Research Article

Gas exchanges and production of watermelon plant under salinity management and nitrogen fertilization[1]

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ABSTRACT

In the Brazilian semi-arid region, the occurrence of water with high salt concentrations is common, making it a limiting factor for the agricultural production. The water-use salinity management strategies are an alternative capable of minimizing the deleterious effects of the stress on plants. This study aimed to evaluate the gas exchanges and production of 'Sugar Baby' watermelon plants under strategies of irrigation with saline water and nitrogen fertilization. The experiment was conducted in a randomized block design, arranged in a 6 x 2 factorial scheme, with five replicates, corresponding to six irrigation strategies with saline water applied at different phenological stages of the crop (control - irrigation with low-salinity water throughout the entire crop cycle, and salt stress at the vegetative stage, vegetative/flowering stage, flowering, fruiting and fruit maturation) and two nitrogen rates (50 % and 100 %, equivalent to 50 mg and 100 mg of N kg^{-1} of soil). Two levels of water salinity were studied: one with a low and the other with a high level of electrical conductivity (0.8 dS m^{-1} and 3.2 dS m^{-1}, respectively). The salinity of 3.2 dS m^{-1} in the vegetative/flowering and fruit maturation phases decreases the stomatal opening, transpiration and CO_2 assimilation rate. The level with 50 % of N provides a higher assimilation rate of CO_2 and fresh fruit mass. The watermelon plant expresses a greater sensitivity to saline stress in the vegetative and flowering phases, a situation that results in a decreased fruit size.

KEYWORDS: *Citrullus lanatus*, salt stress, nitrogen.

RESUMO

Trocas gasosas e produção de melancieira sob manejo de salinidade e adubação nitrogenada

Na região semiárida do Brasil, é comum a ocorrência de água com elevadas concentrações de sais, fator limitante à produção agrícola. O uso de estratégias de manejo da salinidade da água é uma alternativa capaz de minimizar os efeitos deletérios do estresse sobre as plantas. Objetivou-se avaliar as trocas gasosas e a produção da melancieira 'Sugar Baby', sob estratégias de irrigação com águas salinas e adubação nitrogenada. O experimento foi conduzido em delineamento de blocos casualizados, em esquema fatorial 6 x 2, com cinco repetições, sendo seis 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, fase vegetativa/floração, floração, frutificação e maturação dos frutos) e duas doses de nitrogênio (50 % e 100 %, equivalentes a 50 mg e 100 mg de N kg^{-1} de solo). Foram estudados dois níveis de salinidade da água: um com baixa e outro com alta condutividade elétrica (0,8 dS m^{-1} e 3,2 dS m^{-1}, respectivamente). A salinidade de 3,2 dS m^{-1} na fase vegetativa/floração e na maturação dos frutos diminui a abertura estomática, a transpiração e a taxa de assimilação de CO_2. A dose com 50 % de N proporciona maior taxa de assimilação de CO_2 e massa fresca dos frutos. A melancieira expressa maior sensibilidade ao estresse salino nas fases vegetativa e de floração, situação que resulta em diminuição no tamanho dos frutos.

PALAVRAS-CHAVE: *Citrullus lanatus*, estresse salino, nitrogênio.

INTRODUCTION

Watermelon is widely cultivated in Brazil. In 2016, 2,090,432 t of watermelon were produced in 90,447 ha, and the Northeast region was responsible for 32 % of the national production (IBGE 2017), highlighting Bahia, Rio Grande do Norte, Pernambuco and Piauí as the main producing states of this region. In the national scenario, it is the fourth crop in fresh fruit production, only behind orange, banana and pineapple, which occupy the first three places, respectively (IBGE 2017).

In this region, watermelon is cultivated mainly by small and medium-sized farmers, standing out due

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to its great socioeconomic relevance, resulting from its simple management and lower production cost, when compared to other vegetables (Rocha 2010). The semi-arid region of Northeast Brazil is characterized by a marked water scarcity, with a mean annual rainfall below 800 mm and a high variability in the spatial and temporal distribution of rainfall (inter- and intra-annual seasonality), and the adoption of irrigation technology is essential to guarantee a safe agricultural production (Lima et al 2014). However, in this region, the high concentrations of salts in the irrigation water constitute a limiting problem for production.

The use of irrigation is fundamental for watermelon, to express its productive potential throughout the cycle, despite being considered a drought-resistant crop (Martins et al. 2013). However, the use of saline water directly affects plants, limiting their growth and yield, due to the reduction in the osmotic potential of the soil solution and/or to the effects of specific ions, possibly causing a nutritional imbalance as well (Aydin et al. 2012). Among the ways to minimize the deleterious effects of salt stress on watermelon, the use of saline waters varying with the phenological stages of the crop should be considered as an important alternative capable of contributing to the reduction of the concentration and entry of salts in the root zone, because the tolerance to salinity varies between cultivars of the same species, phenological stages of the crop, strategies of water application and time of exposure to salts (Costa et al. 2013).

Nitrogen fertilization has also played a preponderant role in reducing the harmful effects of salts on plants, because nitrogen performs a structural function, being a constituent of several organic compounds, such as amino acids, proteins and proline, among others, increasing the capacity for the osmotic adjustment of plants (Lima et al. 2014). In addition, a higher nitrogen absorption may improve the nutritional status of plants and promote their growth when cultivated in a saline environment (Bruning & Rozema 2013).

