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Original Article

Irrigation with saline water in the cultivation of mini watermelon under phosphate fertilization

Irrigação com águas salinas no cultivo de mini melancia sob adubação fosfatada

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Abstract

The objective of this study was to evaluate the water status, photosynthetic pigments, and photochemical efficiency of mini watermelon plants under salt stress and phosphate fertilization. The experiment was conducted in pots under greenhouse conditions in Pombal, PB, Brazil. The experimental design used was randomized blocks in a 5 × 4 factorial scheme, with five levels of electrical conductivity of irrigation water - ECw (0.3, 1.3, 2.3, 3.3, and 4.3 dS m^{-1}) and four doses of phosphorus (60, 80, 100, and 120% of the recommendation), with three replicates. The relative water content in the tissues decreased with the increase in ECw levels in all phosphorus doses, with decreases of 7.05, 7.81 and 8.83% per unit increase in ECw, in plants fertilized with 80, 100 and 120% P_2O_5. On the other hand, ECw levels increased electrolyte leakage, regardless of phosphorus doses of the recommendation. The synthesis of photosynthetic pigments and the quantum efficiency of photosystem II were inhibited by increasing water salinity from 0.3 dS m^{-1} in plants grown under phosphorus doses above 60% of the recommendation. Water salinity from 0.3 dS m^{-1} reduced chlorophyll *b* contents, initial, maximum, and variable fluorescence of mini watermelon plants, with a decrease of 11.86, 4.51, 4.53, and 4.54% per unit increment of ECw, respectively.

Keywords: *citrullus lanatus*, water scarcity, mitigation, brackish water.

Resumo

Objetivou-se com este trabalho avaliar o status hídrico, os pigmentos fotossintéticos e a eficiência fotoquímica em plantas de mini melancia sob estresse salino e adubação fosfatada. O experimento foi conduzido em vasos sob condições de casa de vegetação em Pombal – PB. O delineamento experimental utilizado foi o de blocos casualizados em esquema fatorial 5 × 4, sendo cinco níveis de condutividade elétrica da água de irrigação - CEa (0,3; 1,3; 2,3; 3,3 e 4,3 dS m^{-1}), quatro doses de fósforo (60; 80; 100 e 120% da recomendação), com três repetições. O conteúdo relativo de água nos tecidos diminuiu com o aumento dos níveis de CEa em todas as doses de fósforo, sendo os decréscimos de 7,05, 7,81 e 8,83% por aumento unitário da CEa, nas plantas adubadas com 80, 100 e 120% de P_2O_5. Por outro lado, os níveis crescentes de CEa aumentaram o extravasamento de eletrólitos, independente das doses de fósforo. A síntese de pigmentos fotossintéticos e a eficiência quântica do fotossistema II foi inibida pelo aumento da salinidade da água a partir de 0,3 dS m^{-1} nas plantas cultivadas sob doses de fosforo acima de 60% da recomendação. A salinidade da água a partir de 0,3 dS m^{-1} reduziu os teores de clorofila *b*, a flourescência inicial, a máxima e a variável das plantas de mini melancia, sendo a diminuição de 11,86; 4,51; 4,53 e 4,54% por incremento unitário da CEa, respectivamente.

Palavras-chave: *citrullus lanatus*, escassez hídrica, atenuador de estresse, água salobra.

1. Introduction

Watermelon (*Citrullus lanatus*) is one of the main fruits produced and consumed in Brazil, being cultivated in almost all Brazilian states (Silva Junior et al., 2020), due to its great importance in Brazilian agribusiness (Ó et al., 2020). In Brazil, 2,278,186 tons of watermelon were produced in 2019, with the Northeast region accounting for 34.03% of the national production (IBGE, 2020). The Sugar Baby watermelon cultivar has stood out in the export market due to its small size, practicality in transport and ease of packaging (Silva et al., 2022). The mini watermelon cultivar Sugar Baby was used in the experiment. This cultivar stands out for its early cycle, with harvest from 75 days after planting. It is a versatile plant, with vigorous foliage and tolerance to high temperatures. It has round fruits, with dark green peel, weighing from 2 to 4 kg. It has pulp with high sugar content, soft and with an intense red color (Silva et al., 2019).

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Despite the potential for the cultivation of this fruit crop, long periods of water scarcity due to the low and irregular rainfall and high evapotranspiration rates in most of the year are common in the Northeast region (Lima et al., 2020a). Thus, irrigated agriculture becomes necessary to ensure agricultural production. However, most sources of water used in irrigation, both surface and underground, have high concentrations of dissolved salts, making it a limiting factor for production in this region (Lima et al., 2016; Fernandes et al., 2021).

