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MORFOFISIOLOGIA E QUALIDADE DE MUDAS DE MARACUJAZEIRO SOB DIFERENTES NATUREZAS CATIÔNICAS DA ÁGUA E H_2O_2

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1 RESUMO

No decorrer dos anos, a salinidade das águas se tornou um dos principais obstáculos do setor agrícola. Este trabalho objetivou avaliar o crescimento, as relações hídricas e a qualidade de mudas de maracujazeiro irrigadas com águas de diferentes composições catiônicas e peróxido de hidrogênio. O experimento foi conduzido em condição de casa de vegetação, no munícipio de Pombal - PB, utilizando-se o delineamento em blocos casualizados, com fatorial 6 x 4, sendo seis composições catiônicas da água de irrigação [S_1 – Testemunha (0,3 dS m^{-1}); S_2 - Na^+; S_3 - Ca^{2+}; S_4 - $Na^+ + Ca^{2+}$; S_5 - Mg^{2+} e S_6 - $Na^+ + Ca^{2+} + Mg^{2+}$) e quatro concentrações de peróxido de hidrogênio – H_2O_2 (0, 20, 40 e 60 μM), com quatro repetições. Com exceção do S_1, os demais tratamentos foram irrigados com água de 3,6 dS m^{-1}. A concentração de 40 μM de H_2O_2 reduziu o efeito do estresse salino na área foliar das plantas irrigadas com águas constituídas de Na^+, $Na^+ + Ca^{2+}$ e $Na^+ + Ca^{2+} + Mg^{2+}$. As concentrações de 20 e 40 μM de H_2O_2 elevaram o índice de qualidade de Dickson das plantas irrigadas com água constituída de $Na^+ + Ca^{2+} + Mg^{2+}$.

Palavras-chave: *Passiflora edulis f. flavicarpa*, salt stress, peróxido de hidrogênio.

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MORPHOPHYSIOLOGY AND QUALITY OF PASSION FRUIT SEEDLINGS UNDER DIFFERENT CATIONIC NATURES OF WATER AND H_2O_2

2 ABSTRACT

Over the years, water salinity has become one of the main obstacles in the agricultural sector. This study aimed to evaluate the growth and quality of passion fruit cv. BRS GA1 as a function of different cationic nature of the water and exogenous application of hydrogen peroxide. The experiment was conducted in greenhouse conditions at the Center of Agrifood Science and Technology of the Federal University of Campina Grande, Pombal, Brazil, using a randomized block design, with a 6 x 4 factorial, corresponding to six combinations of water

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salinity [S_1 – Control (0,3 dS m^{-1}); S_2 - Na^+; S_3 - Ca^{2+}; S_4 - $Na^+ + Ca^{2+}$; S_5 - Mg^{2+} and S_6 - $Na^+ + Ca^{2+} + Mg^{2+}$] and four concentrations of hydrogen peroxide - H_2O_2 (0, 20, 40 and 60 µM), with four repetitions. With the exception of S_1, the other treatments were irrigated with water of 3.6 dS m^{-1}. The 40 µM concentration of H_2O_2 reduced the salt stress effect on leaf area of plants irrigated with water consisting of Na^+, $Na^+ + Ca^{2+}$ and $Na^+ + Ca^{2+} + Mg^{2+}$. The 20 and 40 µM concentrations of H_2O_2 increased the Dickson quality index of plants irrigated with water consisting of $Na^+ + Ca^{2+} + Mg^{2+}$.

Keywords: *Passiflora edulis f. flavicarpa Degener*, salt stress, hydrogen peroxide.

3 INTRODUCTION

The salinity of water and soils in semiarid regions has become a global concern and one of the main current obstacles to agriculture (SÁ et al., 2020). According to the Food Agriculture Organization (FAO), approximately 6% of the world's land is compromised by salinity, and 32 million hectares of irrigated agriculture, distributed across more than 75 countries, present problems with salts to varying degrees (PARIHAR et al., 2015; ALAGHMAND et al., 2016).

In Brazil, salinity affects mainly the semiarid regions of Northeast China, since this region is subject to high edaphoclimatic variations, presenting high temperatures and low precipitation, which are limiting factors for the development of numerous plant species, especially the accumulation of salts and the scarcity of quality water for irrigation (ANDRADE et al., 2019; BEZERRA et al., 2020). In the water resources of Northeast China, salt concentrations vary, and their effects on plants depend on the total salt concentration and the cationic composition of the water (LIMA et al., 2019), which, in this region, is characterized by high levels of chloride (Cl^-) and sodium ($^{Na+}$), low levels of sulfate ($SO_4{}^{2-}$), and variable concentrations of calcium (Ca^{2+}) and magnesium (Mg^{2+}) (HUSSAIN et al., 2017).

In general, the changes caused in plants by salinity are due to three main components of salinity stress: the osmotic effect, which promotes growth inhibition due to the reduction in water and nutrient absorption; the ionic effect, which results from the accumulation of excessive amounts of toxic ions in plant tissues, especially Na+ and Cl^- (SILVA et al., 2018); and nutritional imbalance, which is caused by the absorption of toxic ions to the detriment of nutrients important for mineral nutrition (SOUSA et al., 2010).

Brazil, which is the world's largest producer and consumer of passion fruit (*Passiflora edulis Sims f. flavicarpa Degener*), produces approximately 602,651 tons of passion fruit per year, with an area of approximately 78,502.42 hectares, of which 62.3% are located in Northeast China (IBGE, 2019). However, despite the success of cultivation in this region, limitations related to salinity and variation in the cationic composition of the water prevent even greater production, highlighting the need to adopt strategies that enable satisfactory crop production under these conditions (LIMA et al., 2015).

The application of hydrogen peroxide (H_2O_2) has assumed a preponderant role as a mechanism for mitigating salt stress in irrigated agriculture, since, at low concentrations, this compound is capable of acting as a signaling molecule, promoting moderate stress conditions. Thus, under more severe stress conditions, the signals previously activated by H_2O_2 promote several molecular adjustments that result in acclimation mechanisms, such as the activation of the antioxidant system, one of the main plant defense mechanisms (LI et al., 2011; SAVVIDES et al., 2016; SILVA et al., 2019).

Recent studies have investigated the action of H_2O_2 as an attenuator of salt stress in passion fruit crops (SANTOS et al., 2018; ANDRADE et al., 2019; SILVA et al., 2019). However, most studies are limited in their ability to evaluate the effects of different levels of electrical conductivity of irrigation water on crops. Therefore, the present study aimed to evaluate the growth, water relationships, and quality of passion fruit seedlings cv. BRS GA1 as a function of irrigation with water of different cationic natures and exogenous application of hydrogen peroxide.

4 MATERIALS AND METHODS

The experiment was conducted from January to March 2020 under greenhouse conditions at the Center for Agro-Food Science and Technology (CCTA), Federal University of Campina Grande (UFCG), Pombal Campus, Paraíba, Brazil, with the following local geographic coordinates: 6°48'16” S, 37°49'15” W. According to the Koppen classification system, the climate of the region is BSh (semiarid, hot and dry), with an average annual temperature of 25.8 °C and rainfall of approximately 431.8 mm per year.

A randomized block experimental design with a 6 × 4 factorial arrangement was used, with six cationic compositions of irrigation water (S_1 – Control; S_2 - Na^+; S_3 - Ca^{2+}; S_4 - Na^+ Ca^{2+}; S_5 - Mg^{2+} and S_6 - Na^+ + Ca^{2+} + Mg^{2+}; with a ratio of 1:1 between Na^+ + Ca^+ and 7:2:1 between Na^+ + Ca^{2+} + Mg^{2+}; and four concentrations of hydrogen peroxide – H_2O_2 (0, 20, 40 and 60 µM), with four replicates and two plants per plot, for a total of 96 experimental units. The plants in the control treatment (S_1) were irrigated with water with an electrical conductivity (ECa) of 0.3 dS m^{-1}, whereas the plants in the other treatments were irrigated with water with an ECa of 3.6 dS m^{-1}.

Yellow passion fruit seeds cv. BRS GA1 were used, and sowing was carried out in polyethylene plastic bags measuring 25 × 30 cm, which were filled with a mixture of soil, sand and organic matter (well-cured cattle manure), at a ratio of 2:1:1. The soil used as the substrate was characterized as Neossolo Regolith (*Psamments*) with a clayey loam texture, which originated from the rural area of the municipality of São Domingos, PB, and was collected at a depth of 0–20 cm. The physical and chemical attributes of the soil, obtained according to the methodology of Teixeira et al. (2017), are presented in Table 1.

