

GAS EXCHANGE AND PRODUCTION OF PASSION FRUIT AS AFFECTED BY CATIONIC NATURE OF IRRIGATION WATER¹

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ABSTRACT - Yellow passion fruit is a fruit species widely cultivated throughout the Brazilian semi-arid territory, but its yield is affected by the quality of the waters of this region. In this context, the objective was to evaluate the gas exchange and production of passion fruit cv. BRS Rubi do Cerrado irrigated with waters of different cationic natures. The study was conducted in drainage lysimeters under greenhouse conditions in Campina Grande, PB, Brazil, in a randomized block design, and the treatments were eight cationic natures of irrigation water (S₁ - Control; S₂ - Na⁺; S₃ - Ca²⁺; S₄ - Mg²⁺; S₅ - Na⁺ + Ca²⁺; S₆ - Na⁺ + Mg²⁺; S₇ - Ca²⁺ + Mg²⁺ and S₈ - Na⁺ + Ca²⁺ + Mg²⁺) with three replicates. Plants in the control treatment were irrigated with water of low electrical conductivity (EC_w = 0.4 dS m⁻¹), while those of the other treatments were irrigated using water with EC_w of 3.5 dS m⁻¹. The treatments Na⁺ + Ca²⁺, Na⁺ + Mg²⁺ and Ca²⁺ + Mg²⁺ were prepared in the equivalent ratio of 1:1, and Na⁺+Ca²⁺+Mg²⁺ in the ratio 7:2:1, respectively. Water salinity of 3.5 dS m⁻¹ reduced gas exchange, and stomatal conductance and transpiration were the most sensitive variables of passion fruit. The number of fruits of passion fruit cv. BRS Rubi do Cerrado decreased with water salinity, regardless of the cationic nature. The waters of calcic and calcic+magnesian nature caused the greatest deleterious effects on the production variables of passion fruit, at 259 days after transplanting.

Keywords: *Passiflora edulis* L. Fruit growing. Irrigation. Salinity.

TROCAS GASOSAS E PRODUÇÃO DO MARACUJAZEIRO EM FUNÇÃO DA NATUREZA CATIONICA DA ÁGUA DE IRRIGAÇÃO

RESUMO - O maracujazeiro amarelo é uma espécie frutífera bastante cultivada em todo o território Semiárido brasileiro, contudo, seu rendimento produtivo é afetado pela qualidade das águas desta região. Neste contexto, objetivou-se avaliar as trocas gasosas e a produção do maracujazeiro cv. BRS Rubi do Cerrado irrigado com águas de distintas naturezas catiônicas. O estudo foi conduzido em lisímetros de drenagem em condições de casa de vegetação em Campina Grande, PB, no delineamento em blocos casualizados, sendo os tratamentos oito naturezas catiônicas da água de irrigação (S₁ - Testemunha; S₂ - Na⁺; S₃ - Ca²⁺; S₄ - Mg²⁺; S₅ - Na⁺ + Ca²⁺; S₆ - Na⁺ + Mg²⁺; S₇ - Ca²⁺ + Mg²⁺ e S₈ - Na⁺ + Ca²⁺ + Mg²⁺) com três repetições. As plantas do tratamento testemunha foram irrigadas com água de baixa condutividade elétrica (CEa = 0,4 dS m⁻¹), já os demais tratamentos foram irrigadas com CEa de 3,5 dS m⁻¹. Os tratamentos Na⁺ + Ca²⁺, Na⁺ + Mg²⁺ e Ca²⁺ + Mg²⁺ foram preparados na proporção equivalente de 1:1 e Na⁺+Ca²⁺+Mg²⁺ na proporção 7:2:1, respectivamente. A salinidade da água de 3,5 dS m⁻¹ reduziu as trocas gasosas, sendo a condutância estomática e a transpiração as variáveis mais sensíveis do maracujazeiro. O número de frutos do maracujazeiro cv. BRS Rubi do Cerrado diminuiu com a salinidade da água, independente da natureza catiônica. As águas de natureza cálcica e o cálcica+magnesiana promoveram os maiores efeitos deletérios sob as variáveis de produção do maracujazeiro, aos 259 dias após o transplantio.

Palavras-chave: *Passiflora edulis* Sims. Fruticultura. Irrigação. Salinidade.

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INTRODUCTION

Brazil is the world's largest producer and consumer of passion fruit, having produced in 2018 more than 602,000 tons in a planted area of 43,248 hectares (IBGE, 2019). The highlight in passion fruit production is related to its physical-chemical characteristics, high yield and juice acceptance by the consumer market, the main factors responsible for boosting the commercialization of fruits, significantly influencing the expansion and emergence of new cultivated areas (SANTOS et al., 2014).

In the semi-arid region of Brazil, due to adverse climatic conditions, characterized by having in most of the year high temperatures, high evapotranspiration rates and low rainfall, distributed irregularly in space and time, the use of irrigation becomes indispensable for the agricultural exploitation. However, due to the high demand for good quality water, together with the need to produce food, the use of lower quality water in agricultural activities has become frequent (LIRA et al., 2015; MUNNS; GILLIHAM, 2015; RODRIGUES et al., 2018).

In this scenario, the available water resources are characterized mainly by containing high concentrations of salts, but they vary according to the local geology and the type of source, generally with predominance of chlorinated waters, especially of sodium, calcium and magnesium, and, in some cases, potassium (MEDEIROS; LISBOA; OLIVEIRA, 2003; NASCIMENTO et al., 2017; LIMA et al., 2019).

For certain crops, the excess of salts diluted in irrigation water is considered as a limiting factor to agricultural production, for drastically affecting the growth, yield and quality of agricultural products. When subjected to salt stress, the ions present in the soil solution limit the capacity to absorb water and nutrients by the roots, causing physiological disorders to plants (NOBRE et al., 2013). Given this condition, plants tend to close their stomata, consequently causing disturbances in water relations, in addition to the accumulation of potentially toxic ions in plant metabolism (AMORIM et al., 2010).