Salt stress in plants causes various physiological and metabolic changes, such as nutritional imbalance and oxidative stress, which lead to reductions in water absorption and growth, and can also cause toxicity, due to the action of Na^+ and Cl^- ions (Oliveira et al., 2021, 2022; Pinheiro et al., 2022). In addition, it alters water relations by inducing stomatal closure and inhibition of leaf expansion.

Several studies have been conducted to evaluate the potential of using saline water in the cultivation of mini watermelon and have found the harmful effects of water salinity on growth, gas exchange, photosynthetic pigments, quantum yield, biomass, production and post-harvest quality (Lima et al.; 2020b; Gomes do Ó et al., 2020; Silva et al., 2020, 2021), highlighting that the crop is sensitive to salt stress. Silva et al. (2021) evaluating the effects of water salinity as a function of the phenological stages of mini watermelon found that the intensity of stress depends on irrigation management, species and/or cultivar, irrigation and fertilization management, and climatic conditions in the region. This situation was also observed by Pinheiro et al. (2022) with passion fruit crop and by Soares et al. (2018) in a study with colored fiber cotton genotypes.

Searching for management strategies in the water-soil-plant system under the semi-arid conditions of the Brazilian Northeast is of fundamental importance to ensure the sustainability of irrigated agriculture. In this context, phosphate fertilization is a promising strategy indicated in several studies as an alternative to mitigate the deleterious effects of irrigation water salinity (Oliveira et al., 2010; Sá, 2016; Lima et al., 2020a). Phosphorus is a macro-element involved in many metabolic processes, including energy transfer, signal transduction, biosynthesis of macromolecules, photosynthesis, and respiration (Tang et al., 2019). However, the effects of water salinity and phosphorus nutrition are complex and depend on the species or cultivar, stage of development, composition and concentration of salts, and the level of phosphorus (Miranda et al., 2013). Dias et al. (2021) in a study evaluating the effects of combined fertilization with phosphorus and potassium on West Indian cherry plants under salt stress concluded that fertilization with 60 and 85% of the P_2O_5 recommendation promoted an increase in the synthesis of chlorophyll a and *b*, respectively. In addition, supplying 85% of the P_2O_5 recommendation promoted an increase in maximum and variable florescence in plants submitted to water salinity of 0.6, 2.2, and 3.8 dS m^{-1}, respectively.

Despite the importance of phosphorus, studies that address the role of this element in mitigating salt stress in watermelon cultivation under conditions of protected environment in the semiarid region of Northeast Brazil are scarce in the literature. In view of the above, the objective of this study was to evaluate the water status, photosynthetic pigments and photochemical efficiency of mini watermelon plants cv. Sugar Baby under salt stress and phosphate fertilization.

2. Material and Methods

The experiment was carried out in a protected environment (greenhouse) at the Center of Sciences and Agri-Food Technology - CCTA of the Federal University of Campina Grande - UFCG, located in the municipality of Pombal, PB, Brazil, at the geographical coordinates 6º47'20" S latitude and 37º48'01" W longitude, at an altitude of 194 m.

The experimental design used was randomized blocks in a 5 × 4 factorial scheme, with five levels of electrical conductivity of irrigation water - ECw (0.3, 1.3, 2.3, 3.3, and 4.3 dS m^{-1}) and four doses of phosphorus (60, 80, 100, and 120% of the recommendation of Novais et al. (1991), with three replicates. The 100% dose corresponded to 300 mg of P_2O_5 kg^{-1} of soil.

Plants were cultivated in 20 L plastic pots adapted as lysimeters. Two holes were made at the base of the pots where 16-mm-diameter transparent drains were connected. The tip of the drain inside the lysimeter was wrapped with a non-woven geotextile (Bidim OP 30) to prevent clogging by soil material.

A container was placed below each drain to collect drained water and estimate water consumed by the plants. The pots were filled with a 0.5-kg layer of crushed stone, followed by 23.5 kg of a *Neossolo Regolítico* (Entisol) with sandy clay loam texture, from the rural area of the municipality of São Domingos, PB, whose chemical and physical characteristics (Table 1) were obtained according to the methodology proposed by Teixeira et al. (2017).

For sowing, four seeds were distributed equidistantly in each lysimeter at 2 cm depth. After seedling emergence, thinning was performed in two steps, when the plants had two and three pairs of true leaves, respectively, leaving one plant per container in the last thinning. The plants were cultivated with vertical staking, leaving the main branch and three lateral branches per plant.

