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

ISSN 0100-316X (impresso)
ISSN 1983-2125 (online)
http://dx.doi.org/10.1590/1983-21252021v34n318rc

QUANTUM YIELD, PHOTOSYNTHETIC PIGMENTS AND BIOMASS OF MINI-WATERMELON UNDER IRRIGATION STRATEGIES AND POTASSIUM[1]

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ABSTRACT – This study was conducted with the objective of evaluating the quantum yield, photosynthetic pigments and biomass accumulation of mini watermelon cv. Sugar Baby, under strategies of irrigation with saline water and potassium fertilization. The experiment was conducted in a randomized block design, in a 8 × 3 factorial scheme, with three replicates, corresponding to eight strategies of irrigation with saline water applied at different phenological stages of the crop (control - irrigation with low-salinity water throughout the crop cycle, and salt stress in the vegetative, vegetative/flowering, flowering, flowering/fruiting, fruiting, fruiting/ fruit maturation and fruit maturation stage) and three potassium doses (50, 100 and 150% of the recommendation). The dose of 100% corresponded to 150 mg of K_2O kg^{-1} of soil. Two levels of electrical conductivity of water were used: 0.8 and 4.0 dS m^{-1}. Irrigation with water of 4.0 dS m^{-1} continuously in the vegetative and flowering stages increased the initial fluorescence and decreased the quantum efficiency of photosystem II of mini watermelon fertilized with 100 and 150% of K recommendation. Fertilization with 50% recommendation did not interfere in the fluorescence parameters of the mini watermelon, regardless of the irrigation management strategy. Chlorophyll *a* synthesis is inhibited by salt stress in the vegetative/flowering, flowering, flowering/fruiting, fruiting/maturation stages, as well as for total chlorophyll, except for the flowering stage. Application of 4.0 dS m^{-1} water in the flowering, fruiting/maturation and maturation stages promoted greater biomass accumulation in mini watermelon.

Keywords: *Citrullus lanatus*. Salt stress. Potassium.

RENDIMENTO QUÂNTICO, PIGMENTOS FOTOSSINTÉTICOS E FITOMASSAS DE MINI-MELANCIA SOB ESTRATÉGIAS DE IRRIGAÇÃO E POTÁSSIO

RESUMO – Desenvolveu-se este trabalho com o objetivo de avaliar o rendimento quântico, os pigmentos fotossintéticos e o acúmulo de fitomassas da mini-melancia cv. Sugar Baby, sob estratégias de irrigação com águas salinas e adubação potássica. O experimento foi conduzido em delineamento de blocos casualizados, em esquema fatorial 8 × 3, com três repetições, sendo oito estratégias de irrigação com águas salinas aplicadas em diferentes estádios fenológicos da cultura (controle - irrigação com água de baixa salinidade durante todo o ciclo da cultura, e estresse salino na fase vegetativa, vegetativa/floração, floração, floração/frutificação, frutificação, frutificação/maturação e maturação dos frutos) e três doses de potássio (50, 100 e 150% da recomendação). A dose de 100% correspondeu a 150 mg de K_2O kg^{-1} de solo. Foram utilizados dois níveis de condutividade elétrica da água: 0,8 e 4,0 dS m^{-1}. A irrigação com água de 4,0 dS m^{-1} de forma contínua nas fases vegetativa e de floração aumentou a fluorescência inicial e diminuiu a eficiência quântica do fotossistema II da mini-melancia adubada com 100 e 150% de recomendação do K. A adubação com 50% de recomendação não interferiu nos parâmetros de fluorescência da mini-melancia, independente da estratégia de manejo de irrigação. A síntese de clorofila *a* é inibida pelo estresse salino nas fases vegetativa/floração, floração, floração/ frutificação, frutificação/maturação, assim como para a clorofila *total*, com exceção da fase de floração. A aplicação de água de 4,0 dS m^{-1} nas fases de floração, frutificação/maturação e maturação promoveu maior acúmulo de fitomassas na mini-melancia.

Palavras-chave: *Citrullus lanatus*. Estresse salino. Potássio.

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[1]Received for publication in 07/06/2020; accepted in 04/29/2021.
Paper extracted from the Thesis of the first author
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INTRODUCTION

In the last decade, salinity has stood out as one of the main limitations for agricultural cultivation worldwide, being one of the abiotic stresses that restrict plant growth and production. The accumulation of salts result in osmotic and ionic effects such as toxicity and nutritional imbalance in plants, in addition to altering the physical and chemical properties of the soil (PARIHAR et al., 2015; PEDROTTI et al., 2015), especially in semi-arid regions.

The semi-arid region is characterized by high evapotranspiration and low precipitation; due to these factors, the availability of water for irrigation is reduced in both quantity and quality. With the lack of sources of water with low electrical conductivity, it becomes essential to use waters with high salt concentration to meet the water demand of irrigated agriculture (SILVA et al., 2014). Excess salts in water can cause deleterious effects on gas exchange, synthesis of photosynthetic pigments, and chlorophyll fluorescence (NUNES et al., 2017; SÁ et al., 2018; LIMA et al., 2020a).