In this context, several studies have been conducted with the objective of evaluating the deleterious effects of salinity on several aspects in passion fruit crop (WANDERLEY et al., 2018; FREIRE; NASCIMENTO, 2018; SOUZA et al., 2018; LIMA et al., 2020a). However, these studies were limited to evaluating the different salinity levels, so it is necessary to conduct studies related to the effects of the different cationic compositions of irrigation water on the cultivation of passion fruit cv. BRS Rubi do Cerrado, as a way to identify the cation which promotes the highest and/or lowest sensitivity in the crop under the conditions of the Brazilian semi-arid region, constituting an important tool to assist

in the management of species cultivated under conditions of high concentrations of salts in water, especially of distinct cationic nature.

In view of the above, the objective of this study was to evaluate the gas exchange and production of passion fruit cv. BRS Rubi do Cerrado irrigated with waters of different cationic natures.

MATERIAL AND METHODS

The experiment was carried out from March 2019 to January 2020 in a protected environment of the Academic Unit of Agricultural Engineering of the Federal University of Campina Grande (UFCG), Campus of Campina Grande, PB, Brazil, located by the local geographic coordinates 07° 15' 18" S, and 35° 52' 28" W and altitude of 550 m.

The seedlings were grown in polyethylene bags with volumetric capacity of 1,472 mL, filled with substrate composed of the mixture of soil, washed sand, and earthworm humus, in the proportion of 84, 15 and 1%, respectively. Before and after sowing, irrigations were performed daily with low-salinity water ($EC_w = 0.4 \text{ dS m}^{-1}$) in order to keep the substrate close to the level of field capacity.

Transplanting was performed when the seedlings reached 50 cm in height and started the production of tendrils (45 days after sowing - DAS). After transplantation, all lysimeters were irrigated with low-salinity water (0.4 dS m^{-1}), in order to keep the soil with moisture content at the level corresponding to field capacity. The plants were trained in a vertical trellis system, constructed using smooth galvanized steel wire no. 12, at 1.7 m high from the surface of the soil inside the lysimeter. The treatments began to be applied when the main stem of the plants reached the trellis height.

Nylon string was used to fix the plants and, when the main branch exceeded 10 cm from the trellis height, the first pruning was performed, aiming to induce the secondary branches. When the secondary branches reached one meter in length, the second pruning was performed to establish the growth of the tertiary branches and form the 'curtain' and, when they reached a distance of 20 cm from the ground, the third pruning was performed to avoid their contact with the soil. Throughout the experiment, scissors were used to eliminate unwanted branches as well as tendrils that appeared along the plants.

The treatments consisted of seven combinations of irrigation water of different cationic natures, in addition to the control treatment (public-supply water); with this, the treatments corresponded to: S₁ - Control; S₂ - Na⁺; S₃ - Ca²⁺; S₄ - Mg²⁺; S₅ - Na⁺ + Ca²⁺; S₆ - Na⁺ + Mg²⁺; S₇ - Ca²⁺ + Mg²⁺ and S₈ - Na⁺ + Ca²⁺ + Mg²⁺. Plants in the control treatment (S₁) were irrigated with public-supply water, with

electrical conductivity (ECw) of 0.4 dS m⁻¹, while the other treatments (S₂; S₃; S₄; S₅; S₆; S₇ and S₈) received ECw of 3.5 dS m⁻¹. The treatments Na⁺+Ca²⁺, Na⁺+Mg²⁺ and Ca²⁺+Mg²⁺ were prepared in such a way to have an equivalent ratio of 1:1, and the treatment Na⁺+Ca²⁺+Mg²⁺, a ratio of 7:2:1, respectively.

A randomized block design was used, consisting of eight treatments and three replicates, totaling 24 experimental plots. The plants were grown in drainage lysimeters at spacing of 1.5 m between rows and 2 m between plants. At the bottom of the lysimeters, two holes were drilled and drains with dimensions of 18 mm diameter and 20 cm length were connected. Then, a geotextile (Bidim OP 30 type) was placed to avoid clogging of the drains, followed by a layer of crushed stone to facilitate drainage. To collect the drained volume referring to the leaching fraction, a plastic bottle with capacity of 2 L was placed below each drain, and the drainage value was accounted for and used for soil water balance.

The lysimeters had dimensions of 68 × 60 cm (height and diameter, respectively), with a volumetric capacity of 0.2 m³, and were filled with 240 kg of soil, with a free height of 10 cm at the top of the lysimeter in order to facilitate irrigations. Prior to transplanting, 22 L of water were applied to raise soil moisture to the level corresponding to field capacity, using the soil water balance method. The soil used was classified as sandy clay loam, dystrophic (EMBRAPA, 2018), collected at a depth of 0-30 cm (horizon A), in an area with native vegetation, coming from the municipality of Alagoa Nova, PB, with physical-hydraulic and chemical attributes obtained according to the methodology proposed by Teixeira et al. (2017): Ca²⁺, Mg²⁺, Na⁺, K⁺, Al³⁺ + H⁺ = 1.67, 1.56, 0.04, 79.30 and 7.21 cmol_c kg⁻¹, respectively; pH (water 1:2.5) = 5.3; EC_{se} = 0.41 dS m⁻¹; organic matter = 2.863 dag kg⁻¹; sand, silt and clay = 68.8, 9.6 and 21.6 dag kg⁻¹, respectively; soil bulk density (kg dm⁻³) = 1.16.

Irrigation waters were obtained from the dissolution of sodium (NaCl), calcium (CaCl₂.2H₂O), and magnesium (MgCl₂.6H₂O) chlorides according to the pre-established treatments, based on the electrical conductivity of water acquired from the supply network of the city of Campina Grande, PB, as described in the equation of Richards (1954), considering the relationship between the ECw (electrical conductivity of the public-supply water) and the concentration of salts (10*mmol_cL⁻¹ = 1 dS m⁻¹). The salts used (NaCl; CaCl₂.2H₂O; MgCl₂.6H₂O) had purity of 99.9, 74 and 100%, respectively. After preparation and calibration of ECw, the water was stored in plastic containers with capacity of 100 L, properly identified with the respective treatments and closed, in order to avoid evaporation.

