ISSN 1807-1929
Revista Brasileira de Engenharia Agrícola e Ambiental
Brazilian Journal of Agricultural and Environmental Engineering
v.25, n.6, p.393-401, 2021
Campina Grande, PB – http://www.agriambi.com.br – http://www.scielo.br/rbeaa

DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.v25n6p393-401

Potassium and irrigation water salinity on the formation of sour passion fruit seedlings[1]

Potássio e salinidade da água de irrigação na formação de mudas de maracujazeiro-azedo

Geovani S. de Lima[2*], Maria G. da S. Soares[3], Lauriane A. dos A. Soares[3], Hans R. Gheyi[2], Francisco W. A. Pinheiro[2] & Jailson B. da Silva[3]

[1] Research developed at Universidade Federal de Campina Grande, Unidade Acadêmica de Ciências Agrárias, Pombal, PB, Brazil
[2] Universidade Federal de Campina Grande/Programa de Pós-Graduação em Engenharia Agrícola, Campina Grande, PB, Brazil
[3] Universidade Federal de Campina Grande/Unidade Acadêmica de Ciências Agrárias, Pombal, PB, Brazil

HIGHLIGHTS:
Potassium does not attenuate the deleterious effects of salt stress on the formation of seedlings of sour passion fruit.
Water salinity increases the percentage of cell membrane damage in sour passion fruit seedlings.
Salt stress inhibits growth of sour passion fruit but water with up to 3.5 dS m^{-1} can be used for formation of its seedlings.

ABSTRACT: The high concentration of salt in the waters of the semi-arid region of Northeast Brazil is a limiting factor for agricultural production in the region. In this context, the objective of this study was to evaluate the percentage of cell membrane damage, contents of photosynthetic pigments and growth of sour passion fruit seedlings, cv. BRS RC, under irrigation with saline water and potassium fertilization. The experiment was conducted in a greenhouse, adopting a randomized block design in a 5 x 2 factorial arrangement, with five values of electrical conductivity of irrigation water (0.3; 1.1; 1.9; 2.7 and 3.5 dS m^{-1}) and two potassium doses - KD (50 and 100% of the fertilization recommendation for pot experiments), with two plants per plot, and four replicates. The dose referring to 100% of the recommendation corresponded to 150 mg of K_2O kg^{-1} of soil. Water salinity from 0.3 dS m^{-1} promoted reduction in the chlorophyll synthesis and growth of seedlings of sour passion fruit cv. BRS RC. Despite the reduction in growth, water with electrical conductivity of up to 3.5 dS m^{-1} can still be used to form passion fruit seedlings with acceptable quality for the field. Potassium does not attenuate the deleterious effects of salt stress on the formation of seedlings of sour passion fruit cv. BRS RC.

Key words: *Passiflora edulis* Sims, attenuation, salt stress

RESUMO: A alta concentração de sais nas águas do semiárido do Nordeste brasileiro destaca-se como um fator limitante para a produção agrícola nessa região. Neste contexto, propôs-se com este estudo avaliar o percentual de danos na membrana celular, os teores de pigmentos fotossintéticos e o crescimento das mudas de maracujazeiro-azedo cv. BRS RC irrigados com águas salinas e adubação potássica. O experimento foi conduzido em casa de vegetação. Adotou-se o delineamento experimental em blocos casualizados em arranjo fatorial 5 x 2, sendo cinco valores de condutividade elétrica da água de irrigação (0,3; 1,1; 1,9; 2,7 e 3,5 dS m^{-1}) e duas doses de potássio - DK (50 e 100% da recomendação de adubação para ensaios em vasos), com duas plantas por parcela e quatro repetições. A dose referente a 100% da recomendação correspondeu a 150 mg de K_2O kg^{-1} de solo. A salinidade da água a partir de 0,3 dS m^{-1} promoveu redução na síntese de clorofila e do crescimento das mudas de maracujazeiro-azedo cv. BRS RC. Apesar da redução no crescimento, água com condutividade elétrica de até 3,5 dS m^{-1} ainda pode ser utilizada na formação de mudas de maracujazeiro com qualidade aceitável para o campo. O potássio não atenua os efeitos deletérios do estresse salino na formação de mudas do maracujazeiro-azedo cv. BRS RC.