In general, the damage caused by salt stress results from the osmotic and ionic effects, restricting the absorption of water and nutrients and inducing toxicity by toxic ions, mainly Na^+ and Cl^-, which leads to changes in the physiological and metabolic processes of plants (DIAS et al., 2019). Excess of salts also causes oxidative stress in plants, due to the imbalance between the production of reactive oxygen species and their detoxification by enzymatic and non-enzymatic reactions, consequently resulting in photooxidative damage to DNA, lipid membrane peroxidation, protein denaturation and, finally, cell death (MOHAMED et al., 2020).

Several studies have shown that watermelon is sensitive to salinity (COSTA et al., 2013; SOUSA et al., 2016; SILVA et al., 2020; LIMA et al., 2020a). According to Ayers and Westcot (1999), the threshold level of salinity in irrigation water for watermelon is 3.0 dS m^{-1}. However, salinity tolerance may vary depending on genotype, intensity and duration of stress, crop and irrigation management practices, edaphoclimatic conditions and plant development stages. Thus, irrigation with saline water in the stages of highest tolerance stands out as a strategy to attenuate the effects of salt stress on sensitive plants (SOARES et al., 2018; LIMA et al., 2020b). However, studies addressing the effects of salinity during the phenological stages of mini watermelon are incipient in the literature.

Another aspect that should be considered is potassium fertilization as an alternative capable of reducing the damage caused by salt stress (PRAZERES et al., 2015), due to the importance of this nutrient in several physiological processes, such as photosynthesis, osmotic regulation, electrochemical balance, transport of solutes in xylem and phloem (SHABALA; POTTOSIN, 2014). Potassium application results in accumulation of osmolytes and increase in antioxidant components in plants exposed to salt stress (AHANGER et al., 2017).

Thus, the objective of this study was to evaluate the effects of saline water irrigation management strategies and potassium fertilization on the quantum yield, photosynthetic pigments and biomass accumulation of mini watermelon cv. Sugar Baby in different phenological stages.

MATERIAL AND METHODS

The experiment was carried out from October to December 2017, under greenhouse conditions, at the Federal University of Campina Grande, in Campina Grande -PB, Brazil (7º15’18'S, 35º52’18'W and average altitude of 550 m). Data on temperature and relative air humidity (Figure 1) were collected daily using a thermo-hygrometer.

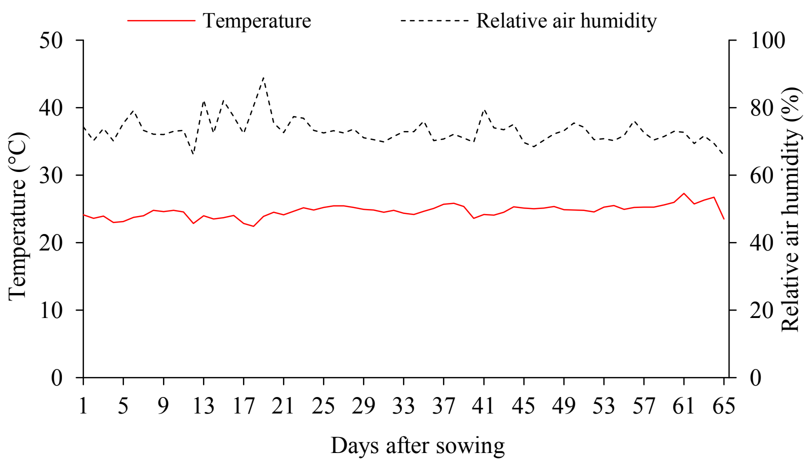


Figure 1. Mean temperature and relative air humidity observed during the experiment inside the greenhouse.

The experimental design was randomized in a 8 × 3 factorial scheme, with three replicates, corresponding to eight saline water irrigation management strategies - IMS (SE - without stress throughout the crop cycle; VE, VE/FL, FR, FR/MAT, MAT, respectively, salt stress in the vegetative, vegetative and flowering, flowering, flowering and fruiting, fruiting, fruiting and fruit maturation, and maturation stages) associated with three potassium doses - KD (50, 100 and 150% of the recommendation). The dose of 100% corresponds to 100 mg of K_2O kg^{-1} of soil (NOVAIS, NEVES, BARROS, 1991). Potassium chloride was used as a source of potassium, supplied via fertigation in three equal applications, at 23, 37 and 46 days after sowing (DAS).

The saline water irrigation management strategies (IMS) consisted of two levels of electrical conductivity (ECw), one of low salinity (ECw = 0.8 dS m^{-1}) and the other of high salinity (ECw = 4.0 dS m^{-1}), varying according to the phenological stages of the plants: vegetative - period from the emergence of the second true leaf to the appearance of the first female flower (14-34 DAS); flowering – from the first female flower to fertilization (35-43 DAS); fruiting - from fertilization to fruit filling (44-58 DAS) and maturation – from fruit filling to harvest (59-65 DAS).

Water salinity of 0.8 dS m^{-1} (control) and 4.0 dS m^{-1} are the levels commonly observed in the semi-arid region of Northeastern Brazil. Thus, the electrical conductivity of 4.0 dS m^{-1} is a value higher than the water salinity threshold level (3.0 dS m^{-1}) for watermelon and aimed to induce osmotic and/or ionic stress in plants to identify the stage(s) of greatest tolerance and/or sensitivity to salt stress.