The irrigations were carried out daily,

applying the volume of water necessary to maintain soil moisture close to the maximum water retention capacity. In each irrigation, the volume of water determined to meet the water needs of the plants was applied, through water balance in the root zone, obtained by the difference between the volume applied and the volume drained, calculated every week. In order to avoid the accumulation of salts in the root zone, a leaching fraction of 0.15 (AYERS; WESTCOT, 1999) was applied. The volume drained was quantified and the electrical conductivity of the drained water was measured; these parameters were used in the calculations to determine the leaching fraction.

When the holes were opened, planting fertilization was carried out according to São José et al. (2000), applying 250 g of single superphosphate and 100 g of potassium chloride at 60%, in addition to 150 g of single superphosphate per plant at the beginning of flowering. Nitrogen and potassium fertilizations were performed monthly, using ammonium sulfate as nitrogen source and potassium chloride as potassium source. In the crop formation stage, the 1N:1K ratio was used taking as reference 10 g of nitrogen; from the beginning of flowering, the N dose was raised to 20 and the K dose to 30 g, increasing the N:K ratio to 1:1.5. Foliar fertilization was also performed monthly, with micronutrients.

When the flowering stage began, due to the low number of carpenter bees (*Xylocopa* spp), the main natural pollinating agent of passion fruit, since the experiment was carried out in a protected environment, artificial pollination was carried out daily from 13:00 to 17:00 hours manually, by touching the fingertips on the anthers until they were covered with pollen and then lightly touching the stigmas of another flower on another plant. Manual pollination began in the second week of September 2019 extending to the second week of November of that year, so the flowering period was eight weeks.

Phytosanitary control was performed when necessary, using agrochemicals, according to recommendations for the crop and following the doses recommended by the manufacturers of each product. Weed control was performed by manual weeding, between the rows of the drainage lysimeters and around the plant collar. In addition, scarifications were also performed using a manual scarifier to eliminate invasive plants around the plant collar and decompress the surface layer of the soil.

The effects of the different treatments on passion fruit crop were measured at 180 days after transplanting (DAT), by evaluating the CO₂ assimilation rate (*A*) (μmol m⁻² s⁻¹), transpiration (*E*) (mol of H₂O m⁻¹ s⁻¹), internal CO₂ concentration (*C_i*) (μmol m⁻² s⁻¹) and stomatal conductance (*g_s*) (mol of H₂O m⁻¹ s⁻¹), determined in the third leaf counted from the apex, using the portable photosynthesis meter (IRGA) called "LCPro+", from ADC BioScientific Ltda.

Fruit harvesting started at 180 DAT. Fruits that detached from the mother plant and fell to the ground were considered in full maturation stage. Still in the almost ripe stage, the fruits of each plant were identified using a marker for whiteboard with the respective numbers of the pots.

Passion fruit production was evaluated by determining the number of fruits per plant (NFruP), performed by direct counting of fruits that reached the full maturation stage, average fruit mass (AFM), and fresh fruit mass (FFM), using a benchtop scale, polar diameter (PD) and equatorial diameter (ED), using a digital caliper and measured as the fruits were harvested, with results expressed in millimeters (mm).

The data obtained were evaluated by analysis of variance by the F test; when significant, the means comparison test (Scott-Knott $p < 0.05$) and the

contrasts between the means of the treatments were performed using the statistical program SISVAR-ESAL. The contrasts were defined as follows: \hat{y}_1 (S_1 vs S_2 ; S_3 ; S_4 ; S_5 ; S_6 ; S_7 ; S_8); \hat{y}_2 (S_2 vs S_3); \hat{y}_3 (S_2 vs S_4); \hat{y}_4 (S_3 vs S_5); \hat{y}_5 (S_5 vs S_6 ; S_7 ; S_8); \hat{y}_6 (S_4 vs S_5) and \hat{y}_7 (S_2 vs S_7).

RESULTS AND DISCUSSION

The summary of the analysis of variance (Table 1) showed that there was a significant effect ($p < 0.01$) of the different cationic natures of irrigation water on the CO_2 assimilation rate (A), stomatal conductance (g_s) and transpiration (E) of yellow passion fruit plants cv. BRS Rubi do Cerrado, at 180 days after transplanting.