The waters were prepared in the laboratory so as to have an equivalent ratio of 7:2:1, corresponding to Na:Ca:Mg, respectively, using NaCl, $CaCl_2.2H_2O$, and $MgCl_2.6H_2O$ salts, a ratio that prevails in the sources of water used for irrigation in small farms of the Northeast region, considering the relationship between ECw and salt concentration (Richards, 1954), according to Equation 1:

$$C\left(\text{mmol}_c\ \text{L}^{-1}\right) \approx 10 \times \text{ECw} \tag{1}$$

Where:
C = concentration of salts to be applied (mmol$_c$ L^{-1}); and,
ECw = electrical conductivity of water (dS m^{-1}).

Table 1. Chemical and physical characteristics of the soil used in the experiment, before the application of the treatments.

Chemical characteristics								
pH (H_2O)	**OM**	**P**	**K^+**	**Na^+**	**Ca^{2+}**	**Mg^{2+}**	**Al^{3+}**	**H^+**
(1:2.5)	**g kg^{-1}**	**(mg kg^{-1})**	**..............cmol$_c$ kg^{-1}..............**					
5.58	2.93	39.2	0.23	1.64	9.07	2.78	0.0	8.61
..........Chemical characteristics............				...........................Physical characteristics...........................				
EC_{se}	CEC	SAR_{se}	ESP	Particle-size fraction (g kg^{-1})			Moisture (dag kg^{-1})	
(dS m^{-1})	cmol$_c$ kg^{-1}	(mmol L^{-1})$^{0.5}$	%	Sand	Silt	Clay	33.42 kPa[1]	1519.5 kPa[2]
2.15	22.33	0.67	7.34	572.7	100.7	326.6	25.91	12.96

pH – Hydrogen potential, OM – Organic matter: Walkley-Black Wet Digestion; Ca^{2+} and Mg^{2+} extracted with 1 M KCl at pH 7.0; Na^+ and K^+ extracted with 1 M NH_4OAc at pH 7.0; $Al^{3+}+H^+$ extracted with 0.5 M CaOAc at pH 7.0; ECse - Electrical conductivity of saturated paste extract; CEC - Cation exchange capacity; SAR_{se} - Sodium adsorption ratio of saturated paste extract; ESP - Exchangeable sodium percentage. [1,2] referring to the moisture contents in the soil corresponding to the field capacity and permanent wilting point

Irrigation was performed daily at 5:00 p.m., applying in each container the volume corresponding to that obtained by the water balance, determined by Equation 2:

$$VI = \frac{(Va - Vd)}{(1 - LF)} \tag{2}$$

Where:
VI = Volume of water to be applied (mL);
Va = volume applied in the previous irrigation event (mL);
Vd = Volume drained (mL); and
LF = leaching fraction of 0.2.

Fertilization with nitrogen and potassium was performed according to the recommendation for pot experiments (Novais et al., 1991), applying 100 and 150 mg kg^{-1} of soil of N and K_2O, respectively, via fertigation, at 15-day intervals equally distributed throughout the crop cycle. Urea (45% N) and potassium chloride (60% K_2O) were used as sources of nitrogen and potassium, respectively. Monoammonium phosphate (48% P_2O_5, 11% N) was used as a source of phosphorus, considering the amount of N added via monoammonium phosphate. P was supplied according to the pre-established treatments, applying one third of the recommended dose as basal and the other two thirds divided into three equal portions and applied at 10-day intervals, with the first one at fifteen days after sowing. Fertilization with micronutrients was performed weekly, through the leaves, using solution (1.0 g L^{-1}) of Ubyfol® [(N (15%); P_2O_5 (15%); K_2O (15%); Ca (1%); Mg (1.4%); S (2.7%); Zn (0.5%); B (0.05%); Fe (0.5%); Mn (0.05%); Cu (0.5%); Mo (0.02%)].

At 40 days after sowing (DAS), the relative water content (RWC), leaf water potential (Ψw), electrolyte leakage (% EL), contents of chlorophyll *a* (Chl *a*) and chlorophyll *b* (Chl *b*), carotenoids (Car), and variables related to chlorophyll *a* fluorescence, namely initial fluorescence (F_0), maximum fluorescence (Fm), variable fluorescence (Fv), and quantum efficiency of photosystem II (PSII), were evaluated.