Palavras-chave: *Passiflora edulis* Sims, atenuação, estresse salino

• Ref. 231697 – Received 03 Dec, 2019
* Corresponding author - E-mail: geovani.soares@pq.cnpq.br
• Accepted 03 Feb, 2021 • Published 10 Mar, 2021
Edited by: Hans Raj Gheyi

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Introduction

Sour passion fruit (*Passiflora edulis* Sims) is a species belonging to the Passifloraceae family (Bernacci et al., 2008), widely cultivated in the semi-arid region of Northeastern Brazil, due to edaphoclimatic conditions favorable to its development, standing out as a fruit crop of high profitability in family farming and guaranteed source of income throughout the year (Araújo et al., 2012). Passion fruit juice and pulp are used in the preparation of various products, especially carbonated beverages, mixed beverages, syrups, jellies, dairy products, ice cream and canned foods (Santos et al., 2017).

In the semi-arid region of Northeastern Brazil, fruit growing is restricted to irrigated conditions, due to the spatial-temporal variability of rainfall, combined with high evaporative demand and the reduction in the availability of water of low electrical conductivity, so the use of water resources of restrictive quality to agricultural production becomes necessary (Freire et al., 2016; Andrade et al., 2019). Salts dissolved in the soil solution inhibit plant growth because of the water absorption restrictions (osmotic effect) and changes in metabolism, absorption of nutrients and ion balance (ionic effect) (Zhang et al., 2019), and induce increased formation of reactive oxygen species (ROS), as by-products, which damage cellular components, degrade photosynthetic pigments and cause lipid peroxidation of the membrane, reducing its fluidity and selectivity (Taibi et al., 2016).

Potassium fertilization should be considered as an alternative capable of alleviating the effects of salt stress on plants, due to the functions that this macronutrient performs in the plant biochemistry and physiology (Abbasi et al., 2016; Ahanger et al., 2017), acting as enzymatic activator, in osmotic adjustment and maintenance of cell turgor, as well as in the regulation of cytoplasmic homeostasis of pH (Barragan et al., 2012). In addition, it is involved in stomatal movement, protein synthesis, photosynthesis, osmoregulation, transport in phloem and in the reduction of excessive absorption of ions such as Na^+ (Ahanger et al., 2017).

Due to the similarity in the physical and chemical properties between sodium and potassium (i.e., ionic radius and ion hydration energy), there is a competition between these elements at the main binding sites in the metabolic processes of the cytoplasm, in enzymatic reactions and in protein synthesis (Almeida et al., 2017). In view of the above, the objective of this study was to evaluate the effect of potassium on attenuating the degenerative action of irrigation water salinity on the percentage of cell membrane damage, contents of photosynthetic pigments and growth of sour passion fruit seedlings, cv. BRS RC.

Material and Methods

The experiment was carried out in a protected environment (greenhouse) of the Center of Science and Agri-Food Technology - CCTA of the Federal University of Campina Grande (UFCG), in Pombal, Paraíba state, Brazil. The municipality is located on the geographic coordinates 6° 47' 20" South latitude and 37° 48' 01" West longitude, at an altitude of 194 m.

The experimental design adopted was randomized blocks in a 5 × 2 factorial arrangement, corresponding to five values of electrical conductivity of irrigation water (0.3; 1.1; 1.9; 2.7 and 3.5 dS m^{-1}) and two doses of potassium fertilization (50 and 100%) according to the recommendation of Novais et al. (1991) for pot experiments, with four replicates and two units per plot. The potassium dose referring to 100% of the recommendation corresponded to 150 mg of K_2O kg^{-1} of soil.