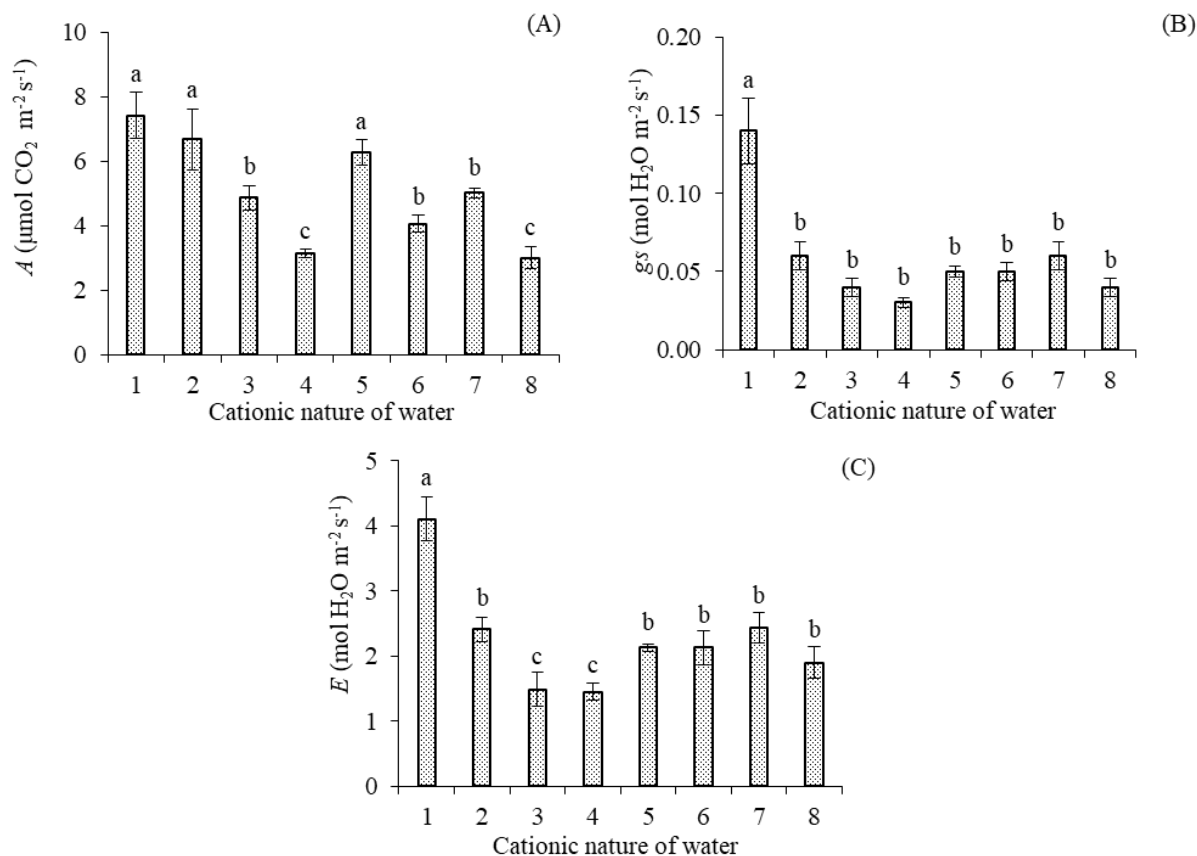
Table 1. Summary of the analysis of variance for CO_2 assimilation rate (A), internal CO_2 concentration (C_i), stomatal conductance (g_s) and transpiration (E) of yellow passion fruit plants cv. BRS Rubi do Cerrado irrigated with water of different cationic natures, at 180 days after transplanting.

VS/Contrasts [#]	DF	Mean square			
		A	C_i	g_s	E
Blocks	2	2.7274 ^{**}	2319.50 ^{ns}	0.0006 ^{ns}	0.5780 [*]
CNW	(7)	8.0025 ^{**}	1089.66 ^{ns}	0.0033 ^{**}	2.0951 ^{**}
\hat{y}_1	1	19.0688 ^{**}	135.72 ^{ns}	0.0212 ^{**}	11.8243 ^{**}
\hat{y}_2	1	4.9868 ^{**}	1204.16 ^{ns}	0.0008 ^{ns}	1.2512 ^{**}
\hat{y}_3	1	18.9748 ^{**}	1120.66 ^{ns}	0.0010 [*]	1.3632 ^{**}
\hat{y}_4	1	2.9821 [*]	1040.16 ^{ns}	0.0004 ^{ns}	0.6016 [*]
\hat{y}_5	1	11.3793 ^{**}	684.69 ^{ns}	0.0000 ^{ns}	0.0014 ^{ns}
\hat{y}_6	1	14.8208 ^{**}	1290.66 ^{ns}	0.0006 ^{ns}	0.6800 [*]
\hat{y}_7	1	4.1833 ^{**}	20.16 ^{ns}	0.0000 ^{ns}	0.0008 ^{ns}
Residual	14	0.4324	800.92	0.0002	0.0960
CV (%)		13.01	13.31	24.16	13.72

[#] \hat{y}_1 (S_1 vs S_2 ; S_3 ; S_4 ; S_5 ; S_6 ; S_7 ; S_8); \hat{y}_2 (S_2 vs S_3); \hat{y}_3 (S_2 vs S_4); \hat{y}_4 (S_3 vs S_5); \hat{y}_5 (S_5 vs S_6 ; S_7 ; S_8); \hat{y}_6 (S_4 vs S_5) and \hat{y}_7 (S_2 vs S_7); SV - Source of variation; DF - Degree of freedom; CV - Coefficient of variation; CNW - Cationic Nature of Water; (*) Significant at 0.05 probability level; (**) Significant at 0.01 probability level; (ns) not significant.

It is verified, through the means comparison test for the CO_2 assimilation rate (A) (Figure 1A), that plants cultivated with low-salinity water (S_1) and those irrigated with water of sodic (S_2) and sodic + calcic (S_3) composition obtained the highest values, equal to 7.41, 6.68 and 6.27 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$, compared to plants grown with water salinized by Ca^{2+} (S_3), Mg^{2+} (S_4), $Na^+ + Mg^{2+}$ (S_6), $Ca^{2+} + Mg^{2+}$ (S_7) and $Na^+ + Ca^{2+} + Mg^{2+}$ (S_8). However, there was no significant effect when comparing the plants of the treatment S_1 with plants irrigated with the treatments S_2 and S_3 . Among the different cationic compositions, it is observed that plants cultivated with water salinized by magnesium (S_4) and sodium + calcium + magnesium (S_8) obtained the lowest values of CO_2 assimilation rate, which corresponded to 3.13 and 3.00 $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$, respectively, at 180 DAT.

The reduction in CO_2 assimilation rate observed in this study may be related to the effect of salts on the soil, due to the reduction in the osmotic potential of the solution, inhibiting the absorption of water and nutrients by plants, resulting in stomatal closure. The increase in the CO_2 assimilation rate is related to the higher CO_2 concentration observed inside the leaves, which may result from stomatal closure in response to abiotic stresses (JADOSKI; SKAR; SALVADOR, 2005), in this case, the water stress caused by excess of salts in the soil. Reduction in CO_2 assimilation rate in passion fruit plants as a function of increasing salinity of irrigation water have also been observed by Andrade et al. (2019) and by Silva et al. (2019) in studies conducted under greenhouse conditions.