To determine the relative water content, 8 leaf discs were collected from each plant, from leaves located in the upper third of the plant, and their fresh mass (FM) was determined. The leaves were immediately weighed, avoiding moisture losses. Then, these samples were placed in plastic bags, immersed in distilled water and kept for 24 hours. After this period and after wiping excess water with paper towels, the turgid mass (TM) was obtained, and the samples were dried in an oven at 65 ºC ± 3 ºC, until constant weight, to obtain dry mass (DM). RWC was determined according to Weatherley (1950), using Equation 3:

$$RWC = \frac{(FM - DM)}{(TM - DM)} \times 100 \tag{3}$$

Where:
RWC = relative water content (%);
FM = leaf fresh mass (g);
TM = leaf turgid mass (g); and
DM = leaf dry mass (g);

Water potential (Ψw) was determined using a Scholander pressure bomb. To determine the Ψw, fully expanded leaves located between the 3rd and 5th positions from the apex, with good phytosanitary status, were collected. To make the measurement, the chamber was pressurized with compressed gas until the exudation of liquid by the xylem, at that point the reading of the applied pressure was recorded. The negative value corresponded to the Ψw of the organ (Turner, 1981). The readings were performed between 6:00 and 7:00 a.m.

Electrolyte leakage in the leaf blade was obtained according to Scotti-Campos et al. (2013), using Equation 4:

$$\% EL = \frac{Ci}{Cf} \times 100 \tag{4}$$

Where:
EL = Electrolyte leakage in the leaf blade;
Ci = initial electrical conductivity (dS m^{-1});
Cf = final electrical conductivity (dS m^{-1}).

Chlorophyll (*a* and *b*) and carotenoid contents were quantified in a spectrophotometer at absorbance (ABS) wavelengths of 470, 646, and 663 nm, according to the methodology of Arnon (1949), using Equations 5, 6, and 7:

$$Chl\ a = 12.21\ ABS_{663} - 2.81\ ABS_{646} \tag{5}$$

$$\text{Chl b} = 20.13\ \text{ABS}_{646} - 5.03\ \text{ABS}_{663} \quad (6)$$

$$\text{Car} = (1000\ \text{ABS}_{470} - 1.82\ \text{Chl a} - 85.02\ \text{Chl b})/198 \quad (7)$$

Where:
Chl *a* – Chlorophyll *a*;
Chl *b* - Chlorophyll *b*; and
Car - Total carotenoids.

The values obtained for the contents of chlorophyll *a*, chlorophyll *b,* and carotenoids in the leaves were expressed in mg g^{-1} of fresh matter (FM).

The photochemical efficiency of mini watermelon plants was measured based on initial, maximum, variable fluorescence, and on the quantum efficiency of photosystem II in leaves preadapted to the dark with leaf clips for 30 min, between 7:00 and 8:00 a.m., using the modulated fluorometer Plant Efficiency Analyser – PEA II®.

The collected data were subjected to analysis of variance by the F test at 0.05 probability level and, when significant, the linear and quadratic polynomial regression analysis was performed for the factors salinity levels and phosphorus doses, using the statistical software SISVAR version 5.7 (Ferreira, 2019).

3. Results and Discussion

There was a significant effect of salinity levels (SL) on the relative water content (RWC), water potential (Ψ_w), electrolyte leakage in the leaf blade (% EL), chlorophyll *a* (Chl *a*), chlorophyll *b* (Chl *b*), and carotenoids (*Car*) contents of the mini watermelon plants at 40 days after sowing (Table 2). Phosphorus doses (PD) significantly influenced Ψ_w, % EL, Chl *a,* and Car, while the interaction between factors (SL × PD) significantly interfered with the RWC, Ψ_w, % EL, Chl *a,* and *Car* of mini watermelon plants.

The relative water content in the leaf tissues of mini watermelon plants decreased with the increase in ECw levels at all phosphorus doses (Figure 1A). Mini watermelon plants fertilized with 60% of the P_2O_5 recommendation obtained the highest RWC (75.59%) when they were irrigated with ECw of 0.3 dS m^{-1}, showing quadratic reductions from this salinity level. When the plants were fertilized with P_2O_5 doses of 80, 100, and 120%, there were linear decreases in RWC of 7.05, 7.81, and 8.83% per unit increase in ECw. When comparing the RWC of plants fertilized with P_2O_5 doses of 80, 100, and 120% and irrigated with water of 4.3 dS m^{-1} to that of plants subjected to water salinity of 0.3 dS m^{-1}, reductions of 28.82, 32.02, and 36.28% were observed, respectively.