The crop used was mini watermelon cv. Sugar Baby, which stands out for its short cycle. It is a rustic plant, with vigorous foliage and tolerant to high temperatures. It has round fruits, with dark green rind, weighing from 2 to 4 kg. It has a soft pulp with high sugar content and intense red color (SILVA et al., 2008).

The plants were grown in plastic containers adapted as drainage lysimeters with 20 L capacity. A 3 cm layer of crushed stone and a geotextile were placed at the base to prevent clogging of the drainage system. To facilitate drainage, a transparent 4 mm diameter tube was connected to the base and to a plastic container for collecting drained water. Then, the containers received 24 kg of an Neosol (*Entisol*) of sandy loam texture, collected at 0-30 cm depth, from the municipality of Lagoa Seca, PB, whose physico-chemical attributes were determined according to Teixeira et al. (2017): Ca^{2+} = 2.60 $cmol_c$ kg^{-1} ; Mg^{2+} = 3.66 $cmol_c$ kg^{-1} ; Na^+ = 0.16 $cmol_c$ kg^{-1} ; K^+ = 0.22 $cmol_c$ kg^{-1} ; H^+ +Al^{3+} = 1.93 $cmol_c$ kg^{-1} ; CEC = 8.57 $cmol_c$ kg^{-1}; organic matter = 1.36 dag kg^{-1} ; P = 6.8 mg kg^{-1}; pH in water (1:2.5) = 5.90; electrical conductivity of soil saturation extract = 0.19 dS m^{-1} ; sand = 732.9 g kg^{-1} ; silt = 142.1 g kg^{-1} ; clay = 125 g kg^{-1} ; moisture at 33.42 kPa = 11.98 dag kg^{-1}; moisture at 1519.5 kPa = 4.32 dag kg^{-1}.

Phosphorus and nitrogen fertilization was performed according to the recommendation of Novais, Neves and Barros (1991), applying 300 and 100 mg kg^{-1} of soil of P_2O_5 and N, respectively, in the form of single superphosphate (crushed to facilitate its application) and calcium nitrate. The recommended amounts of P_2O_5 and N were applied as top-dressing, divided into three equal portions and applied at 15, 32 and 42 DAS for P, while N was applied at 19, 35 and 44 DAS. Micronutrient applications were performed at 27, 34, and 46 DAS using Ubyfol® solution (Mg^{2+} = 1.1%; Boron = 0.85%; Copper (Cu-EDTA) = 0.5%; Iron (Fe-EDTA) = 3.4%; Manganese (Mn-EDTA) = 3.2%; Molybdenum = 0.05%; Zinc = 4.2%; EDTA chelating agent = 70%) at a concentration of 1.5 g L^{-1}.

The water used in the irrigation with the lowest salinity level (0.8 dS m^{-1}) was obtained by diluting the water from the public supply system of Campina Grande (ECw = 1.21 dS m^{-1}), with rain water (ECw = 0.02 dS m^{-1}); the level corresponding to ECw of 4.0 dS m^{-1} was prepared by adding salts in the form of chloride, in order to obtain an equivalent ratio of 7:2:1, of Na:Ca:Mg, respectively, which prevails in sources of water used for irrigation in small properties in Northeastern Brazil (MEDEIROS, 1992). The highest level of irrigation water salinity was prepared considering the relationship between ECw and salt concentration, according to Richards (1954), as shown in Equation 1:

$$Q\ (mmol_c\ L^{-1}) = 10 \times ECw\ (dS\ m^{-1}) \qquad (1)$$

Where:

Q = Quantity of salts to be added ($mmol_c$ L^{-1});

ECw = Electrical conductivity of water (dS m^{-1}).

Sowing was performed with four seeds per lysimeter, planted at 3 cm depth and distributed equidistantly. Prior to sowing, the soil moisture content was increased to the level corresponding to field capacity, using low-salinity water (0.8 dS m^{-1}). After sowing, irrigation was carried out daily, at 17:00 h, applying in each container the volume corresponding to that obtained by the water balance, being the volume of water to be applied to the plants was determined by Equation 2:

$$VI = \frac{(Va - Vd)}{(1 - FL)} \quad (2)$$

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

At 14 DAS, the water with higher salinity level began to be applied, according to the treatments established.

The plants were vertically trained, leaving the main branch and three lateral branches per plant. Pollination was carried out manually, using a flexible wire, by collecting pollen and transporting it to stigma, between 06h00min and 07h00min. After fertilizing the flowers, thinning was performed, leaving only one fruit per plant.

Chlorophyll *a* fluorescence and photosynthetic pigments were determined in the fruiting stage (55 DAS). To evaluate chlorophyll *a* fluorescence, a pulse-modulated fluorometer (Opti Science model OS5p) was used to determine the fluorescence induction variables: initial fluorescence (F_0), maximum fluorescence (Fm), variable fluorescence (Fv = Fm – F_0) and quantum efficiency of photosystem II (Fv/Fm); this protocol was performed after adaptation of leaves in the dark for 30 minutes, using clips of the device, to ensure that all the first acceptors were oxidized, i.e. ensuring that the reaction centers are open.