The present study aimed to evaluate the effects of salinity management strategies and nitrogen fertilization on the gas exchanges and production of 'Sugar Baby' watermelon.

MATERIAL AND METHODS

The experiment was conducted from May to August 2017, under protected conditions (greenhouse), at the Universidade Federal de Campina Grande, in Campina Grande, Paraíba state, Brazil (7º15'18"S, 35º52'28"W and average altitude of 550 m). The data corresponding to the mean temperature during the experimental period are presented in Figure 1.

The experimental design was randomized blocks, in a 6 x 2 factorial scheme [six salinity management strategies; two nitrogen doses: 50 % and 100 % (equivalent to 50 mg and 100 mg of N kg^{-1} of soil of the N recommendation; Novais et al. 1991)]; with five replicates, totaling 60 experimental units. The six strategies for the use of saline water consisted of two levels of electrical conductivity (ECw), being one of low (ECw = 0.8 dS m^{-1}) and the other with high (ECw = 3.2 dS m^{-1}) salinity, varying according to the phenological stages of the plants: vegetative - period between the appearance of the second true leaf and that of the first female flower (25-41 days after sowing - DAS); flowering - from the first female flower to fruit setting (42-55 DAS); fruiting - period from fruit setting to fruit filling (56-66 DAS); and maturation - from fruit filling to harvest (67-85 DAS).

The water salinity of 0.8 dS m^{-1} (control) and 3.2 dS m^{-1} tested in this research are commonly observed in the semi-arid region of the Northeastern Brazil. Thus, the electrical conductivity of 3.2 dS m^{-1} is a value higher than the threshold salinity level (3.0 dS m^{-1}) for the watermelon crop (Ayers & Westcot 1999) and had the objective to induce an osmotic and/or ionic stress on the plants to identify the phase(s) of greater tolerance and/or sensitivity to salt stress.

The watermelon species used in the experiment was 'Sugar Baby', which stands out due to its

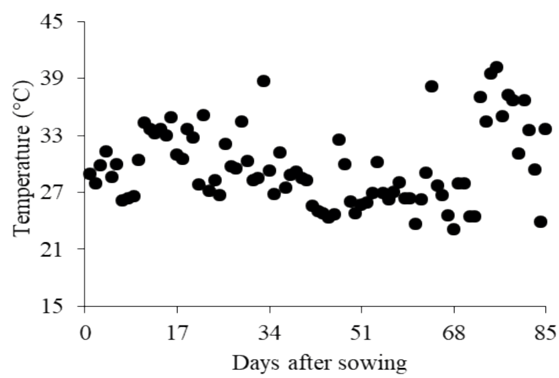

Figure 1. Mean temperature observed during the conduction of the experiment inside the greenhouse.

precocious cycle, and harvest was carried out from 75 days after planting. It is a rustic plant, with vigorous foliage and tolerant to high temperatures. It has round fruits, with a dark green rind, and its pulp is soft, with an intense red color and a high sugar content.

Plants were cultivated in plastic containers adapted as drainage lysimeters with 20 L capacity, which received at the bottom a 3-cm-thick layer of crushed stone and a geotextile to prevent the drainage system from being clogged by soil material, covering the surface of the container base. A 4-mm-diameter transparent tube was connected to the base of each pot in order to facilitate drainage, connected to a plastic container to collect the drained water, so as to work as a drainage lysimeter.

Subsequently, the pots received 24 kg of a sandy loam Entisol (USDA 1999) collected in a cultivated area of Lagoa Seca, Paraíba state, whose chemical and physical characteristics were determined according to Claessen (1997): 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}; Al^{3+} = 0 $cmol_c$ 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 the saturation extract = 0.19 dS m^{-1}; SAR = 0.67 $(mmol\ L^{-1})^{0.5}$; exchangeable sodium = 0.67 %; sand = 732.9 g kg^{-1}; silt = 142.1 g kg^{-1}; clay = 125.0 g kg^{-1}; moisture content at 33.42 kPa = 11.98 dag kg^{-1}; moisture content at 1,519.5 kPa = 4.32 dag kg^{-1}. At the end of the experiment (at 85 DAS), the levels of electrical conductivity of the soil saturation extract (ECse) under different treatments were: control = 1.34; vegetative stage = 1.80; vegetative/flowering stage = 2.18; flowering = 2.76; fruiting = 1.59; and fruit maturation = 5.08 dS m^{-1}.

Fertilization with phosphorus, potassium and nitrogen was performed according to the recommendation for pot experiments (Novais et al. 1991), applying 300 mg kg^{-1} and 150 mg kg^{-1} of soil for P_2O_5 and K_2O, respectively, using single superphosphate as a source of P and potassium nitrate as source of K. The fertilizers were applied as topdressing, split into three equal portions, with phosphorus applied at 16, 32 and 43 DAS and potassium at 22, 40 and 45 DAS. The nitrogen rates were 50 mg kg^{-1} and 100 mg kg^{-1}, which are equivalent to 50 % and 100 % of the N recommendation, split into three portions applied as topdressing at 25, 37 and 47 DAS, using urea as source.