1 - Control; 2 - Na^+ ; 3 - Ca^{2+} ; 4 - Mg^{2+} ; 5 - $\text{Na}^+ + \text{Ca}^{2+}$; 6 - $\text{Na}^+ + \text{Mg}^{2+}$; 7 - $\text{Ca}^{2+} + \text{Mg}^{2+}$ and 8 - $\text{Na}^+ + \text{Ca}^{2+} + \text{Mg}^{2+}$. Bars represent standard error of the mean ($n = 3$). Means followed by equal letters do not differ by the Scott-Knott test ($p \leq 0.05$).

Figure 1. CO₂ assimilation rate - A (A), stomatal conductance - g_s (B) and transpiration - E (C) of yellow passion fruit plants cv. BRS Rubi do Cerrado as a function of the cationic nature of irrigation water, at 180 days after transplanting.

For stomatal conductance (g_s) (Figure 1B), it is verified that plants grown under the lowest salinity level (S_1) differed statistically from all those that were subjected to the different cationic natures (S_2 , S_3 , S_4 , S_5 , S_6 , S_7 and S_8). The means comparison test (Figure 1B) showed increments of 0.08, 0.10, 0.11, 0.09, 0.09, 0.08 and 0.10 $\text{mol H}_2\text{O m}^{-2} \text{ s}^{-1}$, respectively, in the stomatal conductance of plants grown under EC_w of 0.4 dS m^{-1} (S_1) compared to the different cationic natures of water (S_2 , S_3 , S_4 , S_5 , S_6 , S_7 and S_8). It is also verified that there was no statistical difference between treatments S_2 , S_3 , S_4 , S_5 , S_6 , S_7 and S_8 .

The stress caused by the high concentration of salts above the level tolerated by the crop leads to reduction in several physiological parameters of plants, such as water use efficiency, net CO₂ assimilation rate, transpiration and stomatal conductance in glycophytes species, such as passion fruit crop (FREIRE et al., 2014; LI et al., 2017). Lima et al. (2020b), studying the physiological, anatomical and nutritional growth responses of two passion fruit species under saline conditions (0 and 150 mM NaCl), observed a reduction in the stomatal conductance of plants of the species *Passiflora*

edulis as a function of water salinity.

For transpiration (E) (Figure 1C), it was verified that plants irrigated with water with lower electrical conductivity (S_1) obtained the highest values (4.11 $\text{mol H}_2\text{O m}^{-2} \text{ s}^{-1}$), differing statistically from plants cultivated under the highest salinity (S_2 ; S_3 ; S_4 ; S_5 ; S_6 ; S_7 and S_8). The lowest values were obtained when the plants were irrigated with water salinized by calcium (S_3) and magnesium (S_4). There was no significant difference between the plants that received the treatments S_2 , S_5 , S_6 , S_7 and S_8 .

The decrease in the leaf transpiration of plants may be related to the effect of salts on soil and plant, as the increase in irrigation water salinity allowed the accumulation of salts in the soil profile, close to the root system, causing the osmotic effect, hindering the absorption of water and nutrients by the roots, and in response to this stress the plant established greater control over the stomatal opening in order to avoid excessive water loss by transpiration (SOUZA et al., 2011). Reduction in transpiration and stomatal conductance as a function of salinity of irrigation water were also observed in passion fruit plants by Andrade et al. (2019).

According to the summary of the analysis of variance for the contrasts of means for the CO₂ assimilation rate (*A*) (Table 2), there was a significant effect when the plants irrigated with ECw of 0.4 dS m⁻¹ (S₁) were compared with those

cultivated with ECw of 3.5 dS m⁻¹ (S₂; S₃; S₄; S₅; S₆; S₇ and S₈), with an increase of 2.69 mol CO₂ m⁻² s⁻¹ in plants subjected to ECw = 0.4 dS m⁻¹ compared to those under the highest salinity level (3.5 dS m⁻¹).

Table 2. Estimate of mean referring to the CO₂ assimilation rate (*A*), internal CO₂ concentration (*C_i*), stomatal conductance (*g_s*) and transpiration (*E*) of yellow passion fruit plants cv. BRS Rubi do Cerrado irrigated with water of different cationic natures, at 180 days after transplanting.

Contrasts [#]	Mean estimate			
	<i>A</i>	<i>C_i</i>	<i>g_s</i>	<i>E</i>
\hat{y}_1	2.69	-	0.09	2.12
\hat{y}_2	1.82	-	-	0.91
\hat{y}_3	3.55	-	0.02	0.95
\hat{y}_4	-1.41	-	-	-0.63
\hat{y}_5	2.24	-	-	-
\hat{y}_6	-3.14	-	-	-0.67
\hat{y}_7	1.67	-	-	-

[#] \hat{y}_1 (S₁ vs S₂; S₃; S₄; S₅; S₆; S₇; S₈); \hat{y}_2 (S₂ vs S₃); \hat{y}_3 (S₂ vs S₄); \hat{y}_4 (S₃ vs S₅); \hat{y}_5 (S₅ vs S₆; S₇; S₈); \hat{y}_6 (S₄ vs S₅) and \hat{y}_7 (S₂ vs S₇); (-) not significant.

It is also noted that plants irrigated with water prepared with sodium (S₂) had an increase of 1.82 μmol CO₂ m⁻² s⁻¹ in the CO₂ assimilation rate compared to those cultivated with water prepared using calcium (S₃). When observing the contrast of \hat{y}_3 (S₂ versus S₄), a significant difference is verified, with an increase of 3.55 μmol CO₂ m⁻² s⁻¹ in the *A* of plants subjected to salinity of water with sodic composition (S₂) compared to the treatment S₄. It is also observed that when plants were irrigated with water prepared with calcium (S₃), there was a reduction of 1.41 mol CO₂ m⁻² s⁻¹ in the CO₂ assimilation rate compared to those irrigated with water salinized by sodium + calcium (S₅).

The contrast \hat{y}_5 shows that plants irrigated with water composed of sodium + calcium (S₅) had an increase of 2.24 μmol CO₂ m⁻² s⁻¹ in *A* when compared with the treatments S₆, S₇ and S₈. The results obtained for the \hat{y}_6 point to a reduction of 3.14 μmol CO₂ m⁻² s⁻¹ in plants that received water salinized with magnesium (S₄) when compared to plants that received water salinized by the mixture of sodium + calcium (S₅). There was an increase of 1.67 μmol CO₂ m⁻² s⁻¹ when plants received the treatment S₂ compared to those receiving water related to the treatment S₇.