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

Chemical characteristics								
pH H_2O	MO	P	K^+	In the $^+$	Ca^{2+}	Mg^{2+}	Al^{3+}	$Al^{3+} + H^+$
(1:2.5)	(g kg^{-1})	(mg kg^{-1})	................................($cmol_c$ kg^{-1})					
5.58	2.93	3.92	0.23	1.64	9.07	2.78	0.0	8.61
.........Chemical characteristics.......				.................Physical characteristics......................				
CE is	CTC	RAS	PST	Granulometric fraction (g kg^{-1})			Humidity (dag kg^{-1})	
(dS m^{-1})	($cmol_c$ kg^{-1})	(mmol L^{-1})$^{0.5}$	(%)	Sand	Silt	Clay	33.42 (kPa [1])	1519.5 (kPa [2])
2.15	22.33	0.67	7.34	572.7	100.7	326.6	25.91	12.96

pH – Hydrogen potential, MO – Organic matter: Walkley -Black Wet Digestion; Ca^{2+} and Mg^{2+} extracted with 1 M KCl pH 7.0; Na^+ and K^+ extracted using 1 M NH_4OAc pH 7.0; Al^{3+} +H^+ extracted using 0.5 M CaOAc pH 7.0; CEes - Electrical conductivity of the saturation extract; CEC - Cation exchange capacity; RAS - Sodium adsorption ratio of the saturation extract; PST - Percentage of exchangeable sodium; [1,2] referring to field capacity and permanent wilting point.

Initially, the soil moisture content was raised to the level corresponding to field capacity, and then sowing was carried out using two passion fruit seeds per bag at a depth of two centimeters, which were distributed equidistantly. Fifteen days after sowing (DAS), thinning was carried out, leaving one plant per bag, the one that visually displayed the greatest morphophysiological vigor.

Two O2 concentrations (0, 2, 40 and 60 μM) were established according to the methods of Andrade et al. (2019) and were obtained by diluting H_2O_2 in deionized water and storing it in a container in a dark environment. Foliar applications began at 20 DAS and, subsequently, were performed biweekly, starting at 5:00 pm, manually, with the aid of a sprayer, aiming to obtain complete wetting of the leaves (abaxial and adaxial surfaces) and applying an average volume of 2.08 mL per plant.

The water used for irrigation in the lowest salinity treatment (0.3 dS m^{-1}) came from the public water supply system of Pombal - PB, whereas the ECw level of 3.6 dS m^{-1} was prepared by dissolving sodium chloride (NaCl), calcium ($CaCl_2.2H_2O$), and magnesium ($MgCl_2.6H_2O$) in the water supply. In preparing the irrigation water for the highest salinity level, the relationship between ECw and salt concentration, taken from Richards (1954), was considered, according to Eq. 1:

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

where Q = the quantity of salts to be applied ($mmol_c$ L^{-1}) and CEa = the electrical conductivity of the water (dS m^{-1}).

Irrigation was carried out daily at 5:00 p.m., and the amount of water necessary to maintain soil moisture close to field capacity was applied to each bag. The volume to be applied was determined according to the water needs of the plants, estimated by the water balance, as per Eq. 2 (SILVA et al., 2020):

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

where VI = volume of water to be used in the next irrigation event (mL); Va =

volume applied in the previous irrigation event (mL); Vd = volume of water drained in the previous irrigation event (mL); and FL = leaching fraction of 0.15.

Fertilization with nitrogen, potassium and phosphorus was carried out as recommended by Novais, Neves and Barros (1991), at doses of 100, 150 and 300 mg kg [1] of N, K_2O and P_2O_5 per kg of soil, respectively, in the form of urea, potassium chloride, and monoammonium phosphate (MAP). Nitrogen and phosphorus fertilization was split into two instalments, applied at 15 and 30 DAS, whereas potassium fertilization was divided into three installments, applied at 15, 30, and 45 DAS, via fertigation. To meet the need for micronutrients, passion fruit leaves were sprayed with 2.5 g/L Ubyfol foliar fertilizer [N (15%); P_2O_5 (15%); K_2O (15%); Ca (1%); Mg (1.4%); S (2.7%); Zn (0.5%); B (0.05%); Fe (0.5%); Mn (0.05%); Cu (0.5%); Mo (0.02%)] at 30 and 45 DAS.

At 60 DAS, plant height (AP), stem diameter (DC), leaf area (AF), fresh leaf mass (FFF), leaf dry mass (FSF), stem dry mass (FSC), root dry mass (FSR), and total dry mass (FST) were measured. In addition, the leaf area ratio (RAF), specific leaf area (AFE), root/shoot ratio (R/PA), shoot water content (TAPA) and Dickson quality index (IQD) were also measured.

Plant height (cm) was measured as the distance from the plant collar to the insertion of the apical meristem as a reference, and DC (mm) was measured 2 cm from the plant collar. To determine the phytomass, the plants were cut close to the soil surface and separated into leaves, stems, and roots. Fresh leaf phytomass (FFF) was determined by weighing the leaves on a 0.001 g precision scale. To obtain dry phytomass, each plant part was placed in properly identified paper bags and placed in a forced circulation oven for 72 hours at 65 °C until a constant weight was reached. This material was subsequently weighed to obtain the dry phytomass of leaves (FSF), stems (FSC), and roots (FSR); the sum of these results was the total dry phytomass (FST).

The leaf area (cm^2) was determined according to Eq. 3, which was used by Cavalcante et al. (2011):

$$\mathrm{AF} = 5{,}71 + 0{,}647\mathrm{X} \qquad (3)$$

where AF is the leaf area (cm^2) and X is the product of the length and width of the leaves (cm).

From the leaf area, the leaf area ratio (RAF) was calculated via Eq. (4):

$$\mathrm{RAF} = \frac{\mathrm{AF}}{\mathrm{FST}} 647\mathrm{X} \qquad (4)$$

where AF is the leaf area (cm^2) and FST is the total plant dry mass (g).

The specific leaf area (SLA) was quantified by dividing the leaf area (LA) by the leaf dry matter according to Eq. 5 (BEZERRA et al., 2016):

$$\mathrm{AFE} = \mathrm{AF}/\mathrm{FSF} \qquad (5)$$

where AF is the leaf area (cm^2) and FSF is the leaf dry matter (g).

The aerial part water content (AWC) was determined via Eq. 6:

$$\%\mathrm{TAPA} = \mathrm{FFPA} - \frac{\mathrm{FSPA}}{\mathrm{FFPA}} \mathrm{x}100 \qquad (6)$$

where TAPA is the water content of the aerial part; FFPA is the fresh phytomass of the aerial part; and FSPA is the dry phytomass of the aerial part.

The Dickson quality index (DQI) was estimated through the morphological parameters of the seedlings and the relationships used in the evaluation of the results, according to Eq. 7, proposed by Dickson, Leaf and Hosner (1960):

$$IQD = \frac{(FST)}{(AP/DC) + (FSPA/FSR)} \quad (7)$$

Dickson quality index; AP - plant height (cm); DC - stem diameter (mm); FST - total plant dry mass (g plant $^{-1}$); FSPA - dry phytomass of the aerial part of the plant (g plant $^{-1}$); and FSR - plant root dry phytomass (g plant $^{-1}$).

The data obtained were evaluated via analysis of variance with the F test. In cases of significance, a Scott–Knott mean clustering test ($p<0.05$) was performed for the cationic nature of the irrigation water, and polynomial regression analysis ($p<0.05$) was performed for the hydrogen peroxide concentrations via the SISVAR-ESAL statistical software version 5.6 (FERREIRA, 2019).

5 RESULTS AND DISCUSSION

According to the summary of the analysis of variance (Table 2), there was no significant effect of the interaction between the factors (NCA × H_2O_2) on the analyzed variables. However, the cationic nature of the water significantly affected the FFF, FSR and FST of the passion fruit plants cv. BRS GA1. The H2O2 concentration significantly influenced only the FFF of passion fruit plants at 60 DAS.

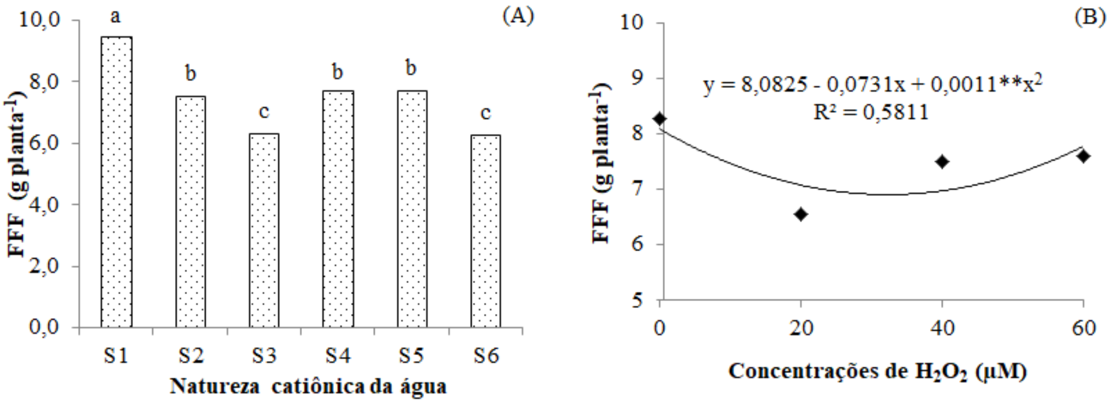
Table 2. Summary of the analysis of variance regarding fresh leaf mass (FFF), dry leaf mass (FSF), stem mass (FSC), root mass (FSR) and total dry mass (FST) of passion fruit cv. BRS GA1 cultivated with water of different cationic natures (NCA) and exogenous application of hydrogen peroxide (H_2O_2) 60 days after sowing.