The decrease in the relative water content in the leaf tissues results from the restriction in water absorption by plants due to the excess of salts in the soil solution, which induces osmotic stress. In addition, stomatal closure mediated by abscisic acid affects the transpiration rate and, therefore, results in lower water absorption by the roots, leading to low relative water content in the plant (Polash et al., 2018).

The leaf water potential of mini watermelon plants decreased significantly with increasing water salinity (Figure 1B). Plants subjected to fertilization with 60, 80, 100, and 120% of P_2O_5 showed linear reductions in their Ψ_w as the ECw levels increased, equal to -0.841, -0.485, -0.594, and -0.460 MPa between those irrigated with ECw of 0.3 and those under 4.3 dS m^{-1}. It is worth pointing out that the greatest reduction in Ψ_w was obtained in plants subjected to the lowest dose of P_2O_5. On the other hand, when the highest dose of P_2O_2 was used (120% of the recommendation), the plants showed a lower reduction in leaf water potential. The reduction in leaf water potential results from the restrictions imposed by the high concentrations of salts in the water, which produce a net accumulation of solutes in the cells, which reduces the osmotic potential of the cell, necessary to maintain turgor pressure (Qin et al., 2010).

Table 2. Summary of the analysis of variance regarding the relative water content (RWC), water potential (Ψ_w), electrolyte leakage in the leaf blade (% EL), chlorophyll *a* (Chl *a*), chlorophyll *b* (Chl *b*), and carotenoids (Car) contents of mini watermelon plants cv. Sugar Baby cultivated with saline water and phosphorus doses at 40 days after sowing (DAS).

Source of variation	DF	Mean squares					
		RWC	Ψ_w	% EL	Chl *a*	Chl *b*	*Car*
Salinity levels (SL)	4	876.55**	0.60**	95.90**	12.15**	5.51**	0.46**
Linear regression	1	2970.07**	2.40**	378.35**	47.25**	21.46**	1.67**
Quadratic regression	1	312.80*	0.001ns	4.13ns	0.06ns	0.29ns	0.09ns
Phosphorus doses (PD)	3	56.81ns	0.10*	20.46*	4.19**	0.43ns	0.24*
Linear regression	1	95.54ns	0.10*	0.21ns	0.22ns	0.26ns	0.05ns
Quadratic regression	1	18.21ns	0.14*	23.86*	6.92**	0.68ns	0.35*
Interaction (SL x PD)	12	84.87**	0.05*	35.84**	1.87**	0.26ns	0.33**
Blocks	2	1.88ns	0.004ns	0.86ns	0.78ns	0.59ns	0.06ns
Residual	38	44.53	0.01	3.62	0.36	0.29	0.04
CV(%)		10.20	25.19	12.82	10.18	20.98	14.88

DF - degrees of freedom; CV (%) - coefficient of variation. *significant at 0.05 probability level. **significant at 0.01 probability level. ns not significant.

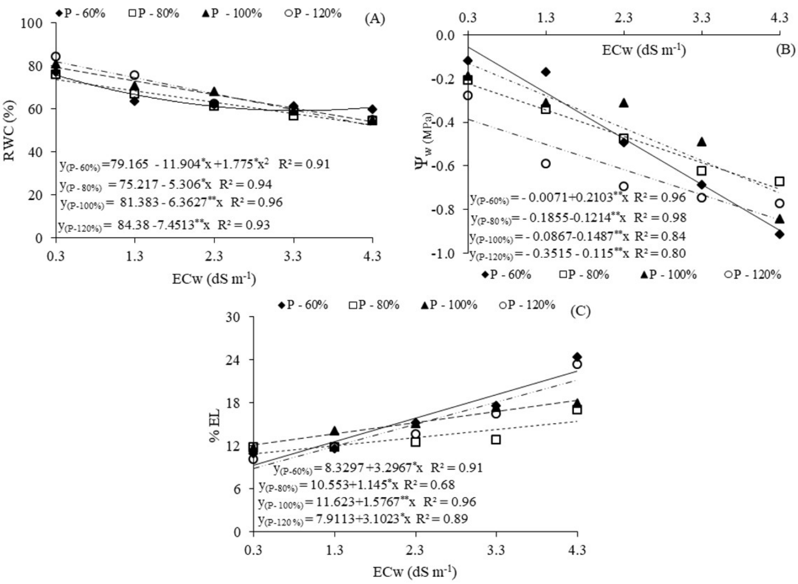

Figure 1. Relative water content - RWC (A), water potential - Ψ_w (B), electrolyte leakage in the leaf blade - % EL (C) of mini watermelon plants cv. Sugar Baby as a function of the interaction between water salinity levels – ECw and phosphorus doses, at 40 days after sowing.