For stomatal conductance (*g_s*), it can be noted by the estimate of the mean (Table 2) that passion fruit plants grown under the lowest level of electrical conductivity (0.4 dS m⁻¹) were statistically superior to those that were subjected to irrigation with water of higher salinity level (3.5 dS m⁻¹), with an increase in *g_s* of 0.09 mol H₂O m⁻² s⁻¹ in plants that received the treatment S₁, compared to the different cationic natures of the water (S₂; S₃; S₄; S₅; S₆; S₇ and S₈).

When comparing passion fruit plants

subjected to the treatment S₂ versus S₄, an increase in *g_s* of 0.02 mol H₂O m⁻² s⁻¹ was noted in plants that received water salinized with sodium (S₂), compared to those that subjected to salinity of water prepared only with magnesium (S₄). There was no significant effect when comparing the treatments S₂ versus S₃, S₃ versus S₅, S₅ versus S₆, S₇ and S₈, S₄ versus S₅ and S₂ versus S₇, indicating similar deleterious effect, regardless of the type of cation present in irrigation water (Table 2).

According to the summary of the analysis of variance for the contrasts of means related to transpiration (*E*) (Table 2), plants grown under water salinity of 0.4 dS m⁻¹ differed statistically from those subjected to the different cationic compositions of water (S₂, S₃, S₄, S₅, S₆, S₇ and S₈), with an increase of 2.12 mol H₂O m⁻² s⁻¹ in plants that received the treatment S₁, in comparison to the other treatments.

When comparing plants that received irrigation water salinized with sodium (S₂) with those that received water salinized with calcium (S₃), an increase of 0.91 mol H₂O m⁻² s⁻¹ was observed in plants irrigated with S₂. Similar behavior occurred when S₂ was compared with S₄, where the increase in transpiration (*E*) was equal to 0.95 mol H₂O m⁻² s⁻¹ in plants that received S₂.

When plants cultivated with water composed of calcium (S₃) were compared to those subjected to water composed of sodium + calcium (S₅), there was a reduction of 0.63 mol H₂O m⁻² s⁻¹ in plants irrigated with calcic water (S₃). Similar result was found when comparing S₄ versus S₅, where there was a reduction of 0.67 mol H₂O m⁻² s⁻¹ in plants irrigated with water salinized by magnesium (S₄) compared to the treatment S₅. There was no significant effect when comparing S₅ versus S₆, S₇

and S_8 , and S_2 versus S_7 , indicating the deleterious effect of salt stress; however, the magnitude is dependent on the type of cation present in irrigation water.

According to the analysis of variance (Table 3), there was a significant effect of the different

cationic natures of irrigation water on the variables polar diameter, fresh fruit mass, average fruit mass and number of fruits of yellow passion fruit plants cv. BRS Rubi do Cerrado.

Table 3. Summary of the analysis of variance for equatorial diameter (ED), polar diameter (PD), fresh fruit mass (FFM), average fruit mass (AFM) and number of fruits (NFruP) of yellow passion fruit plants cv. BRS Rubi do Cerrado irrigated with water of different cationic natures, at 259 days after transplanting.

VS/Contrasts [#]	DF	Mean square				
		ED	PD	FFM	AFM	NFruP
Blocks	2	10.38 ^{ns}	30.17 ^{ns}	24845.50 ^{ns}	512.34 ^{ns}	3.29 ^{ns}
CNW	(7)	47.11 ^{ns}	99.76 [*]	155102.47 ^{**}	1828.80 [*]	21.08 ^{**}
\hat{y}_1	1	33.38 ^{ns}	148.53 ^{ns}	18764.66 [*]	2312.66 ^{ns}	108.48 ^{**}
\hat{y}_2	1	1.78 ^{ns}	109.73 ^{ns}	459045.36 ^{**}	1823.52 ^{ns}	24.00 [*]
\hat{y}_3	1	14.66 ^{ns}	4.52 ^{ns}	46610.19 ^{ns}	719.85 ^{ns}	0.16 ^{ns}
\hat{y}_4	1	16.93 ^{ns}	157.08 ^{ns}	305372.16 [*]	4657.63 ^{**}	6.00 ^{ns}
\hat{y}_5	1	46.14 ^{ns}	87.45 ^{ns}	5449.63 ^{ns}	1634.85 ^{ns}	1.36 ^{ns}
\hat{y}_6	1	43.68 ^{ns}	0.00 ^{ns}	8275.53 ^{ns}	2743.05 [*]	4.16 ^{ns}
\hat{y}_7	1	10.42 ^{ns}	60.54 ^{ns}	186913.50 [*]	1880.44 ^{ns}	8.16 ^{ns}
Residual	14	19.60	37.32	37529.61	541.28	3.83
CV (%)		7.11	7.67	39.78	26.05	34.30

[#] \hat{y}_1 (S_1 vs S_2 ; S_3 ; S_4 ; S_5 ; S_6 ; S_7 ; S_8); \hat{y}_2 (S_2 vs S_3); \hat{y}_3 (S_2 vs S_4); \hat{y}_4 (S_3 vs S_5); \hat{y}_5 (S_5 vs S_6 ; S_7 ; S_8); \hat{y}_6 (S_4 vs S_5) and \hat{y}_7 (S_2 vs S_7); SV - Source of variation; DF - Degree of freedom; CV - Coefficient of variation; CNW - Cationic Nature of Water; (*) Significant at 0.05 probability level; (**) Significant at 0.01 probability level; (ns) not significant.

Through the means comparison test for polar diameter (Figure 2A), it was observed that there was no significant difference between plants grown under irrigation with low-salinity water (S_1) and the treatments S_2 , S_4 , S_5 and S_6 . However, when comparing the PD as a function of the different cationic compositions of the water, there was a significant effect only on plants irrigated with water composed of calcium (S_3), calcium + magnesium (S_7) and sodium + calcium + magnesium (S_8) compared to the treatments S_2 , S_4 , S_5 and S_6 .