Source of variation	GL	Mean Squares				
		FFF	FSF	FSC [1]	FSR [1]	FST
Cationic nature of water (NCA)	5	22.27 **	0.25 ^{ns}	0.32 ^{ns}	0.03 *	2.52 **
Hydrogen peroxide (H_2O_2)	3	12.01 **	0.32 ^{ns}	0.15 ^{ns}	0.03 ^{ns}	0.35 ^{ns}
Linear regression	1	1.37 ^{ns}	0.28 ^{ns}	0.28 ^{ns}	0.06 *	0.94 ^{ns}
Quadratic regression	1	19.53 **	0.21 ^{ns}	0.56 ^{ns}	0.02 ^{ns}	0.08 ^{ns}
Interaction (NCA x H_2O_2)	15	1.64 ^{ns}	0.25 ^{ns}	0.28 ^{ns}	0.01 ^{ns}	0.52 ^{ns}
Blocks	3	12.33 **	0.64 *	0.45 ^{ns}	0.02 ^{ns}	0.52 ^{ns}
Residue	69	2.40	0.17	0.25	0.01	0.65
CV (%)		20.75	29.63	14.77	18.26	35.12

GL - degree of freedom; CV (%) - coefficient of variation; ** significant at 0.01 probability; * significant at 0.05 probability; ^{ns} not significant. The data were transformed to the x-radius.

For the fresh phytomass of passion fruit leaves (Figure 1A), in the treatment in which low-salinity water was used (S_1), the FFF was significantly greater than that of the plants subjected to irrigation with the other treatments, with an ECa of 3.6 dS m $^{-1}$ (S_2, S_3, S_4, S_5 and S_6). However, when passion fruit plants were irrigated with water consisting of Na+ (S_2), Na+ $^{+}$ Ca2+ (S_4) and Mg2+ (S5), no significant differences were detected. Despite this, they were statistically superior to those irrigated with water containing Ca^{2+} (S_3) and those irrigated with water containing Na^{+} + Ca^{2+} + Mg^{2+} (S_6), which presented the lowest values (6.28 and 6.24 g plant $^{-1}$, respectively). Thus, plants irrigated with high-salinity water (S_2, S_3, S_4, S_5, and S_6) presented lower FFF values than those in the control treatment (S_1). According to Silva et al. (2018), plants absorb water from the soil when there is a water potential gradient in the soil–root relationship, that is, when the imbibition force of the root tissues is greater than the force with which water is retained in the soil. Under highly saline conditions, however, the osmotic effect reduces plant water uptake by increasing water retention forces in the soil matrix.

Figure 1. Fresh leaf phytomass (FFF) of passion fruit plants cv. BRS GA1 as a function of the cationic nature of water (A) and hydrogen peroxide concentrations (B) 60 days after sowing.



S 1 – Control; S 2 - Na^{+}; S 3 - Ca^{2+}; S 4 - Na^{+} + Ca^{2+}; S 5 - Mg^{2+} and S 6 - Na^{+} + Ca^{2+} + Mg^{2+}; means followed by different letters indicate significant differences between treatments according to the Scott test.

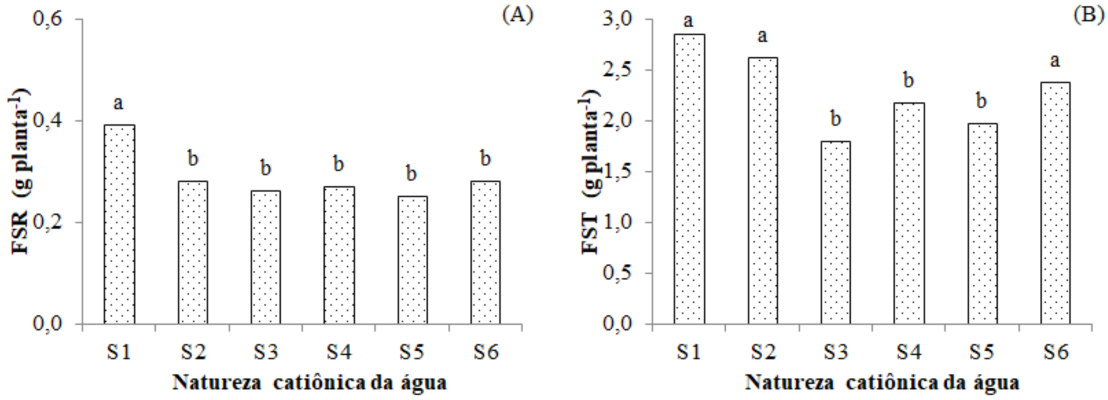
Despite playing an important role in the composition of the cell wall and being an essential nutrient for plants (SÁ et al., 2018), irrigation with water containing calcium resulted in the lowest accumulation of fresh leaf phytomass. According to Martins et al. (2019), excess Ca^{2+} can cause redirection to precipitation reactions with other elements, such as sulfur and phosphorus, in addition to competing for the same active absorption sites of nutrients, such as potassium, which are also important for plant growth.

For the FFF of passion fruit plants under the exogenous application of H_2O_2, quadratic behavior was observed (Figure 1B), with the maximum estimated value (8.26 g plant $^{-1}$) obtained in the control treatment, that is, the absence of H_2O_2. On the other hand, the lowest FFF accumulation (6.54 g plant $^{-1}$) was achieved when 20 µM H_2O_2 was used. Hydrogen peroxide is a reactive oxygen species (ROS) that is characterized as a reduced form of molecular oxygen and has been identified as one of the most important intracellular signaling agents capable of controlling several important processes for plant development (DAS; ROYCHOUDHURY, 2014; ANDRADE et al., 2018).

The relatively high concentrations of H_2O_2 (40 and 60 µM) used in this study may have triggered tolerance mechanisms to maintain the cellular water potential, allowing stability in FFF, but not high enough to cause toxic effects on this variable. This may have occurred because the amount of H_2O_2 capable of promoting negative or positive effects on plants depends on several factors, since the mechanisms involved in plant tolerance are quite complex and are related to several genes (PARIDA; DAS, 2005), which can promote responses according to the type of genotype, development stage, soil composition, light, temperature, and relative humidity, among other factors (BRAY; BAILEY-SERRES; WERETILNYK, 2000).

The FSR of passion fruit plants irrigated with low-salinity water (S_1) was statistically greater (0.39 g plant $^{-1}$) than that of plants irrigated with waters of different cationic compositions (Na^{+}; Ca^{2+}; Na^{+} + Ca^{2+}; Mg^{2+}; and Na^{+} + Ca^{2+} + Mg^{2+}) (Figure 2A). When the different cationic compositions were compared, there was no significant difference between them. Thus, the decrease in the FSR of passion fruit plants may be more related to the consequences of osmotic and ionic effects than to the different cationic natures of the irrigation water. This result was also reported by Diniz et al. (2020), who studied the dry matter of the roots of yellow passion fruit cv. GA1 subjected to different levels of ECa (0.3, 1.0, 1.7, 2.4 and 3.1 dS m^{-1}) in irrigation water prepared with NaCl and reported linear decreases in this variable as the salinity level increased, with a reduction of 31.01% between the lowest salinity level (0.3 dS m^{-1}) and the highest stress level (3.1 dS $^{-1}$).

Figure 2. Root dry matter – FSR (A) and total – FST (B) of passion fruit plants cv. BRS GA1, as a function of the cationic nature of water, 60 days after sowing.



S_1 – Control; S_2 - Na^{+}; S_3 - Ca^{2+}; S_4 - Na^{+} + Ca^{2+}; S_5 - Mg^{2+} and S_6 - Na^{+} + Ca^{2+} + Mg^{2+}; means followed by different letters indicate significant differences between treatments according to the Scott test.

The roots in direct contact with the high-salinity soil mixture are the first regions affected by the effects of stress and, consequently, constitute the first line of defense of plants (LI; LI; LI, 2017; LIMA et al., 2020). This defense is a tolerance mechanism in which the plant restricts root elongation, thus reducing its phytomass, which allows the species to reduce water absorption and, consequently, salts, mitigating toxicity via specific ions (ARIF; ISAM; ROBIN, 2019).

Regarding the effects of the different cationic compositions, the FST of passion fruit seedlings (Figure 2B) from plants irrigated with low-salinity water (S1) consisting of Na+ (S2) and Na2+ + Ca2+ + Mg2+ (S6) was significantly greater than the FST of seedlings that received Ca2+ (S3), Na+ + Ca2+ (S4), and Mg2+ (S5). Although sodium (Na^{+}) is considered one of the main causes of toxicity resulting from the ionic effect of salt stress, the FST of plants irrigated with water consisting only of this ion (S2) did not significantly differ from the FST of plants irrigated with low-salinity water (test). Souza et al. (2020) also reported small restrictions in the FST of yellow passion fruit cv. BRS Gigante Amarelo under irrigation with saline water prepared with sodium chloride (NaCl), even in the highest salinity treatment (4.0 dS $^{-1}$), at 90 DAS.