Seeds of sour passion fruit (*Passiflora edulis* Sims f. flavicarpa O. Deg. x *Passiflora edulis* Sims), cv. BRS RC were used in this study. The cultivar has the characteristics of fruits with red or purplish peel, weight ranging from 120 to 300 g (average of 170 g), soluble solids content in the pulp of 14 °Brix and juice yield of 35%, resistance to the main diseases of passion fruit, such as viral disease (Purple passion fruit mosaic virus), bacterial disease (*Xanthomonas campestris* pv. *passiflorae*), anthracnose (*Glomerella cingulata*) and scab (*Cladosporium herbarum* Link), and high yield (EMBRAPA, 2012).

To obtain the passion fruit seedlings, two seeds were sown in polyethylene bags with dimensions of 15 × 30 cm, filled with a 2:1:1 proportion (volume basis) of an Entisol with sandy loam texture, sand and decomposed bovine manure. The soil used in the substrate came from the rural area of the municipality of São Domingos, Paraíba state, Brazil, collected from 0-0.15 m depth. The containers were distributed on benches at 0.80 m height from the ground. Soil physical and chemical attributes (Table 1) were obtained using the methodologies proposed by Teixeira et al. (2017).

All fertilizations were carried out as topdressing, according to the recommendation of fertilization for pot experiments, contained in Novais et al. (1991), mixing 100 mg of N (urea, 45% N) and 300 mg of P (monoammonium phosphate - MAP,

Table 1. Chemical attributes regarding fertility and physical attributes of the soil used in preparation of substrate for the production of sour passion fruit cv. BRS RC seedlings

Chemical characteristics								
pH H_2O) (1:2.5)	OM (g kg^{-1})	P (mg kg^{-1})	K^+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+
			($cmol_c$ kg^{-1})					
5.58	2.93	39.2	0.23	1.64	9.07	2.78	0.00	8.61

Chemical characteristics				Physical characteristics				
EC_{se} (dS m^{-1})	CEC ($cmol_c$ kg^{-1})	SAR (mmol L^{-1})$^{0.5}$	ESP (%)	Size fraction (g kg^{-1})			Water content (dag kg^{-1})	
				Sand	Silt	Clay	33.42 kPa[1]	1519.5 kPa[2]
2.15	22.33	0.67	7.34	572.70	100.70	326.60	25.91	12.96

pH - Hydrogen potential; OM - Organic matter: Walkley-Black Wet Digestion; Ca^{2+} and Mg^{2+} extracted with 1 M KCl at pH 7.0; Na^+ and K^+ extracted with 1 M NH_4OAc at pH 7.0; Al^{3+} + H^+ extracted with 0.5 M CaOAc at pH 7.0; ECse - Electrical conductivity of the saturation extract; CEC - Cation exchange capacity = Sum of bases + (H^+ + Al^{3+}); SAR - Sodium adsorption ratio of the saturation extract = $Na^+ \times[(Ca^{2+} + Mg^{2+})/2]^{1/2}$; ESP - Exchangeable sodium percentage = 100 × Na^+/CEC; [1,2] refer to field capacity and permanent wilting point, respectively

54% P_2O_5 and 12% N) per kg of soil, applied through irrigation water, at 15 and 30 days after sowing (DAS). Potassium fertilization (K_2O) was split into two applications (18 and 36 DAS) and supplied via fertigation, applying 75 and 150 mg of K_2O kg^{-1} of soil in the treatments K_1 and K_2, respectively, using potassium chloride - KCl (60% K_2O) as a source.