For determining the contents of photosynthetic pigments, extraction was carried out in containers with 8 mL of 80% acetone and five leaf discs with area of 2.8 cm^2. Due to the great oxidation that watermelon leaves undergo, the leaf discs were kept in the dark under refrigeration conditions for 48 hours.

The readings of chlorophyll *a* (*Chl a*), chlorophyll *b* (*Chl b*) and carotenoids (Car) contents were performed by spectrophotometry at wavelengths of 470, 645 and 663 nm, respectively, through Equations 3, 4, 5, and total chlorophyll by Equation 6, according to the methodology proposed by Arnon (1949), in which A is absorbance.

$$\text{Chlorophyll } a \text{ (Chl } a) = 12.21\, A_{663} - 2.81\, A_{645} \quad (3)$$

$$\text{Chlorophyll } b \text{ (Chl } b) = 20.13\, A_{645} - 5.03\, A_{663} \quad (4)$$

$$\text{Carotenoids (Car)} = (1000\, A_{470} - 1.82\, \text{Chl } a - 85.02\, \text{Chl } b)/198 \quad (5)$$

$$\text{Total chlorophyll (Chl } T) = 17.3\, A_{645} + 7.18\, A_{663} \quad (6)$$

Pigment contents were expressed in mg g^{-1} of fresh matter (FM). To determine the dry biomass of stem (SDB), leaves (LDB) and roots (RDB) of the plants of each treatment, the shoots (stem and leaves) and roots were cut at 65 DAS and placed in paper bags, then taken to an oven at 65 °C, where they remained for 72 h. After drying, the material was weighed on a precision scale and the weights of each part (g) were recorded. Total dry biomass (TDB) was obtained by summing stem dry biomass, leaf dry biomass and root dry biomass.

The obtained data were evaluated by analysis of variance by the F test. In cases of significance, the Scott-Knott means comparison test (p≤0.05) was performed for salinity management strategies, while the Tukey test (p≤0.05) was performed for potassium doses using Sisvar software (FERREIRA, 2014).

RESULTS AND DISCUSSION

There was a significant effect of saline water irrigation management strategies on initial fluorescence (F_0) and maximum fluorescence (Fm) (Table 1). Potassium doses significantly influenced F_0, variable fluorescence (Fv) and quantum efficiency of photosystem II (Fv/Fm). There were significant effects of the interaction between the factors (IMS × KD) on F_0, Fm, Fv and Fv/Fm of the mini watermelon cv. Sugar Baby, 55 days after sowing. Unlike this study, Silva et al. (2020) evaluated the photochemical efficiency of mini watermelon cv. Sugar Baby under different strategies of use with saline water and nitrogen fertilization and verified that only the initial fluorescence was significantly affected by nitrogen doses.

Table 1. Summary of the analysis of variance for initial fluorescence (F_0), maximum fluorescence (Fm), variable fluorescence (Fv) and quantum efficiency of photosystem II (Fv/Fm) of mini watermelon cv. Sugar Baby cultivated under saline water irrigation management strategies (IMS) and potassium doses (KD) at 55 days after sowing (DAS).

Sources of variation	DF	Mean squares			
		F_0	Fm	Fv	Fv/Fm
Irrigation management strategies (IMS)	7	1239.64^{*}	6587.10^{*}	3786.57^{ns}	0.002^{ns}
Potassium doses (KD)	2	1540.12^{*}	2282.71^{ns}	7810.90^{*}	0.013^{**}
Interaction (IMS × KD)	14	1033.55^{*}	7723.64^{**}	5866.01^{**}	0.003^{**}
Blocks	2	2948.16^{**}	90835.51^{**}	60100.04^{**}	0.004^{ns}
Residual	46	432.66	2540.18	2036.43	0.001
Mean		123.00	443.68	320.16	0.718
CV (%)		16.91	11.36	14.09	5.31

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

According to the means comparison test (Table 2), fertilization with 50% K_2O did not significantly interfere in the initial fluorescence, regardless of the irrigation strategy adopted. In plants fertilized with 100% K recommendation, the highest F_0 was obtained when water with ECw of 4.0 dS m^{-1} was used in the VE/FL, FL, FR and FR/MAT stages. On the other hand, F_0 was statistically higher in plants grown with 150% of the K recommendation and under the VE/FL and MAT strategies, compared to those of the other treatments.

The increase of F_0 in mini watermelon plants is indicative of damage to the PSII reaction center and reflects the oxidation capacity of quinone, which is the primary electron receptor at the PSII reaction center. Increase in this parameter indicates the destruction of PSII reaction centers or reduction in the capacity for excitation energy transfer from the antenna to the PSII, caused by salt stress (LUCENA et al., 2012; SÁ et al., 2015).

Table 2. Analysis of the interaction between saline water irrigation management strategies (IMS) and potassium doses (KD) for initial fluorescence - F_0 and maximum fluorescence - Fm of mini watermelon cv. Sugar Baby, at 55 days after sowing.