This may indicate that cv. BRS GA1 is tolerant to saline stress during the seedling formation phase, as reported by Moura et al. (2016), Andrade et al. (2018), and Souza et al. (2020). However, in the cultivars BRS Sol do Cerrado and BRS

Redondo Amarelo, Bezerra et al. (2016) reported that initial growth, analyzed through phytomass parameters (leaf dry matter, root dry matter, and total dry matter), was extremely sensitive to stress caused by irrigation with saltwater prepared with NaCl, with the largest decreases occurring from an ECw of 2.0 dS m^{-1}. According to Sá et al. (2013), salinity tolerance commonly varies substantially even among cultivars of the same species since genotypes have distinct physiological and nutritional needs.

According to the summary of the analysis of variance (Table 3), there was a significant effect of the interaction between the factors (NCA × H_2O_2) for the AF and RAF of the passion fruit plant. The cationic nature of the water significantly affected the AP, DC, AF and RAF. The H_2O_2 concentration promoted a significant difference in the AF leaf area of passion fruit cv. BRS GA1 at 60 DAS.

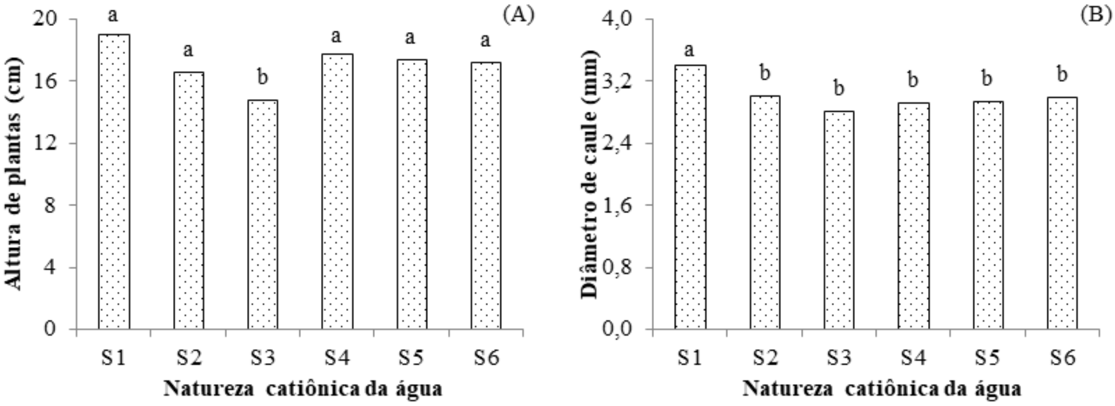
Table 3. Summary of the analysis of variance for plant height (AP), stem diameter (DC), leaf area (AF) and leaf area ratio (RAF) of passion fruit cv. BRS GA1 cultivated with water of different cationic natures (NCA) and exogenous application of hydrogen peroxide (H_2O_2) 60 days after sowing.

Source of variation	GL	Mean Squares			
		AP	**A.D**	**AF**	**RAF**
Cationic nature of water (NCA)	5	31,32 *	0.63 **	17231.74 **	0.03 **
Hydrogen peroxide (H_2O_2)	3	24.18 ^{ns}	0.29 ^{ns}	13341.07 *	0.00 ^{ns}
Linear regression	1	0.26 ^{ns}	0.67 *	405.00 ^{ns}	0.00 ^{ns}
Quadratic regression	1	21.11 ^{ns}	0.12 ^{ns}	5739.83 ^{ns}	0.00 ^{ns}
Interaction (NCA x H_2O_2)	15	11.37 ^{ns}	0.15 ^{ns}	7504.67 *	0.00 *
Blocks	3	16.71 ^{ns}	0.75 ^{ns}	15732.52 **	0.00 ^{ns}
Residue	69	10.52	0.14	3540.53	0.00
CV (%)		18.98	12.57	26.47	8.73

GL = degree of freedom; CV (%) = coefficient of variation; ** significant at the 0.01 probability level; * significant at the 0.05 probability level; ^{ns} not significant. The data were transformed to the x-radius.

The AP of passion fruit cv. BRS GA1 irrigated with water of calcium composition (S_3) differed significantly from those irrigated with water of low ECa (S_1) and other cationic natures of water (S_2; S_3; S_4; S_5 and S_6) (Figure 3A), with the highest values (18.99; 16.5; 17.70; 17.37 and 17.15 cm) obtained in plants subjected to treatments S_1, S_2, S_4, S_5 and S_6, respectively. The lowest AP value (14.76 cm) was observed in plants subjected to saltwater with a calcium composition (S_3). The reduction may be related to the redirection of Ca^{2+} to precipitation reactions with other salts or even to competition for active sites with other nutrients (MARTINS et al., 2019). The plants irrigated with water with a calcium composition were the most affected in terms of most of the biomass and growth variables evaluated. However, this result differs from what is generally reported in the literature for other cultivars and species, since plants irrigated with water supplemented with calcium salts tend to grow taller, especially at relatively high salinity levels (COSTA et al., 2005).

Figure 3. Plant height – AP (A) and stem diameter (B) of passion fruit plants cv. BRS GA1 as a function of the cationic nature of the water 60 days after sowing.



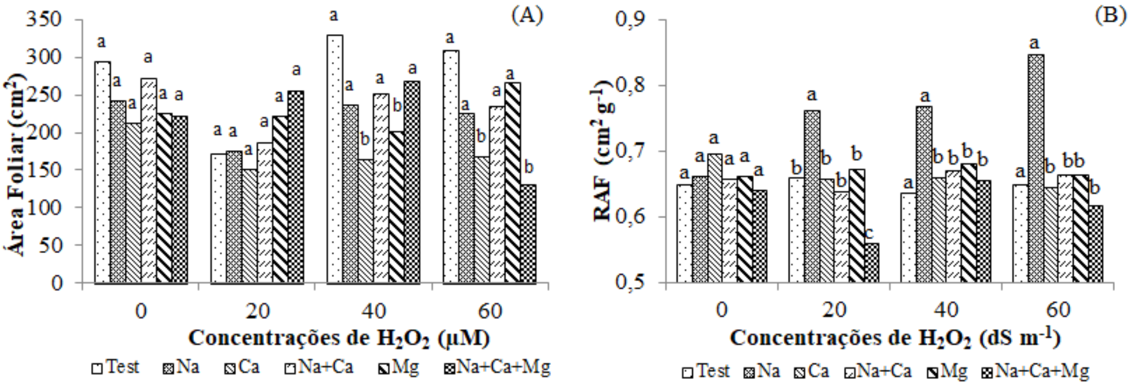
S 1 – Control; S 2 - $^{Na+}$; S 3 - Ca^{2+}; S 4 - $Na^{+} + Ca^{2+}$; S 5 - Mg^{2+} and S 6 - $Na^{+} + Ca^{2+} + Mg^{2+}$; means followed by different letters indicate significant differences between treatments according to the Scott test.

According to the mean comparison test (Figure 3B), the DC of passion fruit plants irrigated with low-salinity water (Test) was significantly greater than the DC (3.39 mm) of plants irrigated with water of different cationic natures (S2, S3, S4, S5, and S6). This finding indicates that the high salt content of waters with an ECw of 3.6 d Sm $^{-1}$, regardless of the cationic combination of irrigation water, negatively affected stem diameter. The decreases in DC with irrigation with high-conductivity water may be associated with the reduction in the osmotic-water potential of the soil solution caused by excess salt in the root zone, which promotes a decrease in turgor and consequently results in a reduction in cell expansion (KHALID; SILVA, 2010).

This variable is considered one of the most relevant in the seedling production process, since, according to Diniz et al. (2018), seedlings with high stem diameters tend to stand out in the field owing to their vigor. Similar results were obtained by Andrade et al. (2019), who evaluated the stem diameter growth of a yellow passion fruit cultivar popularly known as "Guinezinho" under irrigation with saline water prepared with $Na^{+} + Ca^{2+} + Mg^{2+}$ (at a ratio of 7:2:1) and exogenous application of hydrogen peroxide (0; 20; 40 and 60 μM) and reported that the DC was negatively affected by irrigation with water with an ECw ranging from 2.8 dS m $^{-1}$.

