plants grown in a *floating* hydroponic system at 50 days after transplanting in a greenhouse under different electrical conductivities of the nutrient solution (Cols). The vertical bars represent standard errors (n = 4).



In contrast, the K+ contents in the plant leaves fit a decreasing linear model (Figure 3B). The K^+ values decreased by 8.45% per unit increase in the salinity of the nutrient solution, corresponding to a total reduction of 42.86% when the K^+ content in the 6.5 dS m^{-1} treatment was compared with that of the control.

High Na+ concentrations in the root medium can reduce intracellular K^+ concentrations in plants (CHRYSARGYRIS et al., 2019) because of the competitive inhibition of absorption between these ions (MEKAWY et al., 2015). In this sense, Tang et al. (2015) emphasized that maintaining a high K+ concentration and low Na+

concentration in the cytosol plays an important role in plant tolerance to salt stress.

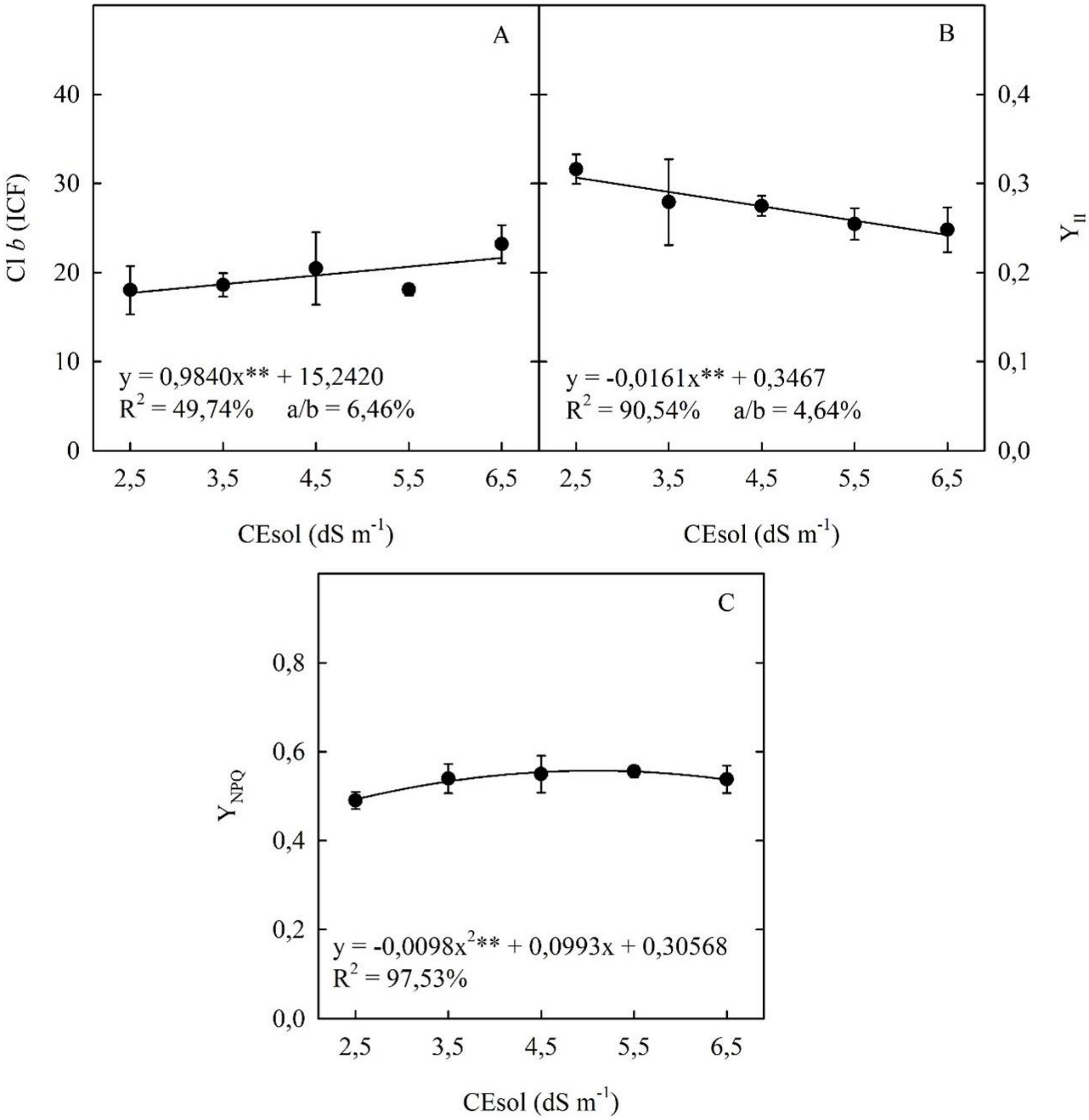
The Cl^- levels in the leaves were considerably greater than the Na^+ levels, regardless of the treatment considered. The high Cl^- values may be related to greater absorption or translocation of this ion to the leaves (BOSCO et al., 2009).

Some plant species tend to accumulate organic solutes in different organs to tolerate environmental stresses (SLAMA et al., 2015). However, inorganic solutes such as Na+ and Cl- can be toxic, and their accumulation in leaves depends on the ability to exclude and/or compartmentalize these ions in organs such as the stem and roots (SPERLING et al., 2014), which can lead to increased energy expenditure and consequently reduced growth (BAI et al., 2019). Similar results were reported by Silva Júnior et al. (2017), who reported a gradual increase in the Na+ ion content in watermelon leaves as the salinity level of the water used for irrigation increased. Cova et al. (2016) also reported a decrease in the K+ content in noni (*Morinda)* leaves. *citrifolia*) with increasing CEsol.