IMS	F_0			Fm		
	KD 50%	KD 100%	KD 150%	KD 50%	KD 100%	KD 150%
1	128.50 aA	105.50 bA	122.50 bA	477.00 aA	474.50 aA	488.00 aA
2	103.00 aA	111.00 bA	105.50 bA	467.00 aA	381.600 bA	395.00 bA
3	113.50 aB	157.00 aA	156.50 aA	517.00 aA	444.00 aA	464.50 aA
4	113.50 aA	133.50 aA	121.50 bA	432.00 aA	439.50 aA	468.00 aA
5	112.50 aA	110.50 bA	120.50 bA	429.00 aA	432.50 aA	381.00 bA
6	109.00 aA	135.00 aA	116.00 bA	414.00 aAB	476.00 aA	350.50 bB
7	127.00 aAB	167.50 aA	118.00 bB	446.00 aA	461.50 aA	452.00 aA
8	102.00 aB	101.00 bB	160.50 aA	441.50 aB	359.00 bB	558.00 aA

Identical letters, lowercase in the column and uppercase in the row, indicate no significant difference between saline water irrigation management strategies (Scott-Knott, $p<0.05$) and potassium doses (Tukey, $p<0.05$), respectively. IMS 1 SE - without stress throughout the crop cycle; IMS 2, 3, 4, 5, 6, 7 and 8 correspond to salt stress in the vegetative - VE; vegetative/flowering - VE/FL; flowering - FL; flowering/fruiting - FL/FR; fruiting - FR; fruiting/maturation - FR/MA and fruit maturation - MAT stages.

In the analysis of K_2O doses considering each saline water irrigation management strategy (Table 2), significant differences were observed in plants grown under high water salinity (4.0 dS m^{-1}) in the stages VE/FL, FR/MAT and MAT. When mini watermelon plants received saline water in the VE/FL stages, the highest F_0 was obtained with potassium doses of 100 and 150% of the recommendation. In plants irrigated with ECw of 4.0 dS m^{-1} in the FR/MAT stages, the highest F_0 value was verified under fertilization with 50 and 100% recommendation, whereas in plants subjected to salt stress in the MAT stage, the highest initial fluorescence was obtained under fertilization with 150%.

The increase of F_0 in these plants may be associated with the salt stress to which they were subjected. Excess of salts can cause damage to photosystem II and, according to Baker and Rosenqvist (2004), salt stress can cause not only these types of damage, but also reduction of quinone by NADPH, available in chloroplasts. In addition, the association with increased potassium fertilization may have further intensified salt stress (DIAS et al., 2018). This fact can be justified by the use of KCl as a source of K, because this fertilizer has a high salt index and, when associated with high electrical conductivity of water, can induce osmotic stress and cause reduction in the availability of water and nutrients to plants (DIAS et al., 2019).

The maximum fluorescence (Table 2) of mini watermelon plants fertilized with 50% of the K recommendation was not significantly influenced, regardless of the irrigation strategy applied. Plants fertilized with 100% recommendation and subjected to salt stress in the VE and MAT stages obtained statistically lower Fm compared to the other irrigation strategies (SE, VE/FL, FL, FL/FR, FR, FR/MAT and MAT). The decrease in maximum fluorescence may be related to the photoinhibition of quinone, associating them with inactivation of PSII in the thylakoid membranes, compromising the flow of electrons between the photosystems (SILVA et al., 2006). On the other hand, plants fertilized with 150% K recommendation and cultivated under the strategies SE, VE/FL, FL, FR/MAT and MAT stood out with higher maximum fluorescence. Maximum fluorescence indicates the maximum intensity of the fluorescence emitted, when virtually all the quinone is reduced and the reaction centers reach their maximum capacity of photochemical reactions, a process that requires electrons from water (SILVA et al., 2015).

Analysis of K doses considering each irrigation management strategy (Table 2) point to significant differences in the Fm of plants grown under the FR and MAT strategies. Plants fertilized with 100% K recommendation and irrigated with ECw of 4.0 dS m^{-1} in the FR stage stood out with higher Fm compared to those that received 150% of the K recommendation. According to Silva et al. (2006), salt stress can affect the flow of electrons between the photosystems, which compromises the maximum fluorescence. Flowers and Flowers (2005) add that this reduction may indicate a slowdown in the photosynthetic activity of these plants, aiming to minimize the toxic effects of salinity.

On the other hand, plants grown under 150% K recommendation and irrigation with water of higher salinity level in the MAT stage had statistically higher Fm compared to those fertilized with 50 and 100% (Table 2). This increase may be related to the fact that potassium is a relevant nutrient for the physiological processes of plants, since it is involved in vital processes such as photosynthesis, osmotic regulation, electrochemical balance, and transport of solutes in xylem and phloem (SHABALA; POTTOSIN, 2014).

For the variable fluorescence of mini watermelon (Table 3), there was a significant difference only when plants were fertilized with 150% of the K recommendation, with the highest values obtained in the strategies SE, FL, FR/MAT and MAT. The Fv of plants grown under the strategies VE, VE/FL, FL/FR and FR did not differ significantly from each other. Backer (2008) states that the reduction of Fv results in the loss of the capacity of plants to transfer the energy of the electrons ejected from the pigment molecules to the formation of the reducing agent NADPH, ATP and Fdr, consequently leading to a lower capacity of CO_2 assimilation in the biochemical phase of photosynthesis.