Sowing was performed using four seeds per lysimeter, which were equidistantly distributed and planted at 3.0 cm of depth. The soil moisture content was raised to a level corresponding to the field capacity in all the experimental units, using low-salinity water. After sowing, irrigations were carried out daily at 5:00 p.m., applying in each container the volume corresponding to the water requirement of the plants, determined by the water balance, based on the water volumes applied and drained in the previous irrigation, plus a leaching fraction of 0.10, in order to reduce the excessive accumulation of salts in the root zone. Low-salinity water was used until 24 DAS and, after this period, waters of lower or higher salinity levels, according to the treatments, began to be applied in each lysimeter.

The water used in the irrigation of the lowest salinity treatment (0.8 dS m^{-1}) was obtained by diluting water from the public supply system of Campina Grande with rainwater (ECw = 0.02 dS m^{-1}), whereas the level corresponding to the electrical conductivity of 3.2 dS m^{-1} was prepared by adding salts in the form of chloride, using an equivalent proportion of 7:2:1 for Na:Ca:Mg, respectively, a ratio that normally prevails in water sources used for irrigation in small properties in the Northeast Brazil. The irrigation water of highest salinity was prepared considering the relationship between electrical conductivity and the concentration of salts ($mmol_c$ L^{-1} = ECw*10), according to Rhoades et al. (1992).

The control of pests (*Bemisia tabaci* and *Aphis gossypii*) and disease (powdery mildew) was carried out by chemical intervention, with preventive applications of insecticides of the Neonicotinoid chemical group (soluble powder) and fungicide of the Dicarboximide chemical group (soluble powder). Invasive plants in the lysimeters were controlled by manual weeding along the experiment. Watermelon plants were vertically trained on a trellis system, in which the main stem was conducted until reaching the trellis and the three lateral branches per plant were left prostrate on the soil, with the fruits protected in plastic containers to avoid contact with the soil. Pollination was performed artificially between 6:00 a.m. and 9:00 a.m. After pollination, only one fruit per plant was left.

The watermelon physiology was evaluated at the phenological stage of maturation (75 DAS), through stomatal conductance - *gs* (mol H_2O m^{-2} s^{-1}), transpiration - *E* (mmol H_2O m^{-2} s^{-1}), CO_2 assimilation rate - *A* (μmol m^{-2} s^{-1}) and internal CO_2 concentration - *Ci* (μmol H_2O m^{-2} s^{-1}). These data were used to estimate the instantaneous water-use efficiency (*A/E*) [(μmol m^{-2} s^{-1}) (mmol H_2O m^{-2} s^{-1})$^{-1}$] and the instantaneous carboxylation efficiency (*A/Ci*) [(μmol m^{-2} s^{-1}) (μmol mol^{-1})$^{-1}$] under photosynthetic photon flux density of 1,200 μmol m^{-2} s^{-1} and airflow rate of 200 mL min^{-1}. These measurements were taken between 7:00 a.m. and 10:00 a.m., with a gas exchange meter containing an infrared gas analyzer (IRGA, model LCpro - SD, ADC Bioscientific, UK). At harvest (85 DAS), the following variables were analyzed: fruit fresh mass, determined on a digital scale with precision of 0.01 g; polar diameter and equatorial diameter of watermelon fruits, measured with a tape.

The obtained data were subjected to analysis of variance by the F test. In case of significance, means were compared by the Tukey test ($p < 0.05$) for the salinity management strategies and nitrogen doses, using the Sisvar software (Ferreira 2011).

RESULTS AND DISCUSSION

There was a difference between the saline water-use strategies, with a significant ($p \leq 0.01$) effect for all the physiological variables analyzed (Table 1). The nitrogen doses caused significant differences ($p \leq 0.01$) only in the CO_2 assimilation rate and instantaneous water-use efficiency. The interaction between salinity management strategies and nitrogen doses caused a significant effect on the CO_2 assimilation rate, internal CO_2 concentration and instantaneous water-use efficiency ($p \leq 0.01$) of the 'Sugar Baby' watermelon, at 75 days after sowing.

According to the results of the means comparison test (Figure 1A), referring to the saline water-use strategies for stomatal conductance, it was verified that the strategy with saline water application at the vegetative stage led to a higher *gs* (0.12 mol H_2O m^{-2} s^{-1}), statistically differing from plants subjected to the vegetative/flowering stage and fruit maturation. When the strategy of saline water application at the fruit maturation stage was adopted (Figure 2A), stomatal conductance decreased to 0.064 mol H_2O m^{-2} s^{-1}, i.e., a reduction of 35.02 % in *gs*, if compared to plants irrigated with low-salinity water (0.8 dS m^{-1}) throughout the cycle. The inhibition of stomatal opening in watermelon plants observed with the vegetative/flowering stage and fruit maturation (Figure 2A) may have occurred due to the excess of salts in the soil solution, causing a reduction in the absorption of water and nutrients and, consequently, an imbalance in the water and ionic homeostasis, a situation that leads to alterations in the photosynthetic apparatus (Syvertsen & Garcia-Sanchez 2014). In addition, the largest reduction in *gs* was observed in the fruit maturation strategy (Figure 2A), which may also be related to the accumulation of salts in the soil (ECse = 5.08 dS m^{-1}), in comparison to the other treatments, which accumulated less salts (on average ECse = 1.93 dS m^{-1}) during this stage of crop development.