The irrigation water of the treatment with lowest salinity (0.3 dS m^{-1}) came from the public supply system of the municipality of Pombal, Paraíba state. Other salinity levels of irrigation water were prepared by dissolving NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$ in the public-supply water in the equivalent proportion of 7:2:1, respectively, which prevails in the sources of water used for irrigation in small properties of Northeastern Brazil. The irrigation water of the respective salinity level was prepared considering the relationship between the electrical conductivity of irrigation water (ECw) and the concentration of salts [mmol$_c$ L^{-1} = 10 x ECw (dS m^{-1}]), according to the methodology contained in Richards (1954).

After sowing, irrigation was performed manually every 24 hours, applying the volume corresponding to that obtained by the water balance. The volume of water to be applied to the plants was determined by Eq. 1:

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

where:

VI - volume of water to be used in the irrigation event, mL;

Va and Vd - volume of water applied and drained in the previous irrigation event; and,

LF - leaching fraction (0.20).

At 60 days after sowing, plant height (PH), stem diameter (SD), leaf area (LA), contents of chlorophyll a, chlorophyll b and carotenoid, percentage of cell membrane damage and leaf osmotic potential were evaluated. Dry biomass of leaf (LDB), stem (StDB), root (RDB) and total (TDB) were also measured. Plant height was obtained by taking as reference the distance from the collar up to the insertion of the apical meristem of plant. Stem diameter was measured at 5 cm from the plant collar. Leaf area was obtained by measuring the length and width of all leaves of the plants according to the methodology described by Cavalcante et al. (2002), using Eq. 2:

$$LA = \sum 0.81(L \times W) \quad (2)$$

where:

LA - leaf area of the plant, cm^2; and,

$(L \times W)$ - product of length (L) and width (W) of leaf > 2 cm.

To determine biomass, the plants were cut close to the soil surface and separated into leaves, stem and roots. Subsequently, the different parts were placed in a paper bag and dried in a forced air oven, at a temperature of 65 °C, until reaching constant weight. Then, the plant material was weighed to obtain the values (g per plant) for dry biomass of leaf (LDB), stem (StDB), root (RDB), shoot (ShDB). The sum of LDB, StDB and RDB resulted in the total dry biomass (TDB) of the plant.

Chlorophyll and carotenoid contents, in mg g^{-1} of fresh leaf mass (FM), were quantified using a spectrophotometer at absorbance (ABS) wavelengths of 470, 646, and 663 nm, according to the methodology of Arnon (1949), using Eqs. 3, 4 and 5:

$$\text{Chl a} = 12.21\text{ABS}663 - 2.81\text{ABS}646 \quad (3)$$

$$\text{Chl b} = 20.13\text{ABS}646 - 5.03\text{ABS}663 \quad (4)$$

$$\text{Car} = \frac{(1000\text{ABS}470 - 1.82\text{Chl a} - 85.02\text{Chl b})}{198} \quad (5)$$

where:

Chl a - Chlorophyll a;

Chl b - Chlorophyll b; and,

Car - carotenoids.

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

The percentage of cell membrane damage was obtained according to Scotti-Campos et al. (2013), Eq. 6:

$$\%D = \frac{Ci}{Cf}100 \quad (6)$$

where:

%D - percentage of cell membrane damage;

Ci - initial electrical conductivity, dS m^{-1}; and,

Cf - final electrical conductivity, dS m^{-1}.

Leaf osmotic potential was determined according to the methodology contained in Bagatta et al. (2008), Eq. 7:

$$\psi s(\text{MPa}) = -C\left(\frac{\text{mOsmol}}{\text{kg}}\right) \cdot 2.58 \times 10^{-3} \quad (7)$$

where:

ψs (MPa) - leaf osmotic potential; and,

C - osmolality of the sample, found in the osmometer reading.

The quality of passion fruit seedlings was determined using the Dickson Quality Index - DQI (Dickson et al., 1960), Eq. 8:

$$DQI = \frac{(TDB)}{\left(\frac{PH}{SD}\right) + \left(\frac{ShDB}{RDB}\right)} \quad (8)$$

where:

DQI - Dickson quality index;

PH - plant height (cm);

SD - stem diameter (mm);

TDB - total dry biomass (g per plant);

ShDB - shoot dry biomass (g per plant); and, RDB - root dry biomass (g per plant).