Table 3. Analysis of the interaction between the factors saline water irrigation management strategies (IMS) and potassium doses (KD) for variable fluorescence - Fv and quantum efficiency of photosystem II - Fv/Fm of mini watermelon cv. Sugar Baby, at 55 days after sowing.

IMS	Fv			Fv/Fm		
	KD 50%	KD 100%	KD 150%	KD 50%	KD 100%	KD 150%
1	358.50 aA	369.00 aA	343.00 aA	0.75 aA	0.77 aA	0.70 aA
2	364.00 aA	270.00 aB	289.50 bAB	0.77 aA	0.71 aA	0.72 aA
3	403.00 aA	287.00 aB	308.00 bB	0.78 aA	0.66 bB	0.66 aB
4	318.50 aA	306.00 aA	346.50 aA	0.72 aA	0.69 aA	0.74 aA
5	316.50 aA	322.00 aA	260.50 bA	0.74 aA	0.73 aA	0.68 aA
6	305.00 aAB	341.00 aA	234.50 bB	0.72 aA	0.71 aA	0.67 aA
7	319.00 aA	294.00 aA	334.00 aA	0.70 aAB	0.65 bB	0.73 aA
8	339.00 aAB	258.00 aB	397.50 aA	0.75 aA	0.72 aA	0.71 aA

Identical letters, lowercase in the column and uppercase in the row, indicate no significant difference between saline water irrigation management strategies (Scott-Knott, $p<0.05$) and potassium doses (Tukey, $p<0.05$), respectively. IMS 1 SE - without stress throughout the crop cycle; IMS 2, 3, 4, 5, 6, 7 and 8 correspond to salt stress in the vegetative - VE; vegetative/flowering - VE/FL; flowering - FL; flowering/fruiting - FL/FR; fruiting - FR; fruiting/maturation - FR/MA and fruit maturation - MAT stages.

Regarding the analysis of K recommendation doses considering each saline water irrigation management strategy (Table 2), it was verified that fertilization with 100 and 150% K recommendation resulted in a decrease in Fv when plants were subjected to the strategies VE and VE/FL. When plants were fertilized with 150% K recommendation and irrigated with water of 4.0 dS m^{-1} in the FR stage, the Fv was statistically lower than the values found in plants that received 50 and 100% of the K recommendation. On the other hand, for plants grown under high water salinity in the MAT stage, the highest Fv was obtained under fertilization with 50 and 150% K recommendation. However, there were no significant differences between plants fertilized with 50 and 100% K recommendation and irrigated with ECw of 4.0 dS m^{-1} in the MAT stage. Possibly, the increase in potassium fertilization intensified the salt stress imposed by irrigation water salinity (4.0 dS m^{-1}), which may have resulted in damage to Fv, as previously reported by Dias et al. (2019).

The quantum efficiency of photosystem II (Fv/Fm) of mini watermelon plants fertilized with 50 and 150% K recommendation was not significantly influenced in relation to the saline water irrigation management strategies (Table 3). Plants grown under fertilization with 100% of the K recommendation and irrigated with high-salinity water in the VE/FL and FR/MAT stages obtained the lowest values of Fv/Fm compared to those under the other strategies (SE, VE, FL, FL/FR, FR and MAT). Reduction in quantum efficiency of photosystem II indicates changes in the photosynthetic system caused by environmental and biotic stress factors (BAKER; ROSENQVIST, 2004). The decrease observed in Fv/Fm is a consequence of the excessive accumulation of salts from irrigation water, restricting water absorption due to osmotic effects and its interference in physiological processes.

Analysis of K doses considering each saline water irrigation management strategy (Table 3) showed that there is a significant difference in the quantum efficiency of photosystem II of mini watermelon plants under the VE/FL and FR/MAT strategies. In plants irrigated using water with ECw of 4.0 dS m^{-1} in the VE/FL stages, the lowest values of quantum efficiency of photosystem II were obtained under fertilization with doses of 100 and 150% K recommendation. On the other hand, when high-salinity water was used in the FR/MAT stages, the lowest Fv/Fm was observed at the dose of 100% K recommendation.

The decrease in the quantum efficiency of photosystem II in plants subjected to salt stress in the VE/FL and FR/MAT stages may be related to the disorders in the photosynthetic apparatus and its reduction consists in the limitation of photochemical activity. According to Silva et al. (2015), Fv/Fm values between 0.75 and 0.85 indicate that the photosynthetic apparatus is intact. However, in the present study the values are lower, possibly due to the low efficiency in the absorption of light energy by the PSII antenna complex and its conversion into chemical energy.

There were significant effects of saline water irrigation management strategies on *Chl a* and *Chl T* (Table 4). Potassium doses and the interaction between factors (IMS × KD) did not significantly influence the photosynthetic pigments of mini watermelon cv. Sugar Baby, at 55 days after sowing. When analyzing the photosynthetic pigments of mini watermelon, Silva et al. (2020) observed significant differences caused by irrigation management strategies only for chlorophyll *b* and total chlorophyll, at 65 days after sowing.