Due to the significant reduction in the *gs* of watermelon plants irrigated with high-salinity water during the fruit maturation stage, the leaf transpiration (Figure 2B) was also compromised, with a value of 0.773 mmol H_2O m^{-2} s^{-1}, hence lower than that of plants subjected to the other salinity management strategies, which showed transpiration values of 1.30, 1.32, 1.23, 1.36 and 1.37 μmol H_2O m^{-2} s^{-1},

Table 1. Analysis of variance summary for CO_2 assimilation rate (*A*), transpiration (*E*), stomatal conductance (*gs*), internal CO_2 concentration (*Ci*), instantaneous water-use efficiency (*WUEi*) and instantaneous carboxylation efficiency (*CEi*) of 'Sugar Baby' watermelon cultivated under salinity management strategies (SMS) and nitrogen doses (ND), at 75 days after sowing.

SV	DF	Mean square					
		gs	*E*	*A*	*Ci*	*WUEi*	*CEi*
SMS	5	0.0039**	0.5100**	152.2400**	15,522.8**	48.6900**	0.0052**
ND	1	0.0006^{ns}	0.0006^{ns}	32.4800**	915.9^{ns}	54.0700**	0.0001^{ns}
SMS x ND	5	0.00005^{ns}	0.0800^{ns}	18.7100**	8,861.96**	26.7600**	0.001^{ns}
Blocks	4	0.0004^{ns}	0.1300*	2.0800^{ns}	1,349.07^{ns}	4.3500^{ns}	0.0009^{ns}
Residual	44	0.0003	0.0400	2.2300	1,150.24	2.5700	0.0005
CV (%)		18.0300	17.1700	13.3100	17.7100	17.7600	33.9600
Mean		0.0990	1.2200	11.2100	191.5300	9.0300	0.0650

SV: source of variation; DF: degree of freedom; CV (%): coefficient of variation. ** Significant at 0.01 of probability; * significant at 0.05 of probability; ^{ns} not significant.

respectively at the control, vegetative, vegetative/ flowering, flowering and fruiting stages. The reduction of transpiration obtained in watermelon plants cultivated under irrigation with saline water at the fruit maturation stage results from a stomatal limitation, due to the difficulty of absorbing water because of the reduction in the soil water potential, which leads to a partial stomatal closure, restricting both the exit of water vapor and the entry of CO_2 inside the cell (Suassuna et al. 2014).

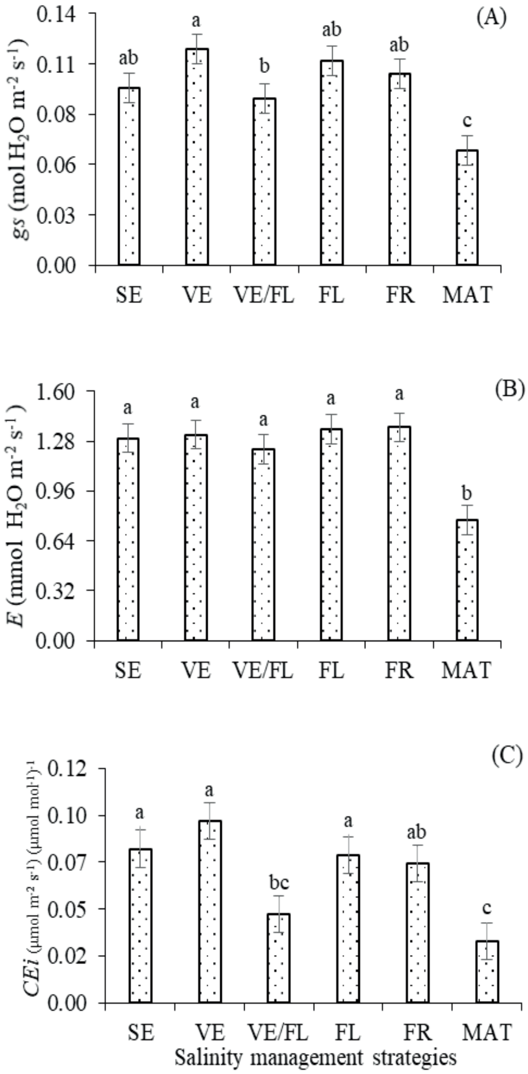

Figure 2. Stomatal conductance - *gs* (A), transpiration - *E* (B) and instantaneous carboxylation efficiency - *CEi* (C) of 'Sugar Baby' watermelon, as a function of the salinity management strategies. The vertical bars represent the mean standard error (n = 5). Means followed by the same letter do not differ by the Tukey test at $p < 0.05$. SE: control, irrigation with low-salinity water along the entire crop cycle; VE: salt stress only at the vegetative stage; VE/FL: salt stress at the vegetative and flowering stages; FL: salt stress at the flowering stage; FR: salt stress at the fruiting stage; MAT: salt stress at the fruit maturation stage.