Electrolyte leakage in the leaf blade of mini watermelon plants increased linearly with water salinity (Figure 1C). Plants fertilized with 60, 80, 100, and 120% of P_2O_5 increased their % EL by 39.57, 10.84, 13.56, and 39.21% per unit increase in ECw. When compared to plants subjected to fertilization with 60, 80, 100, and 120% of P_2O_5 and irrigated with ECw of 4.3 dS m^{-1} to those under the lowest salinity level (0.3 dS m^{-1}), increments of 142.22, 42.03, 52.14, and 140% were observed in % EL, respectively.

Electrolyte leakage in the plasma membrane is one of the main criteria for identifying salt stress-tolerant plants, as this is the primary site of ion-specific injury and is always accompanied by the generation of reactive oxygen species (Hniličková et al., 2019). In addition, the increase in electrolyte leakage may indicate efflux of K^+, which is abundant in plant cells (Demidchik et al., 2014). Wanderley et al. (2020), when evaluating the damage to the cell membrane in leaves of yellow passion fruit seedlings irrigated with saline water, also observed that ECw levels caused a linear increase in the percentage of cell damage at 85 days after sowing.

The chlorophyll *a* content of mini watermelon plants decreased linearly as a function of the increase in water salinity, by 12.22, 11.24, 6.24, and 6.27% per unit increase in ECw (Figure 2A). When comparing the Chl *a* content of plants subjected to ECw of 4.3 dS m^{-1} to that of plants under water salinity of 0.3 dS m^{-1}, decreases of 4.10, 3.61, 1.51, and 1.89 mg g^{-1} FM were observed. Contrary to the results observed for % EL (Figure 1C), fertilization with 60% of P_2O_5 resulted in a greater reduction in chlorophyll *a* synthesis. The decrease in chlorophyll *a* content is a phenomenon commonly associated with the adverse effects of salt stress on membrane stability (Saleh, 2012) and can also be attributed to increased degradation and inhibition of the synthesis of this pigment. In addition, the reduction in Chl *a* content may be accompanied by the inactivation of photochemical reactions, especially those mediated by PSII in plants exposed to stress and by the activity of enzymes such as chlorophyllase, hydroxylase, and dioxygenase (Zhao et al., 2019).

The carotenoid content of mini watermelon plants fertilized with 60, 80, 100, and 120% of P_2O_5 decreased with the increase in irrigation water salinity (Figure 2B), with reductions of 6.70, 12.50, 8.45, and 11.76% per unit increment, respectively. Plants grown under ECw of 4.3 dS m^{-1} reduced their Car content by 0.498, 1.070, 0.545, and 1.004 mg g^{-1} FM compared to those irrigated with water of low electrical conductivity (0.3 dS m^{-1}). In plants grown under salt stress conditions, the synthesis of carotenoids is important due to their action as antioxidant agents, protection of plasma membrane lipids from oxidative stress (Gomes et al., 2017), by dissipation of excess energy through the xanthophyll cycle, and they can act as chloroplast membrane stabilizers, reducing membrane fluidity and susceptibility to lipid peroxidation (Yamamoto, 2016). According to Taibi et al. (2016), the decrease in carotenoid content can also be considered an indication that protection by carotenoids was not one of the most important mechanisms under salt stress.

The chlorophyll *b* content of mini watermelon plants was also significantly reduced with the increase in water electrical conductivity levels (Figure 2C), by 11.86% per unit increase in ECw. Plants subjected to water salinity of 4.3 dS m^{-1} reduced Chl *b* by 49.20% (1.69 mg g^{-1} FM) compared to those irrigated with ECw of 0.3 dS m^{-1}. The decrease in chlorophyll biosynthesis in plants under salt stress is a typical symptom of oxidative stress and can be attributed to the inhibition of chlorophyll synthesis along with the activation of its degradation by the chlorophyllase enzyme (Taibi et al., 2016). Unlike the results obtained in this study, Silva et al. (2021) evaluated the effects of irrigation with saline water (ECw of 0.8 and 4.0 dS m^{-1}) varying the