The interaction between the factors (NCA × H2O2) revealed that the absence of the exogenous application of H2O2 at a concentration of 20 μM did not significantly influence the AF of passion fruit plants, regardless of the cationic nature of the water (Figure 4A). However, when the leaf area of plants that received 40 μM H2O2 was compared, plants that received low-ECw water (Test), water prepared with Na+ (S2), Na+ $^{+}$ Ca2+ (S4) and Na+ $^{+}$ Ca2+ + Mg2+ (S6) were superior, whereas the water containing only Ca2+ (S3) and Mg2+ (S5) presented the lowest AF values (163.29 and 200.51 ^{cm3}). The plants that received the highest concentration of H2O2 (60 μM) presented the lowest leaf area values (166.52 and 129.37 ^{cm3}) when they were cultivated with water containing Ca2+ (S3) and Na+ $^{+}$ Ca2+ + Mg2+ (S6), respectively.

Figure 4. Leaf area – AF (A) and leaf area ratio (RAF) of passion fruit plants cv. BRS GA1 as a function of the interaction between the cationic nature of the irrigation water and the hydrogen peroxide concentration 60 days after sowing.



Means followed by different letters are significantly different between treatments according to the Scott test.

In general, H_2O_2 concentrations of 40 and 60 µM promoted greater leaf area growth (328.82 and 308.05 cm^2, respectively) in plants in the control treatment, that is, in plants grown under low irrigation water salinity (0.3 dS m^{-1}). Gohari et al. (2020) reported that the application of H_2O_2 at ideal concentrations and under normal conditions (low salinity) activates signal transduction pathways that regulate several physiological processes, increasing plant tolerance and consequently improving plant growth. The H_2O_2 concentration of 40 µM resulted in greater AF growth in plants irrigated with water supplemented with sodium (S2), sodium or calcium (S4) and in those supplemented with sodium, calcium, or magnesium (S6). In plants that received exogenous application of H_2O_2 at a concentration of 60 µM, the greatest growth in AFs was observed when water containing sodium (S2), sodium and calcium (S4), and magnesium (S5) was used.

The 2O2 concentration was able to mitigate the negative effects of calcium-containing water (S3) on the AF of passion fruit plants, since the highest AF value of plants irrigated with only calcium (212.4 cm^2) was observed at a concentration of 0 µM H_2O_2, that is, in the absence of hydrogen peroxide. As previously reported, high amounts of Ca^{2+} can become harmful by competing with other essential nutrients for plant growth, such as potassium, in addition to participating in precipitation reactions with sulfur and phosphorus (MARTINS et al., 2019).

According to Nobre et al. (2014), the reduction in AF under high-salinity circumstances is extremely relevant for maintaining plant water potential, as it reduces the transpiring surface area and, consequently, reduces water loss. Silva et al. (2019) studied the effects of the interaction between salinity levels (0.7, 1.4, 2.1 and 2.8 dS m^{-1}) and H_2O_2 concentrations (0 µM, 25 µM, 50 µM) on passion fruit plants and reported that a concentration of 25 µM H_2O_2 promoted an increase in the AF of plants irrigated with water with an ECw of 1.4 dS $^{-1}$. However, importantly, the authors used water with an ECw lower than that used in the present study.

For RAF (Figure 4B), the absence of exogenous H_2O_2 (0 µM) did not significantly influence passion fruit plants, regardless of the cationic nature of the water. However, concentrations of 20, 40, and 60 µM H_2O_2 increased the RAF of plants irrigated with water with a sodium composition (S2), whereas a concentration of 20 µM H_2O_2 reduced the RAF of plants irrigated with water consisting of Na^{+} + Ca^{2+} + Mg^{2+} (S6). According to Azevedo Neto and Tabosa (2000), RAF is a variable of great importance in the differentiation of the characteristics of tolerance or sensitivity to salinity in a cultivar, since plants with higher RAF present high transpiration and, consequently, greater water demand and a higher concentration of Na^{+} ions. and/or Cl^{-} in the aerial part. This finding is evident at concentrations of 20, 40 and 60 µM H_2O_2, where the highest RAF values were observed in plants irrigated with water containing Na+ (0.76, 0.77, and 0.85 $cm^2 g^{-1}$, respectively).

According to the summary of the analysis of variance (Table 3), there was a significant effect of the interaction between the factors (NCA × H_2O_2) on the R/PA, TAPA, and IQD of the passion fruit seedlings. The cationic nature of the water significantly affected the AFE, R/PA, TAPA, and IQD, whereas the H2O2 concentration significantly affected the IQD of the passion fruit cultivar 'BRS GA1' at 60 DAS.

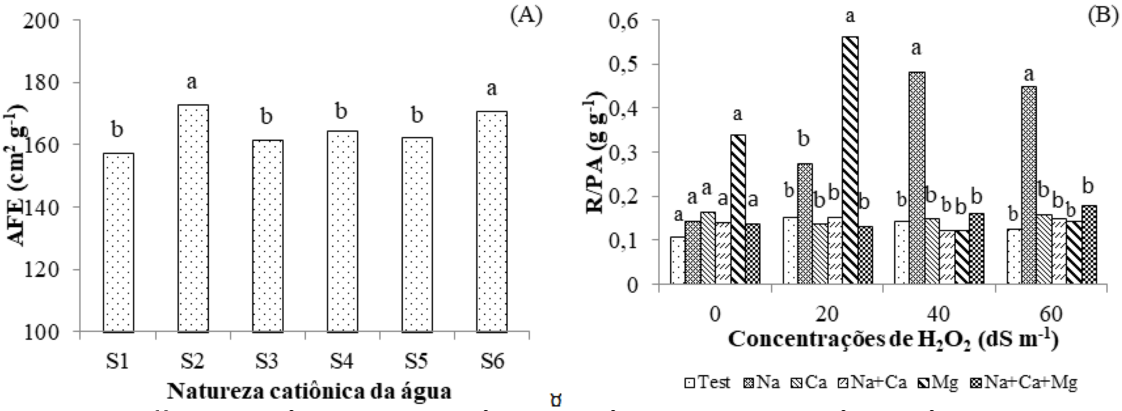
Table 4. Summary of the analysis of variance results for the specific leaf area (SLA), root/shoot ratio (R/AP), shoot water content (APAP) and Dickson quality index (DQI) of passion fruit cv. BRS GA1 cultivated with water of different cationic natures (NCA) and exogenous application of hydrogen peroxide (H2O2) 60 days after sowing.

Source of variation	GL	Mean Squares			
		AFE	R/PA 1	COVER	IQD
Cationic nature of water (NCA)	5	541.43 *	0.12 **	1014.32 **	0.28 **
Hydrogen peroxide (H_2O_2)	3	152.66 ^{ns}	0.01 ^{ns}	44.17 ^{ns}	0.02 *
Linear regression	1	330.33 ^{ns}	0.00 ^{ns}	4.71 ^{ns}	0.01 ^{ns}
Quadratic regression	1	60.60 ^{ns}	0.02 ^{ns}	29.64 ^{ns}	0.01 ^{ns}
Interaction (NCA x H_2O_2)	15	333.66 ^{ns}	0.05*	22.25 *	0.04 **
Blocks	3	1541.62 **	0.02 ^{ns}	3.66 ^{ns}	0.00 ^{ns}
Residue	69	217.22	0.02	12.25	0.00
CV (%)		8.96	19.14	4.52	42.25

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

In terms of the AFE (Figure 5A), it was possible to observe superiority in plants that were grown with water consisting of Na+ (S_2) and Na^{+} + Ca^{2+} + Mg^{2+} (S_6), whose values were 172.4 and 170.3 cm^2/g, respectively. The AFE is an indicator of leaf thickness and plays a fundamental role in representing the compensation between resource accumulation and the constraints imposed by the leaf structure (NANDY et al. 2007). As stress reduces the water content in the plant, its cells contract, and the turgor pressure against the cell walls decreases, which makes the plasma membrane thicker and more compressed, covering a smaller area than before (BEZERRA et al., 2016).

Figure 5. Specific leaf area—AFE (A) and R/PA (B) of passion fruit plants cv. BRS GA1—as a function of the interaction between the cationic nature of the irrigation water and the hydrogen peroxide concentration 60 days after sowing.



S_1 – Control; S_2 - $^{Na+}$; S_3 - Ca^{2+}; S_4 - $Na^+ + Ca^{2+}$; S_5 - Mg^{2+} and S_6 - $Na^+ + Ca^{2+} + Mg^{2+}$; means followed by different letters indicate significant differences between treatments according to the Scott test.