As observed for stomatal conductance (Figure 2A) and transpiration (Figure 2B), it can be noted that watermelon plants under saline water irrigation at the vegetative stage did not differ significantly from those subjected to the control, flowering and fruiting (Figure 2C). However, plants receiving high-salinity water (3.2 dS m^{-1}) in succession in the vegetative/flowering and fruit maturation stages obtained the lower values for instantaneous carboxylation efficiency (Figure 2C), being 0.0451 and 0.0315 [(μmol m^{-2} s^{-1}) (μmol mol^{-1})$^{-1}$], and, for the control, flowering and fruiting, the mean values were respectively 0.078, 0.075 and 0.071 [(μmol m^{-2} s^{-1}) (μmol mol^{-1})$^{-1}$]. When the watermelon plants were irrigated with saline water consecutively at the vegetative and flowering stages and at fruit maturation, their instantaneous carboxylation efficiency decreased to about 0.03369 and 0.04729[(μmol m^{-2} s^{-1}) (μmol mol^{-1})$^{-1}$], if compared to plants that did not receive irrigation with saline water along the cycle. The instantaneous carboxylation efficiency is closely related to the stomatal opening and closing. However, in this study, the reduction in the stomatal conductance did not alter the CO_2 diffusion to the substomatal chamber, a situation observed through the internal CO_2 concentration in plants that were subjected to the vegetative/flowering stage and fruit maturation (Figure 2C). Such reduction in the instantaneous carboxylation efficiency is possibly related to the action of other environmental factors (probably of non-stomatal origin), favoring the oxygenation of RuBisCO and the increase of the photorespiratory pathway, resulting in a significant reduction in the carbon compounds (Voss et al. 2013).

The analysis of the interaction between the use of saline water and nitrogen doses for the CO_2 assimilation rate (Figure 3A) demonstrated that watermelon plants that received a N dose corresponding to 50 % of the recommendation had a significant difference in the vegetative/ flowering stage and fruit maturation, showing a lower CO_2 assimilation (8.58 μmol m^{-2} s^{-1} and 8.51 μmol m^{-2} s^{-1}, respectively), if compared to the other strategies of salinity management (control, vegetative stage, flowering and fruiting). As observed for plants that were subjected to 50 % of

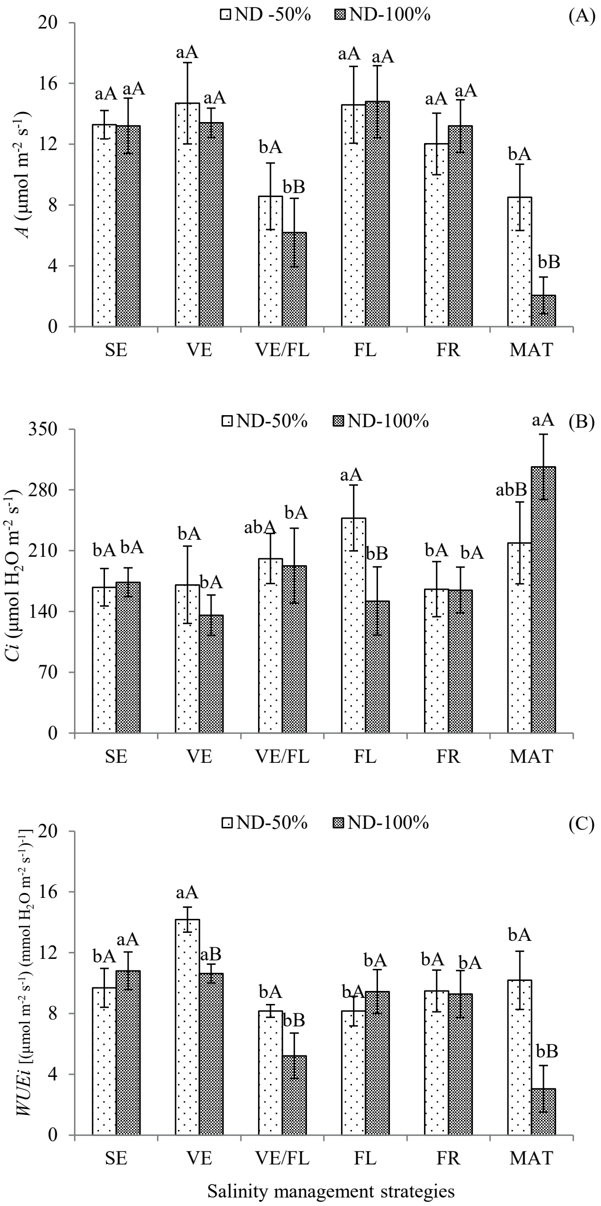

Figure 3. CO_2 assimilation rate - *A* (A), internal CO_2 concentration - *Ci* (B) and instantaneous water-use efficiency - *WUEi* (C) of 'Sugar Baby' watermelon, as a function of the interaction between the salinity management strategies and nitrogen doses (ND), at 75 days after sowing. The vertical bars represent the mean standard error (n = 5). In each management strategy, means with the same lowercase letters indicate no significant differences (Tukey; $p < 0.05$); between the doses, and with the same uppercase letters, indicate that, for the same dose, there are no differences (Tukey; $p < 0.05$) among the management strategies, respectively. SE: control, irrigation with low-salinity water along the entire crop cycle; VE: salt stress only at the vegetative stage; VE/FL: salt stress at the vegetative and flowering stages; FL: salt stress at the flowering stage; FR: salt stress at the fruiting stage; MAT: salt stress at the fruit maturation stage.