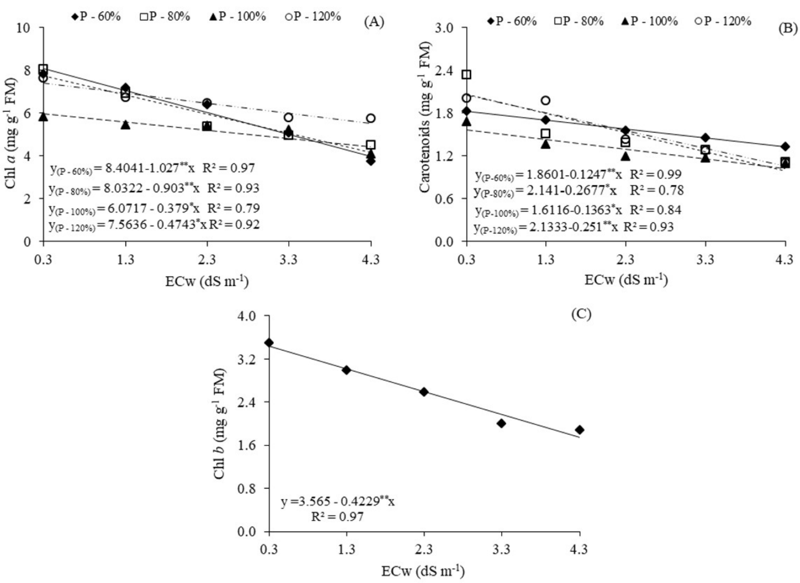

Figure 2. Contents of chlorophyll *a* – Chl *a* (A) and carotenoids (B) of mini watermelon plants cv. Sugar Baby as a function of the interaction between water salinity levels – ECw and phosphorus doses (A and B) and chlorophyll *b* contents as a function of ECw levels (C), at 40 days after sowing.

Table 3. Summary of the analysis of variance for the initial fluorescence (F_0), maximum fluorescence (Fm), variable fluorescence (Fv), and quantum efficiency of photosystem II (PSII) of mini watermelon plants cv. Sugar Baby cultivated with saline waters and phosphorus doses, at 40 days after sowing (DAS).

Source of variation	DF	Mean squares			
		F_0	Fm	Fv	PSII
Salinity levels (SL)	4	28625.64**	460494.00*	276787.72*	0.07**
Linear regression	1	107161.63**	1685544.03**	942704.13**	0.29**
Quadratic regression	1	2229.42ns	103505.35ns	136116.21ns	0.006ns
Phosphorus doses (PD)	3	4732.91ns	68466.24ns	63256.53ns	0.006ns
Linear regression	1	2307.41ns	37096.32ns	57907.41ns	0.007ns
Quadratic regression	1	5226.66ns	12441.60ns	33796.26ns	0.004ns
Interaction (SL x PD)	12	2351.23ns	92977.24ns	78089.93ns	0.008*
Blocks	2	11399.26ns	35349.81ns	72895.55ns	0.006ns
Residual	38	3512.95	61925.57	64813.09	0.004
CV(%)		9.99	10.63	14.57	10.50

DF - degrees of freedom; CV (%) - coefficient of variation. *significant at 0.05 probability level. **significant at 0.01 probability level. ns not significant.

development stages of mini watermelon cv. Sugar Baby, and found that irrigation with water of 4.0 dS m^{-1} did not significantly influence the synthesis of chlorophyll *b*.

There was a significant effect of water salinity levels on the initial fluorescence (F_0), maximum fluorescence (Fm), variable fluorescence (Fv), and quantum efficiency of photosystem II (PSII) (Table 3). The phosphorus doses did not significantly influence any of the variables analyzed, while the interaction between the factors (SL × PD) significantly affected only the quantum efficiency of photosystem II of mini watermelon at 40 days after sowing.

Chlorophyll *a* fluorescence decreased linearly with the increase in water salinity levels. According to the regression equation (Figure 3), the initial, maximum, and variable fluorescence decreased by 4.51, 4.53, and 4.54% per unit increase in ECw, respectively, that is, plants subjected to the highest level of water salinity (4.3 dS m^{-1}) reduced their F_0, Fv, and Fm by 18.30, 18.39, and 18.42%, respectively, compared to those cultivated with the lowest ECw level (0.3 dS m^{-1}). Reduction of F_0 occurs as a response to the decrease in the capacity for transferring excitation energy from the light-harvesting