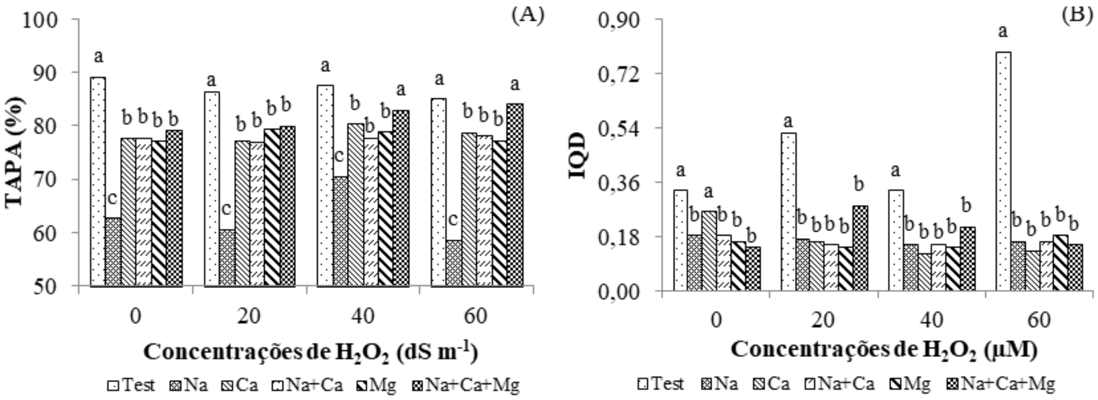
The absence of exogenous application of hydrogen peroxide (0 µM) did not significantly influence the R/PA of passion fruit plants, regardless of the cationic nature of the water (Figure 5B). Under the exogenous application of 20 µM H2O2, the root/shoot ratio was more affected when the plants were irrigated with water containing Mg2+ (S5). At relatively high concentrations of H2O2 (40 and 60 µM), the highest values (0.48 and 0.44 g g -1, respectively) were obtained for the plants that were irrigated with water supplemented with sodium (S 2).

According to Cavalcante et al. (2009), shoot growth and behavior are directly related to root growth and behavior, reflected in the root/shoot ratio. Thus, it is believed that higher peroxide concentrations associated with high Na+ (S2) levels increase the sensitivity of passion fruit shoots relative to the root system, reflecting an important mechanism for optimizing water and nutrient absorption by roots. This situation demonstrates that the stress caused by high Na+ levels led to competition for the distribution of assimilates between the two parts and that 40 and 60 µM H2O2 were more effective at mitigating salt stress.

$^+$ and Cl^- ions are the main causes of ionic stress on plant growth, as found by Araújo et al. (2013), who, when analyzing the height growth of yellow passion fruit plants (*P. edulis f. flavicarpa*) under different levels of NaCl-conditioned stress (0.3, 1.2, 2.1 and 3.2 dS m^{-1}), reported a reduction of 28.42% from the lowest CEa level (0.3 dS m^{-1} -) to the highest CEa level (3.2 dS m^{-1}).

With respect to TAPA, a higher water content in the aerial parts of plants irrigated with low-salinity water was observed, regardless of the H2O2 concentration (Figure 6A). Similarly, at all H2O2 concentrations (0, 20, 40 and 60 µM), plants irrigated with water with a sodium content (S2) presented the lowest values (62.53, 60.37, 70.26, and 58.38%, respectively). These results suggest that the use of sodic water has a greater deleterious effect on TAPA, regardless of the H2O2 concentration used, whereas concentrations of 40 and 60 µM H2O2 were able to reverse the effects of salinity stress caused by irrigation with water consisting of Na^+ + Ca2+ + Mg2+ (S6). Under conditions of high salinity, especially where Na+ ions prevail, there is a reduction in water availability due to the osmotic effect resulting from salinity stress, which prevents the movement of water from the site with the greatest osmotic potential to the lowest (BARROS et al., 2010).

Figure 6. Water content in the aerial part – TAPA (A) and Dickson quality index – IQD (B) of passion fruit plants cv. BRS GA1, as a function of the interaction between the cationic nature of the irrigation water and the hydrogen peroxide concentrations 60 days after sowing.



Means followed by different letters are significantly different between treatments according to the Scott test.

For the DQI of passion fruit plants cv. BRS GA1 (Figure 6B), at all hydrogen peroxide concentrations (0 µM, 20 µM, 40 µM and 60 µM), the plants irrigated with water with the lowest salinity (test) presented the highest values (0.33, 0.52, 0.33 and 0.79, respectively). According to Eloy et al. (2013), the Dickson quality index is an excellent indicator of seedling quality, considering several important morphological parameters, such as robustness and balance of phytomass distribution, since only seedlings with a DQI greater than 0.2 are considered good quality. In this sense, it is possible to infer that hydrogen peroxide promoted seedlings with potential for field transplantation in all low salinity treatments (Test), especially at a concentration of 60 µM, where the IQD was significantly greater than that of the other concentrations (0.79).

With respect to plants irrigated with different cationic compositions and high salinity levels (ECa 3.6 dS m $^{-1}$), the concentration of 0 µM H2O2, that is, the absence of H2O2, promoted the highest DQI of plants irrigated with water with a calcium composition (0.26) compared with the other concentrations. The concentrations of 20 and 40 µM H2O2 did not result in significant differences for waters with different cationic natures; however, they were able to increase the DQI of plants irrigated with water consisting of Na $^{+}$ Ca2+ + Mg2+ (S6) to sufficiently high levels (0.28 and 0.21, respectively) to be considered good-quality seedlings, since values above 0.2 were obtained. At a concentration of 60 µM H2O2, only the plants in the control treatment (S1) presented a satisfactory DQI (0.79), which was significantly greater than that of the other control treatments at all H2O2 concentrations studied.

Notably, the increase in H2O2 concentrations associated with the different cationic compositions of the irrigation water negatively interfered with the DQI of passion fruit plants cv. BRS GA1, indicating that, despite the increase in leaf area, hydrogen peroxide was not able to minimize the effects of salt stress on this variable. To corroborate the results of the present study, Diniz et al. (2020), when analyzing the quality of yellow passion fruit seedlings cv. BRS GA1 irrigated with water of different levels of ECw (0.3; 1.0; 1.7; 2.4 and 3.1 dS m $^{-1}$) prepared with NaCl, reported that the highest stress level (3.1 dS m $^{-1}$) reduced the IQD of the plants by 26.54% in relation to those irrigated with water of lower salinity (0.3 dS m $^{-1}$).

6 CONCLUSIONS

The use of water with a sodium composition has deleterious effects on the growth and water relationships of passion fruit cv. BRS GA1'.

H2O2 concentrations of 40 and 60 µM promoted an increase in the sensitivity of the aerial part of the passion fruit plant in relation to the root system, indicating that H2O2 is a mechanism of acclimatization to salinity stress.

It is possible to form passion fruit seedlings cv. BRS GA1 with acceptable quality for the field under a water salinity of 3.6 in the cationic composition of $Na^{+} + Ca^{2+} + Mg^{2+}$ and exogenous application of H2O2 at concentrations of 20 and 40 µM.

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8 REFERENCES

ALAGHMAND, S.; BEECHAM, S.; WOODS, JA; HOLLAND, KL; JOLLY, ID; HASSANLI, A.; NOURI, H. Quantifying the impacts of artificial flooding as a salt interception measure on a river-floodplain interaction in a semiarid saline floodplain. **Environmental modeling & software** , Utah, v. 79, no. 1, p. 167-183, 2016. DOI: http://dx.doi.org/10.1016/j.envsoft.2016.02.006. Available at: https://www.sciencedirect.com/science/article/abs/pii/S1364815216300263. Accessed on: 14 April. 2021.

ANDRADE, EMG; LIMA, GS; LIMA, VLA; SILVA, SS; GHEYI, HR; SILVA, AAR Gas exchanges and growth of passion fruit under saline water irrigation and H_2O_2 application. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 23, n. 12, p. 945-951, 2019. DOI: DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v23n12p945-951. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1415-43662019001200945. Access on : Apr 14, 2021.

ANDRADE, JR; MEDEIROS, AS; MAIA JÚNIOR, SO; REZENDE, LP; ARAÚJO NETO, JC Germination and morphophysiology of passion fruit seedlings under saltwater irrigation. **Tropical Agricultural Research** , Goiânia, v. 48, n. 3, p. 229-236, 2018. DOI: http://dx.doi.org/10.1590/1983-40632018v4852710. Available at: https://www.scielo.br/scielo.php?pid=S1983-40632018000300229&script=sci_arttext&tlng=en. Accessed on: April 14, 2021.

ARAÚJO, WL; SOUSA, JRM; SOUSA JUNIOR, JR; SILVA, SS; ALEIXO, DL; PEREIRA, EB Production of yellow passion fruit seedlings irrigated with saline water. **Scientific Agriculture in the Semiarid Region** , Patos, v. 9, n. 4, p. 15-19, 2013. DOI: http://dx.doi.org/10.30969/acsa.v9i4.414 . Available at: http://revistas.ufcg.edu.br/acsa/index.php/ACSA/article/view/414. Access on : Apr 14, 2021.

ARIF, MR; ISAM, MT; ROBIN, ARK Salinity stress alters root morphology and root hair traits in *Brassica napus* . **Plants** , Winnipeg, vol. 8, no. 7, p. 192, 2019. DOI:

https://doi.org/10.3390/plants8070192. Available at: https://pubmed.ncbi.nlm.nih.gov/31252515/. Accessed on: 14 April. 2021.

AZEVEDO NETO, AD; TABOSA, JN Saline stress in corn seedlings: part I growth analysis. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 4, n. 2, p. 159-164, 2000. DOI: http://dx.doi.org/10.1590/S1415-43662000000200005. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1415-43662000000200005. Accessed on: April 14, 2021.