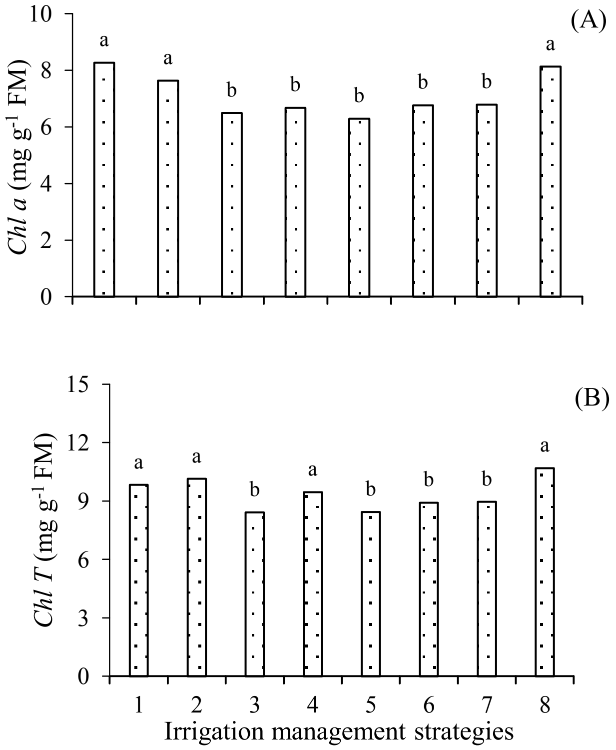
Table 4. Summary of the analysis of variance for the contents of chlorophyll *a* (*Chl a* - mg g^{-1} FM), chlorophyll *b* (*Chl b* - mg g^{-1} FM), total chlorophyll (*Chl T* - mg g^{-1} FM) and total carotenoids (*Car* - mg g^{-1} FM) of mini watermelon cv. Sugar Baby cultivated under saline water irrigation management strategies (IMS) and potassium doses (KD) at 55 days after sowing (DAS).

Sources of variation	DF	Mean squares			
		Chl a	*Chl b*	*Chl T*	*Car*
Irrigation management strategies (IMS)	7	5.30^{**}	1.36^{ns}	6.05^{**}	0.54^{ns}
Potassium doses (KD)	2	0.31^{ns}	0.11^{ns}	0.79^{ns}	0.0004^{ns}
Interaction (IMS × KD)	14	0.88^{ns}	0.68^{ns}	2.22^{ns}	0.19^{ns}
Blocks	2	3.17^{*}	0.44	1.34^{ns}	1.16^{**}
Residual	46	0.81	0.63	1.83	0.21
Mean		7.13	2.22	9.35	2.26
CV (%)		12.70	35.71	14.49	20.43

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

The saline water irrigation management strategies significantly influenced chlorophyll *a* - *Chl a* and total chlorophyll - *Chl T* (Figure 2A and 2B). It was observed that plants grown under the strategies VE/FL, FL, FL/FR, FR and FR/MAT obtained the lowest values of *Chl a* and *Chl T*, except for the FL strategy. The reduction in the synthesis of photosynthetic pigments of these plants results from the stress caused by either the high salinity of water (4.0 dS m^{-1}), which may have stimulated the activity of the chlorophyllase enzyme, which acts on the degradation of photosynthetic pigment molecules, or by photooxidation caused by the oxidative stress. Excess of salts can also induce damage to chloroplasts and, therefore, imbalance and loss of activity of pigmentation proteins (FREIRE et al., 2013).

There was a significant effect of saline water irrigation management strategies for SDB, LDB and TDB of mini watermelon (Table 5). Potassium doses and the interaction between factors (IMS × KD) did not significantly influence the dry biomass of mini watermelon cv. Sugar Baby, at 65 days after sowing.



Means with different letters indicate that the treatments differ from each other by the Scott-Knott test, p<0.05. 1 SE - without stress throughout the crop cycle; 2, 3, 4, 5, 6, 7 and 8 correspond to salt stress in the vegetative - VE; vegetative/flowering - VE/FL; flowering - FL; flowering/fruiting - FL/FR; fruiting - FR; fruiting/maturation - FR/MA and fruit maturation - MAT stages.

Figure 2. Chlorophyll *a* - *Chl a* (A) and total chlorophyll - *Chl T* (B) contents of mini watermelon cv. Sugar Baby, as a function of saline water irrigation management strategies, at 55 days after sowing.