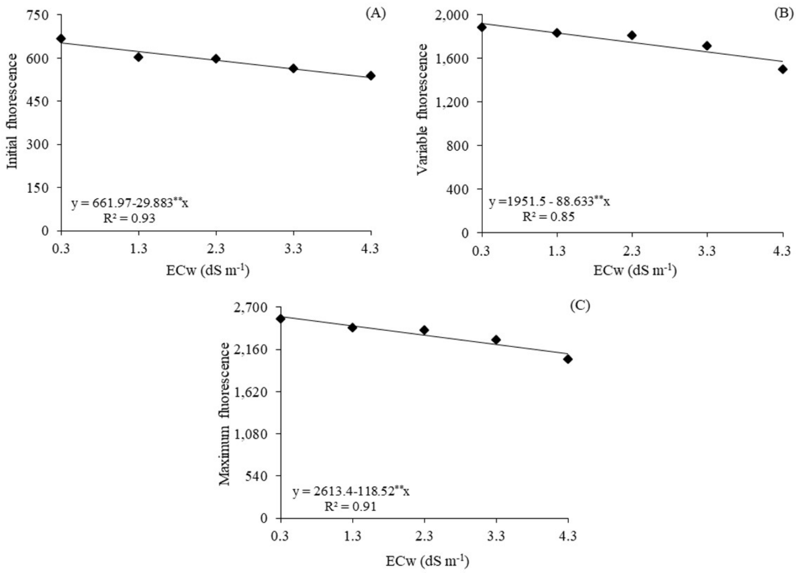

Figure 3. Initial (A), variable (B), and maximum (C) fluorescence of mini watermelon plants cv. Sugar Baby as a function of water salinity levels – ECw and phosphorus doses, at 40 days after sowing.

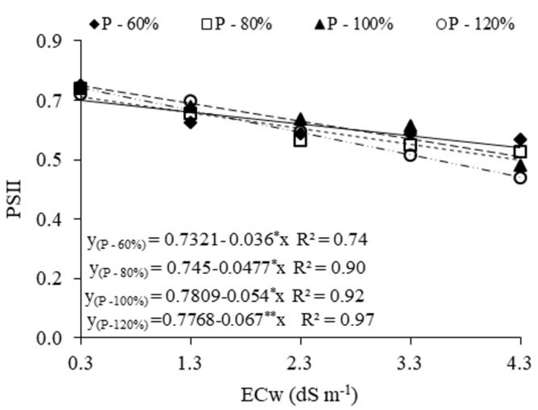

Figure 4. Quantum efficiency of photosystem II - PSII (B) of mini watermelon plants cv. Sugar Baby as a function of the interaction between water salinity levels - ECw and phosphorus doses, at 40 days after sowing.

system to the reaction center, possibly resulting from the decrease in leaf water potential (Azevedo Neto et al., 2011; Lima et al., 2019), caused by the high salt concentrations in the water used for irrigation.

For Oliveira et al. (2018), the decrease of Fm indicates a possible slowdown in photosynthetic activity aimed at minimizing the toxic effects of salinity. These authors also mention that the increase in Fm may indicate an attempt to compensate the photosynthetic process for damage caused by salinity, increasing its activity to obtain greater CO_2 assimilation, and the absence of difference in this variable indicates tolerance of the plant to salinity. According to Melo et al. (2017), reductions in Fv associated with decreases in Fm, as found in this study, suggest a possible decrease in chlorophyll efficiency in response to increased salinity, possibly indicating ionic toxicity.

Regarding the quantum efficiency of photosystem II of mini watermelon plants (Figure 4), there was a linear decrease with the increase in the electrical conductivity of the water at all doses of phosphorus. The regression equations (Figure 4) showed reductions in PSII of 19.96, 26.11, 28.25, and 35.42% in plants fertilized with 60, 80, 100, and 120% of phosphorus, respectively, and irrigated with ECw of 4.3 dS m^{-1}, compared to those under water salinity of 0.3 dS m^{-1}. Photosystem II is considered a sensitive indicator of the photosynthetic performance of the plant, besides being sensitive to salt stress, and its decrease indicates damage to the photosynthetic apparatus (Oliveira et al., 2018), in the case of this study caused by the high ECw, thus constituting an efficient indicator in the selection of salinity-tolerant genotypes.

4. Conclusions

The relative water content in the leaf tissues decreases with the increase in the levels of electrical conductivity of the water at all doses of phosphorus, with decreases of 7.05, 7.81 and 8.83% per unit increase in ECw, in the plants fertilized with 80, 100 and 120% of P_2O_5. On the other hand, ECw levels increased electrolyte leakage, regardless of phosphorus doses.

The synthesis of photosynthetic pigments and the quantum efficiency of photosystem II is inhibited by increasing water salinity from 0.3 dS m^{-1} in plants grown under phosphorus doses above 60% of the recommendation.

Water salinity from 0.3 dS m^{-1} reduces chlorophyll *b* contents, initial, maximum, and variable fluorescence of mini watermelon plants, with a decrease of 11.86, 4.51, 4.53, and 4.54% per unit increment of ECw, respectively.

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