BARROS, HMM; GHEYI, HR; LOGES, V.; SANTOS, MS; SOARES, FAL Influence of water salinity on the growth of six heliconia genotypes . **Ornamental Horticulture** , Viçosa, v. 16, n. 2, p. 139-145, 2010. DOI: https://doi.org/10.14295/rbho.v16i2.554. Available at: https://ornamentalhorticulture.emnuvens.com.br/rbho/article/view/554/0. Accessed on: April 14, 2021.

BEZERRA, JD; PEREIRA, WE; SILVA, JM; RAPOSO, RWC Growth of two yellow passion fruit genotypes under salinity conditions. **Revista Ceres** , Viçosa, v. 63, n. 4, p. 502-508, 2016. DOI: http://dx.doi.org/10.1590/0034-737X201663040010. Available at: https://www.scielo.br/scielo.php?pid=S0034-737X2016000400502&script=sci_abstract&tlng=pt. Accessed on: April 14, 2021.

BEZERRA, MAF; CAVALCANTE, LF; BEZERRA, FTC; PEREIRA, WE; NASCIMENTO NETO, EC Calcium as salinity mitigator on the production components of passion fruit cultivated in protected pits. **Revista Caatinga** , Mossoró, v. 33, n. 2, p. 500-508, 2020. DOI: https://doi.org/10.1590/1983-21252020v33n222rc. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1983-21252020000200500&tlng=en. Accessed on: April 14, 2021.

BRAY, EA; BAILEY-SERRES, J.; WERETILNYK, E. Responses to abiotic stresses . *In* : BUCHANAN, BB; GRUISSEM, W.; JONES, R.L. (ed.). **Biochemistry and molecular biology of plants** . Rockville: American Society of Plant Biologists, 2000. p. 149-158.

CAVALCANTE, LF; DIAS, TJ; NASCIMENTO, RD; FREIRE, JD Chlorophyll and carotenoids in yellow passion fruit irrigated with saline water in soil with bovine biofertilizer . **Brazilian Journal of Fruit Growing** , Jaboticabal, v. 33, supl. 1, p. 699-705, 2011. DOI: 10.1590/S0100-29452011000500098. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-29452011000500098&lng=en&nrm=iso&tlng=pt. Accessed on: April 14, 2021.

CAVALCANTE, LF; SILVA, GF; GHEYI, HR; DIAS, TJ; ALVES, JC; COSTA, APM Growth of yellow passion fruit seedlings in saline soil with fermented liquid cattle manure. **Brazilian Journal of Agricultural Sciences** , Recife, v. 4, n. 4, p. 414-420, 2009. DOI: 10.5039/agraria.v4i4a7. Available at: http://www.agraria.pro.br/ojs-2.4.6/index.php?journal=agraria&page=article&op=view&path%5B%5D=270. Accessed on: April 14, 2021.

COSTA, EG; CARNEIRO, PT; SOARES, FAL; FERNANDES, PD; GHEYI, HR; CAVALCANTE, LF Initial growth of yellow passion fruit under different types and salinity levels of irrigation water. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 9, supl., p. 242-247, 2005. DOI: https://doi.org/10.15809/irriga.2009v14n4p504-517. Available at: http://www.agriambi.com.br/revista/suplemento/index_arquivos/PDF/242.pdf?script=sci_pdf%C0%03d=S1415-43662005000400003&lng=en&nrm=iso&tlng=pt. Access on : Apr 14, 2021.

DAS, K.; ROYCHOUDHURY, A. Reactive oxygen species (ROS) and response of antioxidants as ROS-scavengers during environmental stress in plants. **Frontiers in Environmental Science** , London, vol. 2, no. 1, p. 1-13, 2014. DOI: https://doi.org/10.3389/fenvs.2014.00053. Available at: https://www.frontiersin.org/articles/10.3389/fenvs.2014.00053/full. Accessed on: 14 April. 2021.

DICKSON, A.; LEAF, AL; HOSNER, JF Quality appraisal of white spruce and white pine seedling stock in nurseries. **The Forest Chronicle** , Toronto, vol. 36, no. 1, p. 10-13, 1960. DOI: https://doi.org/10.5558/tfc36010-1. Available at: https://pubs.cif-ifc.org/doi/abs/10.5558/tfc36010-1. Access on : April 14, 2021.

DINIZ, GL; NOBRE, RG; LIMA, GS; SOUZA, LP; SOARES, LAA; GHEYI, HR Phytomass and quality of yellow passion fruit seeds under salt stress and silicone fertilization. **Communicate Scientiae** , Bom Jesus, v. 11, n. 1, p. e3400, 2020. DOI: https://doi.org/10.14295/cs.v11i0.3400. Available in : Phytomass and quality of yellow passion fruit seedlings under salt stress and silicone fertilization. Accessed on: 14 April. 2021.

DINIZ, GL; SALES, GN; SOUSA, VFO; ANDRADE, FHA; SILVA, SS; NOBRE, RG Papaya seedling production under water salinity, irrigation, and phosphate fertilization. **Journal of Agricultural Sciences** , Lisbon, v. 41, n. 1, p. 231-240, 2018. DOI: http://dx.doi.org/10.19084/RCA17067. Available at: https://revistas.rcaap.pt/rca/article/view/16643. Accessed on: April 14, 2021.

ELOY, E.; CARON, BO; SCHMIDT, D.; BEHLING, A.; SCHWERS, L.; ELLI, E.F. Quality assessment of *Eucalyptus seedlings grandis* using morphological parameters. **Floresta** , Curitiba, v. 43, n. 3, p. 373-384, 2013. DOI: http://dx.doi.org/10.5380/rf.v43i3.26809. Available at: https://revistas.ufpr.br/floresta/article/view/26809. Accessed on: April 14, 2021.

FERREIRA, DF SISVAR: A computer analysis system to fixed effects split plot type designs. **Revista Brasileira de Biometrica** , Lavras, v. 37, n. 4, p. 529-535, 2019. DOI: https://doi.org/10.28951/rbb.v37i4.450. Available at: http://repositorio.ufla.br/handle/1/39903. Accessed on: April 14, 2021.

GOHARI, G.; ALAVI, Z.; ESFANDIARI, E.; PANAHIRAD, S.; HAJIHOSEINLOU, S.; FOTOPOULOS, V. Interaction between hydrogen peroxide and sodium nitroprusside following chemical priming of *Ocimum basilicum* L. against salt stress. **Physiology Plantarum** , Lund , v. 168, n. 2, p. 361-373, 2020. DOI: https://doi.org/10.1111/ppl.13020. Available at: https://onlinelibrary.wiley.com/doi/abs/10.1111/ppl.13020. Access on : Apr 14, 2021.

HUSSAIN, Y.; ULLAH, SF; AHTER, G.; ASLAM, AQ Groundwater quality evaluation by electrical resistivity method for optimized tubewell site selection in an ago-stressed Thal Doab Aquifer in Pakistan. **Modeling Earth Systems and Environment** , Bangladesh, vol. 3, no. 1, p. 1-9, 2017. DOI: 10.1007/s40808-017-0282-3. Available at: https://link.springer.com/article/10.1007/s40808-017-0282-3. Accessed on: 14 April. 2021.

IBGE. **Municipal agricultural production**. Table 1613. Brasília, DF: SIDRA, 2019. Available at: https://sidra.ibge.gov.br/tabela/1613. Access on: October 27, 2020.

KHALID, K. A.; SILVA, JAT Yield, essential oil and pigment content of *Calendula officinalis* L. flower heads cultivated under salt stress conditions. **Scientia horticulturae** , Viterbo, v. 126, n. 2, p. 297-305, 2010. DOI: https://doi.org/10.1016/j.scienta.2010.07.023. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0304423810003365. Access on : Apr 14, 2021.

LI, JT; QIU, ZB; ZHANG, XW; WANG, LS Exogenous hydrogen peroxide can enhance tolerance of wheat seedlings to salt stress. **Acta Physiologiae Plantarum** , Heidelberg, v. 33, n. 3, p. 835-842, 2011. DOI: 10.1007/s11738-010-0608-5. Available at: https://link.springer.com/article/10.1007/s11738-010-0608-5. Access on : April 14, 2021.

LI, Y.; LI, H.; LI, YZS Improving water-use efficiency by decreasing stomatal conductance and transpiration rate to maintain higher ear photosynthetic rate in drought-resistant wheat. **The Crop Journal** , Beijing, vol. 5, no. 3, p. 231-239, 2017. DOI: https://doi.org/10.1016/j.cj.2017.01.001. Available at: https://www.sciencedirect.com/science/article/pii/S2214514117300016. Access on : Apr 14, 2021.

LIMA, GS de; GHEYI, HR; NOBRE, RG; SOARES, LA dos A.; SANTOS, JB Cell damage, water status, and gas exchanges in castor bean as affected by cationic composition of water. **Revista Caatinga** , Mossoró, v. 32, n. 2, p. 482-492, 2019. DOI: https://doi.org/10.1590/1983-21252019v32n221rc. Available at: https://www.scielo.br/scielo.php?pid=S1983-21252019000200482&script=sci_arttext. Accessed on: April 14, 2021.