The $^+/K^+$ ratio is highly related to crop tolerance to salinity and can be used as an index of sodium toxicity, with values equal to or less than 1.0 being necessary for optimal metabolic efficiency in nonhalophytic plants (GREENWAY; MUNNS, 1980). In the present study, a linear increase was observed with increasing salinity, which was due to the increase in sodium concentration and decrease in K^+ concentration, with a value of 0.83 being observed in the 6.5 dS m^{-1} treatment (Figure 1C). This value (below 1.0) suggests that cellular metabolism was not affected by the salinity level studied and that the reduction in MF and/or MSPA cannot be attributed to an imbalance in the Na^+/K^+ ratio. As previously suggested, these reductions may be related to the diversion of energy from growth to maintenance; that is, the decreases in MF and MSPA may reflect a reduction in carbon gain. associated with the metabolic cost of energy for acclimatization to saline stress (MUNNS; TESTER, 2008; BAI et al., 2019).

Figure 4 shows that there was a linear increase in the chlorophyll *b* index with increasing salinity of the nutrient mixture, corresponding to an increase of 22.23% when the control treatment was compared with the highest salinity treatment (Cols = 6.5 dS m^{-1}).

Figure 4. Chlorophyll *b* index - Cl *b* (A), quantum yield of photochemical energy conversion of FSII - Y_{II} (B) and quantum yield of regulated energy loss - Y_{NPQ} (C) in leaves of mini-watermelon cv. Sugar Baby plants grown in a *floating hydroponic system* at 50 days after transplanting in a greenhouse as a function of the electrical conductivity of the nutrient solution (CEsol). The vertical bars represent standard errors (n = 4).



A comparison of the effects of salinity on the fluorescence variables revealed a reduction in Y_{II} of 4.61% per unit increase in CEsol (Figure 4B) and a small increase in Y_{NPQ}, with a maximum estimated value of 0.56 at a salinity of 5.1 dS m^{-1} (Figure 4C).

Salinity is believed to affect photosynthetic pigments through an increase in the number of chloroplasts, which is considered a mechanism of salt tolerance (SILVA et al., 2016; COVA et al., 2020). In this study, the increase in salinity did not alter the Cl an index *in* the leaves of mini watermelons, indicating that salinity did not induce Cl a synthesis or degradation at the CEsol levels studied. However, the observed increase in the chlorophyll *b* index with increasing salinity in the nutrient solution may have occurred because of the negative regulation of the activity of the enzyme chlorophyll b reductase, which is responsible for the transformation of chlorophyll *b* into chlorophyll *a* (DIRAY-ARCE et al., 2015).

The nonsignificant results of the minimum fluorescence (F_0), maximum fluorescence (F_m), and potential quantum yield of photosystem II (F_v / F_m) contents indicate that the salinity doses studied in the mini-watermelon plants were not able to impair energy transfer from the antenna to the FSII reaction centers (BOLHÀR-NORDENKAMPF; ÖQUIST, 1993), which was also observed by Ribeiro et al. (2020). In this work, the authors reported that the FSII efficiency and yield were not affected by the salinity levels tested (up to 4.0 dS m^{-1}).

Salinity stress decreased Y_{II} by 4.64% for each unit increase in CEsol, corresponding to a 21% reduction in the CEsol 6.5 dS m^{-1} treatment compared with the control treatment (2.5 dS m^{-1}). This decrease indicates that, under saline stress, a smaller amount of excitation energy is used for the synthesis of ATP (adenosine triphosphate) and NADPH (nicotinamide adenine dinucleotide phosphate) in chloroplasts (TAIZ et al., 2017). The lower Y_{II} values are often attributed to the imbalance in the electron transport rate and the reduction in ATP and NADPH consumption during the CO_2 assimilation process (SILVA et al., 2012; POMPEIANO et al., 2016) and may, at least in part, explain the reduction in MF and MSPA with increasing CEsol.

Unlike the results obtained for Y_{II}, the regulated dissipation yield (Y_{NPQ}) increased with salt stress, indicating that salinity favored the dissipation of nonphotochemical energy. Y_{NPQ} represents the dissipation of excess energy in the form of heat through the xanthophyll cycle (SHOUKAT et al., 2019). Under salt stress conditions, this cycle acts as a photoprotective mechanism, helping to maintain the high oxidative state of the primary electron acceptors of PSII and reducing the probability of photodamage and photooxidative stress in chloroplasts (SILVA et al., 2012).

6 CONCLUSIONS

The salinity of the nutrient solution increases the dissipation of energy by the xanthophyll cycle and reduces the excitation energy available for photosynthesis, which, at least in part, explains the reduction in shoot biomass and fruit mass of the mini watermelon cultivar Sugar Baby.

Organic solutes do not contribute to the osmotic adjustment of mini watermelon leaves cv. Sugar Baby grown under saline conditions.

The Na^+/K^+ ratio indicates that a CEsol of up to 6.5 dS m^{-1} does not affect ionic homeostasis in the leaves of mini watermelon cv. Sugar Baby.

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