the N recommendation, when a N dose equivalent to 100 % of the recommendation was used, the lowest values for CO_2 assimilation rate (6.19 μmol m^{-2} s^{-1} and 2.06 μmol m^{-2} s^{-1}) were observed in plants cultivated under the vegetative/flowering stage and fruit maturation, statistically differing from those subjected to the control, vegetative stage, flowering and fruiting. The reduction in the CO_2 assimilation rate in watermelon plants under the vegetative/flowering stage and fruit maturation (Figure 3A) may be related to the increment and the N source used in this study, because the supply of N by urea (45 % of amidic N) and the action of urease enzyme lead to the transformation of amidic N to ammoniacal N. As the process of NH_4^+ absorption through the roots depends on its entry, mediated by a transporter, when it is transported into the cell, it causes an electrical imbalance (Silva et al. 2010), whose ammonium flux is difficult to control, due to the need for cellular homeostasis of the element, which may induce toxicity to plants (Bittsánzky et al. 2015). Excess of ammonium may cause a reduction in intracellular pH and osmotic imbalance, favoring the increment in the content of reactive oxygen species, inducing oxidative stress and leading to alterations in the CO_2 assimilation by plants (Bittsánszky et al. 2015).

According to the analysis of N doses at each salinity management strategy (Figure 3A), there were significant differences in the CO_2 assimilation rate when watermelon plants were subjected to the vegetative/flowering stage and fruit maturation, also obtaining the lowest CO_2 assimilation. The reduction in the CO_2 assimilation in the vegetative/flowering stage may be related to the duration of the stress, in which the period of exposure to the effects of salts was longer, since it encompassed two stages of crop development. On the other hand, the reduction in the CO_2 assimilation rate of plants subjected to the fruit maturation strategy may be related to limitations of non-stomatal origin, because, in this treatment, plants had no restriction in the CO_2 diffusion to the substomatal chamber (Figure 3B), i.e., there was availability of carbon dioxide for the photosynthetic process, but there were limitations in the activity of ribulose-1,5-bisphosphate carboxylase/oxygenase (Silva et al. 2014).

The means comparison test (Figure 3A) showed that the *A* of watermelon plants that received a N dose of 50 % was higher than that of plants cultivated under 100 % of N. This result may possibly have occurred because the N dose of 50 % favored a higher photosynthetic activity (stomatal conductance and transpiration) in watermelon plants, when compared to the dose of 100 % of N, hence resulting in a greater assimilation of CO_2. Melo et al. (2016), working with fertilization management in watermelon, also found that the dose of 50 % of the N recommendation favored a higher photosynthetic activity.

For the internal CO_2 concentration (Figure 3B), it was observed that plants cultivated under fertilization with 50 % of N and subjected to the use of saline water (flowering stage, fruit maturation and vegetative/flowering stage) had a greater increment in the intercellular concentration of CO_2, with values of 247.6 μmol H_2O m^{-2} s^{-1}, 219 μmol H_2O m^{-2} s^{-1} and 201 μmol H_2O m^{-2} s^{-1}, respectively. On the other hand, when N doses of 100 % of the recommendation were used, plants that were irrigated using the fruit maturation strategy were the ones with the highest value of internal CO_2 concentration (306.5 μmol H_2O m^{-2} s^{-1}).

According to the N doses analysis at each salinity management strategy (Figure 3B), there was a significant difference in the internal CO_2 concentration when watermelon plants were subjected to flowering and fruit maturation and, for the former strategy, the N dose corresponding to 50 % led to a greater increment in the internal CO_2 concentration. However, at the fruit maturation stage, the highest intercellular concentration of CO_2 was observed under 100 % of the N recommendation. The highest internal CO_2 concentration observed in the fruit maturation strategy may be related to the damage to the photosynthetic apparatus in response to the process of leaf tissue senescence caused by salt stress, in which carbon dioxide entering the leaf mesophyll cell was not being metabolized, whose process of fixation during the carboxylation phase had been compromised (Silva et al. 2013). On the other hand, the reduction in the CO_2 concentration may be attributed to the decrease in the stomatal conductance, a common response of plants to salt stress. This situation is associated not only with the damage to the photosynthetic apparatus during the carboxylation phase, but also with the increase in photorespiration, since RuBisCO is the enzyme which catalyzes the first step of this metabolic pathway (Silva et al. 2014).

The instantaneous water-use efficiency of 'Sugar Baby' watermelon was also influenced by the interaction between the strategies of use of saline water and nitrogen doses (Figure 3C). In the isolated-effect analysis of the interaction (salinity management strategy at each N dose) for the N dose of 50 %, it was observed that the vegetative stage strategy was the one that caused the highest water-use efficiency [14.18 (μmol m^{-2} s^{-1}) (mmol H_2O m^{-2} $s^{-1})^{-1}$]. For the other strategies, there was no significant difference among them. When watermelon plants were fertilized with a N dose of 100 %, the highest values for water-use efficiency were obtained in the control and vegetative stage [10.81 and 10.63 (μmol m^{-2} s^{-1}) (mmol H_2O m^{-2} $s^{-1})^{-1}$, respectively]. Although there was no statistical significant effect when the other strategies were compared, it can be observed that plants cultivated under stress at the fruit maturation and vegetative/flowering stage had the lowest mean values for water-use efficiency.