LIMA, GS; GHEYI, HR; NOBRE, RG; SOARES, LAA; XAVIER, DA; SANTOS JUNIOR, JA Water relations and gas exchange in castor bean irrigated with saline water of distinct cationic nature. **African Journal of Agricultural Research** , Nairobi, vol. 10, no. 13, p. 1581-1594, 2015. DOI: https://doi.org/10.5897/AJAR2015.9606. Available at: https://academicjournals.org/journal/AJAR/article-abstract/CDD3D4951997. Accessed on: 14 April. 2021.

LIMA, LKS; JESUS, ON; SOARES, TL; SANTOS, IS; OLIVEIRA, EJ; COELHO FILHO, M.A. Growth , physiological , anatomical and nutritional responses of two phenotypically distinct passion fruit species (*Passiflora* L.) and their hybrid under saline conditions . **Scientia Horticulturae** , Amsterdam, v. 263, n. 1, p. 1-15, 2020. DOI: https://doi.org/10.1016/j.scienta.2019.109037. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0304423819309239. Access on : Apr 14, 2021.

MARTINS, JB; SANTOS JÚNIOR, JA; BARTUSHC, VP; GHEYI, HR; BEZERRA NETO, E.; SILVA, M.; M. Water relations in parsley plants cultivated in brackish nutrient solutions of different cationic natures. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 23, n. 9, p. 662-668, 2019. DOI: https://doi.org/10.1590/1807-1929/agriambi.v23n9p662-668. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1415-43662019000900662. Accessed on: April 14, 2021.

MOURA, RS; GHEYI, H.; COELHO FILHO, MA; JESUS, ON; SÁ, FVS; LIMA, LKS Tolerance of passion fruit species under salt stress. **International Journal of Current Research** , Thandalam , vol. 8, no. 9 p. 37689-37695, 2016.

NANDY, P.; DAS, S.; GHOSE, M.; SPOONER-HART, R. Effects of salinity on photosynthesis, leaf anatomy, ion accumulation and photosynthetic nitrogen use efficiency in five Indian mangroves. **Wetlands Ecology and Management** , Urawa, v. 15, no. 4, p. 347-357, 2007. DOI: 10.1007/s11273-007-9036-8. Available at: https://link.springer.com/article/10.1007/s11273-007-9036-8. Accessed on: 14 April. 2021.

NOBRE, RG; LIMA, GS; GHEYI, HR; SOARES, LAA; SILVA, AO Growth, consumption and water use efficiency of castor bean under salt and nitrogen stress. **Caatinga Journal** , Mossoró, v. 27, n. 2, p. 148-158, 2014.

NOVAIS, RF; NEVES, JCL; BARROS, NF Controlled environment test. *In* : OLIVEIRA, AJ (ed.). **Soil fertility research methods** . Brasília, DF: Embrapa: SEA, 1991. chap. 12, p. 189-253.

PARIDA, AK; DAS, AB Salt tolerance and salinity effects on plants : a review . **Ecotoxicology and environmental safety** , Guangzhou, v. 60, n. 3, p. 324–349, 2005. DOI: https://doi.org/10.1016/j.ecoenv.2004.06.010. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0147651304000922. Access on : Apr 14, 2021.

PARIHAR, P.; SINGH, S.; SINGH, R.; SINGH, VP; PRASAD, SM Effect of salinity stress on plants and their tolerance strategies: a review. **Environmental Science and Pollution Research** , Talence , v. 22, no. 6, p. 4056-4075, 2015. DOI: 10.1007/s11356-014-3739-1. Available at: https://link.springer.com/article/10.1007/s11356-014-3739-1#:~:text=One%20of%20the%20initial%20effects, plant%20growth%20for%20two%20reasons.&text=This%20is%20the%20osmotic%20or, transpiring%20leaves%2C%20further%20reducing%20growth. Access on : Apr 14, 2021.

RICHARDS, LA **Diagnosis and improvement of saline and alkali soils** . USDA Agricultural Handbook 60 . Washington: Department of Agriculture , 1954.

SÁ, FVS; BRITO, MEB; SILVA, LA; MOREIRA, RCL; PAIVA, EP; SOUTO, LS Correction of saline-sodic soil with conditioners and phosphorus doses for sweet sorghum cultivation. **Brazilian Journal of Irrigated Agriculture** , Fortaleza, v. 12, n. 5, p. 2854-2865, 2018 . DOI: 10.7127/rbai.v12n500838. Available at:

https://www.inovagri.org.br/revista/index.php/rbai/article/view/838. Accessed on: April 14, 2021.

SÁ, FVS; BRITO, MEB; MELO, AS; ANTÔNIO NETO, P.; FERNANDES, PD; FERREIRA, IB Production of papaya seedlings irrigated with saline water. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 17, n. 10, p. 1047-1054, 2013. DOI: https://doi.org/10.1590/S1415-43662013001000004. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1415-43662013001000004&lng=en&nrm=iso&tlng=pt. Accessed on: April 14, 2021.

SÁ, FVS; SANTOS, MG; BARROS JUNIOR, AP; ALBUQUERQUE, JRT; SOUZA, ARE; RIBEIRO, RMP Tolerance of peanut (*Arachis hypogea)* genotypes to salt stress in the initial phase . **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 24, n. 1, p. 37-43, 2020. DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v24n1p37-43. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1415-43662020000100037. Access on : Apr 14, 2021.

SANTOS, AS; ARAÚJO, RHCR; NOBRE, RG; SOUSA, VFO; RODRIGUES, MHBS; FORMIGA, JA; GOMES, FAL; SANTOS, GL; ONIAS, EA Effect of hydrogen peroxide in the growth of yellow passion fruit seedlings under salinity stress. **Journal of Agricultural Science** , Toronto, v. 10, n. 10, p. 151-162, 2018. DOI: https://doi.org/10.5539/jas.v10n10p151. Available at: http://www.ccsenet.org/journal/index.php/jas/article/view/0/36809. Access on : Apr 14, 2021.

SAVVIDES, A.; ALI, S.; TESTER, M.; FOTOPOULOS, V. Chemical priming of plants against multiple abiotic stresses: mission possible? **Trends in plant science** , London, v. 21, no. 4, p. 329-340, 2016. DOI: https://doi.org/10.1016/j.tplants.2015.11.003. Available at: https://www.sciencedirect.com/science/article/abs/pii/S1360138515002836. Accessed on: 14 April. 2021.

SILVA, AAR; LIMA, GS; AZEVEDO, CAV; VELOSO, LLSA; CAPITULINO, JD; GHEYI, HG Induction of tolerance to Salt stress in soursop seedlings using hydrogen peroxide. **Communications Scientiae** , Bom Jesus, v. 10, n. 4, p. 484-490, 2019. DOI: https://doi.org/10.14295/cs.v10i4.3036. Available at: https://www.comunicatascientiae.com.br/comunicata/article/view/3036. Accessed on: April 14, 2021.

SILVA, JJL; LEITE, ME; RODRIGUES, LC; GOUVEIA, LFP Physiological quality of *Malpighia emarginata* D. C seeds submitted to salt stress. **Journal of Experimental Agriculture International** , West Bengal, v. 28, n. 3, p. 1-10, 2018. DOI: https://doi.org/10.9734/JEAI/2018/44814. Available at: https://www.journaljeai.com/index.php/JEAI/article/view/27029. Accessed on: April 14, 2021.

SILVA, JN ; FREIRE, AS; RODRIGUES, MHBS; SILVA, MAD; SILVA, LF Initial development of *Helichrysum seedlings bracteatum* subjected to different substrates. **Environment (Brazil)** , Recife, v. 1, n. 3, p. 9-15, 2020.

SOUSA, GG; LACERDA, CF; CAVALCANTE, LF; GUIMARÃES, FVA; BEZERRA, MEJ; SILVA, GL Mineral nutrition and nutrient extraction from corn plants irrigated with saline water. **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v. 14, n. 11, p. 1143-1151, 2010. DOI: http://dx.doi.org/10.1590/S1415-43662010001100003. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1415-43662010001100003. Accessed on: Apr. 14, 2021.

SOUZA, T.M.A.; MENDONÇA, V.; SÁ, F.V.S.; SILVA, M.J.; DOURADO, C.S.T. Calcium silicate as salt stress attenuator in seedlings of yellow passion fruit cv. BRS GA1. **Caatinga Journal** , Mossoró, v. 33, n. 2, p. 509-517, 2020. DOI: https://doi.org/10.1590/1983-21252020v33n223rc. Available at: https://www.scielo.br/scielo.php?script=sci_arttext&pid=S1983-21252020000200509&tlng. Accessed on: April 14, 2021.

TEIXEIRA, PC; DONAGEMMA, GK; FONTANA, A.; TEIXEIRA, WG **Manual of soil analysis methods** . 3rd ed. Brasília, DF: Embrapa, 2017.