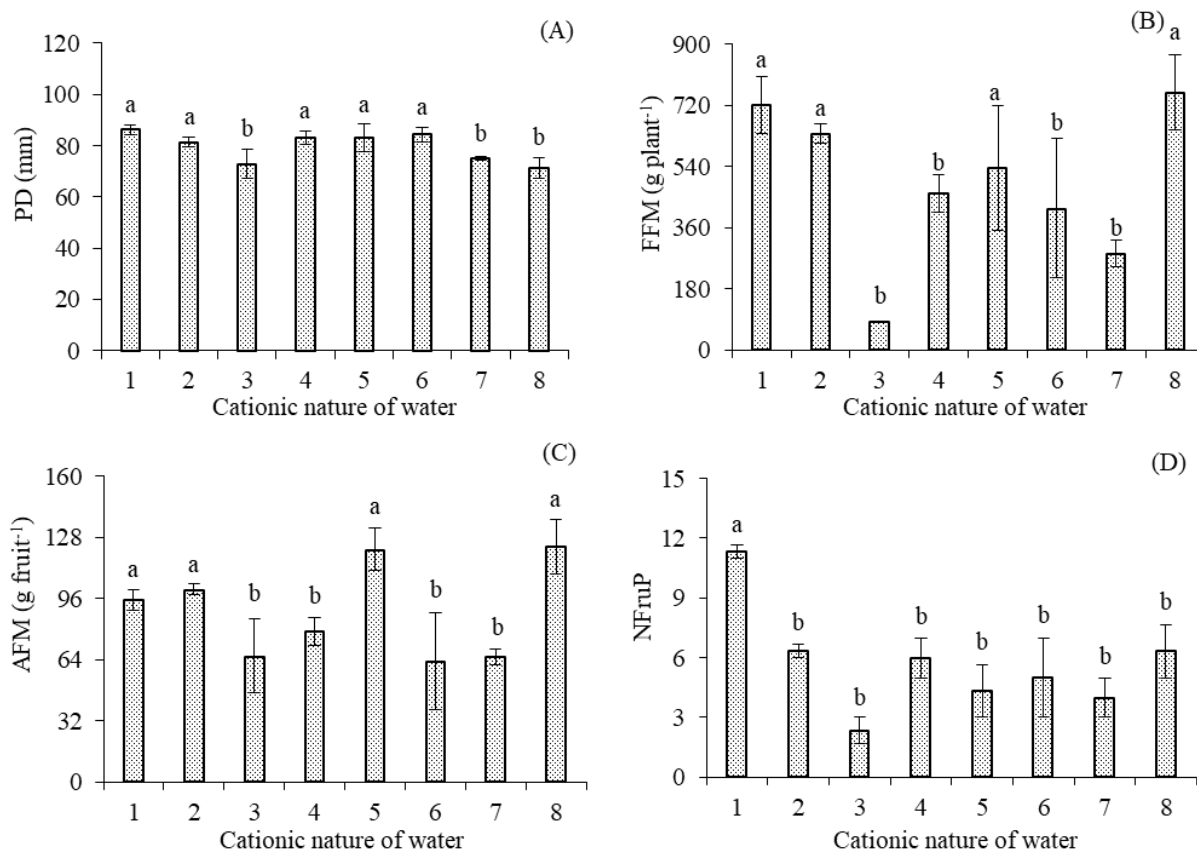
It is noted that, except for the treatment S_5 , all other treatments containing Ca^{2+} in their composition (S_3 , S_7 and S_8) had the lowest results for PD of yellow passion fruit cv. BRS Rubi do Cerrado. According to Pallardy (2008), among the osmotic agents, calcium chloride is the salt that has the greatest deleterious effect on plant development, as Ca^{2+} is a secondary messenger of signal transduction, and small variations in its concentration promote changes in the activity of enzymes linked to this nutrient.

For the fresh fruit mass per plant (Figure 2B), it was verified that there was no significant difference between plants subjected to the treatments

S_1 (Control), S_2 (Na^+), S_5 (Na^+ + Ca^{2+}) and S_8 (Na^+ + Ca^{2+} + Mg^{2+}). It is worth highlighting that the lowest values (84.0; 460.92, 416.43 and 284.20 g plant⁻¹) were obtained when irrigation was performed with water composed of Mg^{2+} (S_3), Mg^{2+} (S_4) Na^+ + Ca^{2+} (S_6) and Na^+ + Mg^{2+} (S_7), respectively, with no statistical difference between the means obtained by these treatments.

For the average fruit mass (Figure 2C), it was observed that the highest values (95.26; 100.73; 121.59 and 123.31 g fruit⁻¹) were obtained when the plants were irrigated with water composed of S_1 , S_2 , S_5 , and S_8 , respectively, statistically differing from those that received the treatments S_3 , S_4 , S_6 and S_7 , which obtained the lowest values (65.86; 78.86; 63.30 and 65.49 g fruit⁻¹, respectively).

Dias et al. (2012), studying the physical quality and production of yellow passion fruit with saline waters (0.5; 1.5; 2.5; 3.5 and 4.5 dS m⁻¹), observed more drastic losses in fruit quality when plants were irrigated using water with ECw greater than 2.5 dS m⁻¹, with average values of 191.29 g plant⁻¹ for plants irrigated with the lowest salinity level and 151.87 g fruit⁻¹ for plants that were irrigated using water with salinity of 3.5 dS m⁻¹.



1 - Control; 2 - Na⁺; 3 - Ca²⁺; 4 - Mg²⁺; 5 - Na⁺ + Ca²⁺; 6 - Na⁺ + Mg²⁺; 7 - Ca²⁺ + Mg²⁺ and 8 - Na⁺ + Ca²⁺ + Mg²⁺. Bars represent standard error of the mean (n = 3). Means followed by equal letters do not differ by the Scott-Knott test (p < 0.05).