Regarding the analysis of N doses at each salinity management strategy (Figure 3C), significant responses were observed for water-use efficiency when watermelon plants were cultivated under the vegetative stage, vegetative/flowering stage and fruit maturation. The highest values for water-use efficiency, of the order of 14.18, 8.17 and 10.19 [(μmol m^{-2} s^{-1}) (mmol H_2O m^{-2} $s^{-1})^{-1}$], respectively, were obtained in plants under a N dose of 50 %, while those subjected to a N dose of 100 % had lower values, of the order of 10.63, 5.22 and 3.05 [(μmol m^{-2} s^{-1}) (mmol H_2O m^{-2} $s^{-1})^{-1}$], respectively for the vegetative stage, vegetative/flowering stage and fruit maturation. In general, the dose equivalent to 50 % of the N recommendation resulted in a higher instantaneous water-use efficiency when watermelon plants were subjected to the vegetative stage, vegetative/flowering stage, fruiting and fruit maturation. According to the means comparison test (Figure 3C), watermelon plants subjected to irrigation with high-salinity water during the vegetative stage and fertilized with 50 % of the N recommendation showed the highest water-use efficiency (14.18 μmol m^{-2} s^{-1}). When there is a reduction of water availability due to the alteration in the osmotic potential of the soil, there is a natural tendency towards reducing the transpiration flow and performing mechanisms of osmotic adjustment, in order to ensure the water absorption and maintain the cells turgid (Taiz et al. 2017).

In general, watermelon plants irrigated with high-salinity water (3.2 dS m^{-1}) at the vegetative, flowering and fruit maturation stages had expressive reductions in the physiological variables evaluated, probably due to the cumulative stress caused by the accumulation of salts in the soil solution, which causes alterations in the water and osmotic potentials, influencing the absorption of water and nutrients and, consequently, inhibiting the photosynthetic process. However, it is important to point out that the alterations in the physiological processes of the plants may be different according to management practices, time of exposure to salinity and even the genotype itself (Munns & Tester 2008).

According to the analysis of variance summary, there was a significant difference ($p < 0.01$) between the strategies of use of saline water for the equatorial and polar diameters of the fruits (Table 2). The N doses caused a significant difference in the fruit mass and polar diameter. For the interaction between salinity management strategies and nitrogen doses, there was a significant effect ($p < 0.01$) on the equatorial and polar diameters of the fruits.

The N doses significantly influenced the mass of watermelon fruits and, based on the means comparison test (Figure 4), plants fertilized with 50 % of the N recommendation obtained a higher fruit mass (1,055.9 g plant^{-1}), if compared to those who received 100 % of N, which had a mean value of 892.8 g, i.e., an increase of 18.27 % in the fruit fresh mass of watermelon plants that received 50 % of N, when compared to those cultivated under the highest N dose (100 % of the recommendation of Novais et al. 1991). The highest value for fruit fresh mass obtained in plants under the N dose of 50 % is considered within the appropriate range for commercialization, because, for this cultivar, the mass should range from 1.0 kg to 3.0 kg. On the other hand, the reduction in the fruit fresh mass of watermelon plants may have occurred because the higher N dose supplied caused an alteration in the ionic homeostasis, as previously explained by Silva et al. (2010) and Bittsánzky et al. (2015), becoming harmful to physiological and biochemical processes and resulting in a lower accumulation of fresh mass. Melo et al. (2016), evaluating the morphophysiological responses of watermelon with the application of NPK doses, concluded that the dose of 50 % of the NPK recommendation favored a higher photosynthetic activity for watermelon plants, what contributes to the formation of fruits with a greater mass.

There was a significant interaction between the strategies of use of saline water and nitrogen doses for the equatorial and polar diameters of watermelon fruits (Figures 5A and 5B). According to the analysis of salinity management strategies at each N dose, plants cultivated under the dose of 50 % of N obtained the lowest values (37.75 cm and 38.12 cm) for equatorial and polar diameter at the vegetative/flowering stage. However, under a N dose of 100 %, the vegetative and vegetative/flowering stages were the ones that led to the formation of fruits with the smallest diameters (38 cm and 39.5 cm for equatorial diameter and 38.75 cm and 39.0 cm for polar diameter, respectively).

The greater reduction of fruit size at the vegetative and vegetative/flowering stages (Figure 5A) is a reflex of the reduction in the water potential caused by the excess of salts in the soil. This situation imposes a higher expenditure of energy to maintain

Table 2. Analysis of variance summary for fruit fresh mass (FFM), equatorial (ED) and polar (PD) diameters of 'Sugar Baby' watermelon fruits cultivated under salinity management strategies (SMS) and nitrogen doses (ND), at 85 days after sowing.

SV	DF	Mean square		
		FFM	ED	PD
SMS	5	81,306.7^{ns}	26.4400**	36.2000**
ND	1	399,105.7*	4.5300^{ns}	27.3300**
SMS x ND	5	53,156.7^{ns}	25.9400**	24.1600**
Blocks	4	62,744.5^{ns}	3.4300^{ns}	3.0800^{ns}
Residual	44	49,498.2	2.9100	3.3300
CV (%)		22.8300	4.1100	4.3300
Mean		974.3500	41.5400	42.300

SV: source of variation; DF: degree of freedom; CV (%): coefficient of variation. ** Significant at 0.01 of probability; * significant at 0.05 of probability; ^{ns} not significant.