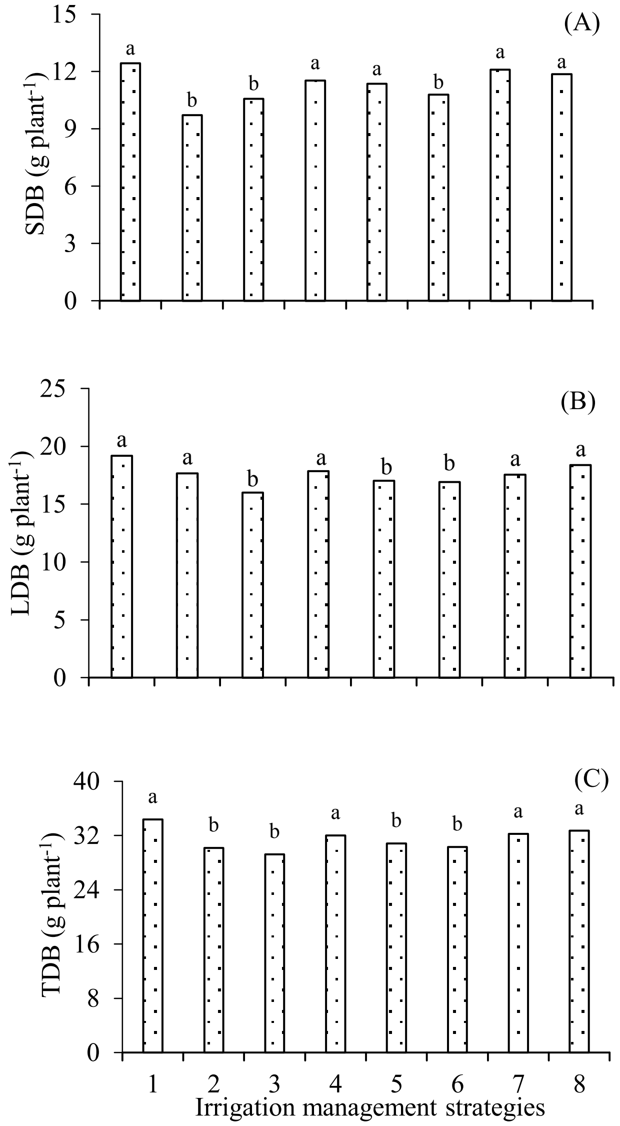
Table 5. Summary of the analysis of variance for root dry mass (RDB), stem dry mass (SDB - g plant^{-1}), leaf dry mass (LDB - g plant^{-1}) and total dry mass (TDB - g plant^{-1}) of mini watermelon plants cv. Sugar Baby grown under saline water irrigation management strategies (IMS) and potassium doses (KD) at 65 days after sowing (DAS).

Sources of variation	DF	Mean squares			
		RDB	SDB	LDB	TDB
Irrigation management strategies (IMS)	7	0.12^{ns}	7.16^{*}	8.44^{*}	24.75^{**}
Potassium doses (KD)	2	0.20^{ns}	5.43^{ns}	1.01^{ns}	12.16^{ns}
Interaction (IMS × KD)	14	0.12^{ns}	3.18^{ns}	3.71^{ns}	7.98^{ns}
Blocks	2	0.04^{ns}	2.83^{ns}	0.31^{ns}	5.15^{ns}
Residual	46	0.10	3.04	2.77	6.51
Mean		2.58	11.30	17.57	31.47
CV (%)		12.79	15.43	9.47	8.10

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

The SDB of plants grown under the VE, VE/FL and FR strategies was statistically lower than those subjected to the treatments SE, FL, FL/FR, FR/MAT and MAT (Figure 3A). In relation to LDB (Figure 3B), plants under the strategies VE/FL, FL/FR and FR obtained the lowest biomass accumulation compared to those irrigated under SE, VE, FL, FR/MAT and MAT.

For TDB (Figure 3C), plants grown under the VE, VE/FL, FL/FR and FR strategies obtained the lowest biomass accumulation when compared to the other irrigation management strategies. The reduction of dry biomass may be related to the deleterious effects of salt stress, which reduces the capacity of plants to absorb water and nutrients, immediately causing interference in the processes of CO_2 assimilation, translocation of carbohydrates to sink tissues and diversion of energy sources to other processes, such as osmotic adjustment, synthesis of compatible solutes, repair of damage caused by salinity and maintenance of basic metabolic processes (LIMA et al., 2020c).



Means with different letters indicate that the treatments differ from each other by the Scott-Knott test, p<0.05. 1 SE - without stress throughout the crop cycle; 2, 3, 4, 5, 6, 7 and 8 correspond to salt stress in the vegetative - VE; vegetative/flowering - VE/FL; flowering - FL; flowering/fruiting - FL/FR; fruiting - FR; fruiting/maturation - FR/MA and fruit maturation - MAT stages.

Figure 3. Stem dry mass - SDB (A), leaf dry mass - LDB (B) and total dry mass - TDB (C) of mini watermelon cv. Sugar Baby, as a function of saline water irrigation management strategies, at 65 days after sowing.

By analyzing SDB, LDB and TDB (Figure 3A, 3B and 3C), it can be observed that the saline water irrigation management strategies FL, FR/MA and MA led to the smallest decreases (on average 5.75% compared to SE), so these stages are more tolerant to salinity.

CONCLUSIONS

Irrigation using water with electrical conductivity of 4.0 dS m^{-1} continuously in the vegetative and flowering stages increases the initial fluorescence and decreases the quantum efficiency of photosystem II of mini watermelon fertilized with 100 and 150% K recommendation.

Fertilization with 50% K recommendation does not interfere with the fluorescence parameters of mini watermelon, regardless of the irrigation management strategy adopted.

Chlorophyll *a* synthesis is inhibited by salt stress in the vegetative/flowering, flowering, flowering/fruiting, fruiting/maturation stages, as well as total chlorophyll, except for plants subjected to stress in the flowering stage.

Application of 4.0 dS m^{-1} water in the flowering, fruiting/maturation and maturation stages promotes greater biomass accumulation in mini watermelon, at 65 days after sowing.

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