Figure 2. Polar diameter - PD (A), fresh fruit mass - FFM (B) average fruit mass - AFM (C) and number of fruits - NFruP (D) of yellow passion fruit plants cv. BRS Rubi do Cerrado, as a function of the cationic nature of irrigation water, at 259 days after transplanting.

The number of fruits per plant was also significantly influenced by the salinity of the irrigation water and, through the means comparison test (Figure 2D), it was verified that plants irrigated with water of the control treatment (S₁) obtained higher values (11.33 fruits), differing statistically from those of all other treatments (S₂, S₃, S₄, S₅, S₆, S₇ and S₈). However, when comparing plants grown under different cationic natures, it is observed that there was no significant difference between them.

The reduction in production may be related to the action of excess salts in the soil solution, which results in the reduction of osmotic potential, imposing restriction on the absorption of water and nutrients by the plant, besides causing ionic toxicity (especially Na⁺ and Cl⁻) and nutritional imbalance, negatively affecting fruit quality parameters (DIAS et al., 2012).

In addition to salt stress, another factor that may have contributed to low production or induction of flower abortion, and consequently a lower number of fruits, was thermal stress, caused by the high

temperatures inside the greenhouse during the flowering and fruiting stages, being observed in this period average temperatures of 29.1 °C.

According to the summary of the analysis of variance for the contrasts of means for the fresh fruit mass (Table 4), there was a significant effect on plants irrigated with ECw of 0.4 dS m⁻¹ (S₁) in comparison to those cultivated under ECw of 3.5 dS m⁻¹ (S₂; S₃; S₄; S₅; S₆; S₇ and S₈), where plants subjected to water of lower salinity level (0.4 dS m⁻¹) obtained an increase in FFM of 267.37 g plant⁻¹ compared to the other treatments studied (S₂, S₃, S₄, S₅, S₆ and S₇). In addition, it is also observed that plants irrigated with water of sodic composition (S₂) had an increase of 553.20 g plant⁻¹ in FFM compared to those grown using water prepared with calcium (S₃).

When comparing S₃ versus S₅, it was observed that there was a reduction of 451.20 g plant⁻¹ in plants irrigated with calcic water (S₃) in comparison to plants irrigated with water composed of sodium + calcium (S₅). When analyzing the

contrast \hat{y}_7 , corresponding to treatments S_2 versus S_7 , there was a significant difference, with an increase in FFM of 353 g plant⁻¹ in plants that were irrigated with treatment S_2 in comparison to S_7 . There was no

significant effect when comparing the treatments S_2 versus S_4 , S_5 versus S_6 , S_7 , S_8 and S_4 versus S_5 (Table 4).

Table 4. Estimation of means for equatorial diameter (ED) and polar diameter (PD), fresh fruit mass (FFM), average fruit mass (AFM) and number of fruits (NFruP) of passion fruit plants irrigated with water of different cationic natures, at 259 days after transplanting.

Contrasts [#]	Mean estimate				
	ED	PD	FFM	AFM	NFruP
\hat{y}_1	-	-	267.37	-	6.42
\hat{y}_2	-	-	553.20	-	4.00
\hat{y}_3	-	-	-	-	-
\hat{y}_4	-	-	-451.20	-55.72	-
\hat{y}_5	-	-	-	-	-
\hat{y}_6	-	-	-	-42.76	-
\hat{y}_7	-	-	353.00	-	-

[#] \hat{y}_1 (S_1 vs S_2 ; S_3 ; S_4 ; S_5 ; S_6 ; S_7 ; S_8); \hat{y}_2 (S_2 vs S_3); \hat{y}_3 (S_2 vs S_4); \hat{y}_4 (S_3 vs S_5); \hat{y}_5 (S_5 vs S_6 ; S_7 ; S_8); \hat{y}_6 (S_4 vs S_5) and \hat{y}_7 (S_2 vs S_7); (-) not significant.

Also according to the contrasts of means (Table 4), a significant effect was observed for the average fruit mass when comparing treatments S_3 versus S_5 , where it was noted that plants irrigated with water salinized by calcium (S_3) had the average fruit mass reduced by 55.72 g fruit⁻¹ compared to plants that were irrigated with water composed of sodium + calcium (S_5). On the other hand, plants irrigated with water prepared using magnesium (S_4) obtained a reduction of 42.76 g fruit⁻¹ compared to those that were subjected to salinity of the water composed of sodium + calcium (S_5).

There was no significant difference in the average fruit mass for the other contrasts of the means (\hat{y}_1 ; \hat{y}_2 ; \hat{y}_3 ; \hat{y}_5 and \hat{y}_7), denoting a similar effect among the cations studied on the yellow passion fruit crop.

For the number of fruits, there was a significant effect when the treatment of low salinity (S_1) was compared to the other treatments (S_2 ; S_3 ; S_4 ; S_5 ; S_6 ; S_7 ; S_8), and an increase of 6.42 fruits per plant was observed in plants that received the control treatment (S_1) in comparison to all other treatments (Table 4). A significant effect was also observed when the treatments S_2 versus S_3 were compared, where the plants subjected to salinity of the water of sodic composition (S_2) obtained an average increase of 4 fruits compared to plants that were irrigated with water salinized using calcium (S_3).

There was no significant difference for AFM when comparing the treatments S_2 versus S_4 ; S_3 versus S_5 ; S_5 versus S_6 , S_7 , S_8 ; S_4 versus S_5 and S_2 versus S_7 , which indicated that the types of salts perform similar functions in the functioning of the plants.

CONCLUSIONS

Water salinity of 3.5 dS m⁻¹ reduces gas exchange, and stomatal conductance and transpiration are the most sensitive variables of passion fruit.

The number of fruits of passion fruit cv. BRS Rubi do Cerrado decreases with water salinity, regardless of the cationic nature.

Waters of calcic and calcic+magnesian nature promote the greatest deleterious effects on the production variables of passion fruit, at 259 days after transplanting.

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