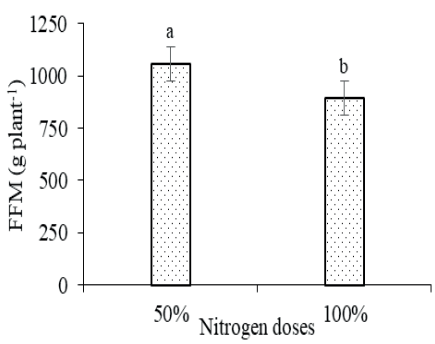

Figure 4. Fruit fresh mass - FFM (A) of 'Sugar Baby' watermelon, as a function of nitrogen doses. The vertical bars represent the mean standard error (n = 5). Means followed by the same letter do not differ by the Tukey test ($p < 0.05$).

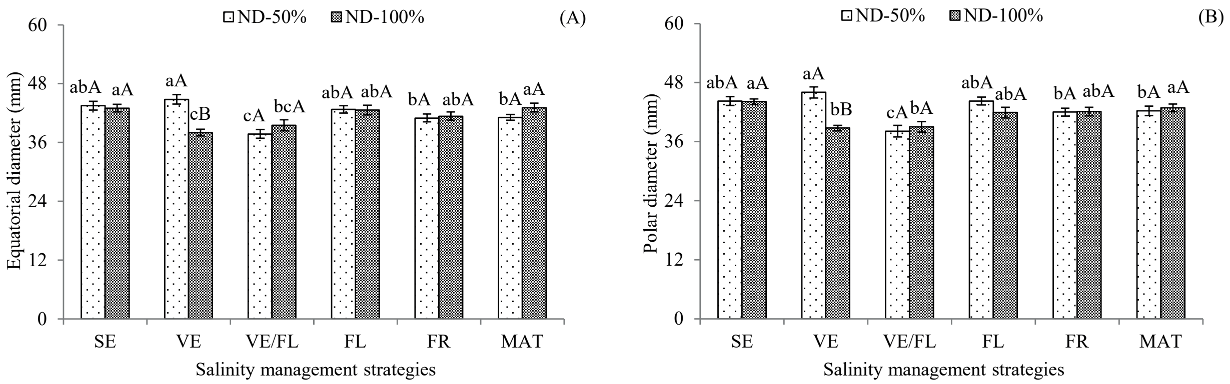

Figure 5. Equatorial (A) and polar (B) diameter of 'Sugar Baby' watermelon fruits, as a function of the interaction between salinity management strategies and nitrogen doses (ND), at 85 days after sowing. The vertical bars represent the mean standard error (n = 5). In each management strategy, means with the same lowercase letters indicate no significant difference (Tukey; $p < 0.05$); between the doses, and with the same uppercase letters, indicate that, for the same dose, there are no differences (Tukey, $p < 0.05$) among the management strategies, respectively. SE: control, irrigation with low-salinity water along the entire crop cycle; VE: salt stress only at the vegetative stage; VE/FL: salt stress at the vegetative and flowering stages; FL: salt stress at the flowering stage; FR: salt stress at the fruiting stage; MAT: salt stress at the fruit maturation stage.

the metabolic activities of plants and, consequently, induces the formation of fruits with a lower mass. Additionally, at the vegetative/flowering stage, there were limitations in the stomatal opening, imposing reductions in the transpiration and CO_2 assimilation rate. Studies conducted with melon irrigated with low- and high-salinity waters also found a reduction of growth at the initial development stages (Terceiro Neto et al. 2012). As a consequence, it inhibited growth at the other stages, such as fruiting and fruit maturation, thus leading to lower values of polar and equatorial diameters

According to the analysis of N doses at each strategy (Figure 5B), there was a significant difference for the equatorial and polar diameters in the vegetative stage, where the dose of 50 % of the N recommendation led to the formation of fruits with larger polar and equatorial diameters (46.00 cm and 44.80 cm, respectively). This may have occurred because the dose of 50 % of N favored a higher photosynthetic activity in watermelon plants, resulting in a greater increase in fruit mass, because, according to Dudley et al. (2008), N participates in the formation of organic compounds and constituents of the chlorophyll molecule, nucleic acids, amino acids and proteins.

CONCLUSIONS

1. Irrigation with saline water showing electrical conductivity of 3.2 dS m^{-1} in the vegetative/flowering and fruit ripening stages inhibits the stomatal opening, transpiration and the CO_2 assimilation rate of 'Sugar Baby' watermelon;
2. The dose with 50 % of the N recommendation (50 mg of N kg^{-1} of soil) results in a higher assimilation rate of CO_2 and fresh mass for watermelon fruits;
3. The 'Sugar Baby' watermelon expresses a greater sensitivity to salt stress when the plants are irrigated with water of a high electrical conductivity (3.2 dS m^{-1}) successively in the vegetative and flowering stages, a situation that directly reflects the decrease in fruit size.

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