The data were subjected to analysis of variance by the F test ($p \leq 0.05$) and, when significant, polynomial regression analysis was performed for the electrical conductivity factor and means comparison test (Tukey, $p \leq 0.05$) was performed for potassium doses. When there was significant interaction between the factors, the electrical conductivity was further analyzed considering each potassium dose, using the statistical program Sisvar version 5.6 (Ferreira, 2011).

Results and Discussion

According to the summary of the analysis of variance (Table 2), the interaction between the factors (SL × KD) did not influence any of the variables of the sour passion fruit cv. BRS RC analyzed at 60 days after sowing. Water salinity levels significantly affected leaf osmotic potential (Ψs), percentage of cell membrane damage (%D) and contents of chlorophyll a (Chl a), chlorophyll b (Chl b) and carotenoids (Car) of sour passion fruit seedlings. Potassium doses did not cause a significant effect on any of the variables analyzed.

Diniz et al. (2020a), when evaluating the levels of photosynthetic pigments in yellow passion fruit cv. BRS GA1 as a function of water salinity and silicon fertilization, observed significant differences only in the contents of chlorophyll b and carotenoids at 60 DAS.

The osmotic potential in the leaf tissues of seedlings of passion fruit cv. BRS RC was reduced linearly as water salinity increased, decreasing by 116.27% per unit increment in ECw (Figure 1A). A comparison of the osmotic potential of seedlings cultivated under ECw of 3.5 dS m^{-1} with that of those which received the lowest salinity level (0.3 dS m^{-1}) showed a decrease of -3.21 MPa. The reduction in leaf osmotic potential occurs due to the increase in the concentrations of ions (Na^+, Cl^-) and organic solutes in cells, which is a strategy for maintaining a gradient of water potential between the cell and the environment and metabolic activities that are essential for survival under salt stress conditions (Benzarti et al., 2014). In a study with West Indian cherry (*Malpighia emarginata* Sesse & Moc. ex DC.), cv. BRS 366 Jaburu, irrigated with saline water (ECw between 0.8 and 3.8 dS m^{-1}) in the post-grafting stage, Pinheiro et al. (2019) also observed that plants that were irrigated with water of 3.8 dS m^{-1} had a more negative leaf ψs (-1.60 MPa) than those irrigated with water of 0.8 dS m^{-1} (-0.85 MPa).

Water salinity increased the percentage of cell membrane damage of sour passion fruit seedlings (Figure 1B). It can be verified that the seedlings irrigated with water of 3.5 dS m^{-1} showed a 16.82% more damage to the leaf membrane compared to those irrigated with water of low ECw (0.3 dS m^{-1}). The increase in the percentage of cell membrane damage is mainly related to the efflux of K^+, which is abundant in plant cells (Hnilicková et al., 2019), reflecting the extent of lipid peroxidation caused by reactive oxygen species, consequently causing changes in cellular homeostasis, which leads to membrane instability (Sharma et al., 2012). Cell membrane damage in castor bean plants (*Ricinus communis* L.), cv. BRS Energia, was increased in response to the increase in salinity from 0.6 to 4.5 dS m^{-1} and the cationic nature of irrigation water (Lima et al., 2019).

With the increase in water salinity, chlorophyll a content decreased by 18.87% per unit increase in ECw (Figure 1C). Comparatively, seedlings subjected to ECw of 3.5 dS m^{-1} decreased their chlorophyll synthesis by 64.01% (3.794 mg g^{-1} FM) compared to those that received 0.3 dS m^{-1}. In yellow passion fruit (*Passiflora edulis* f. flavicarpa) plants, Cavalcante et al. (2011) found that the increase in irrigation water salinity to 2.5 dS m^{-1} did not compromise chlorophyll a content.

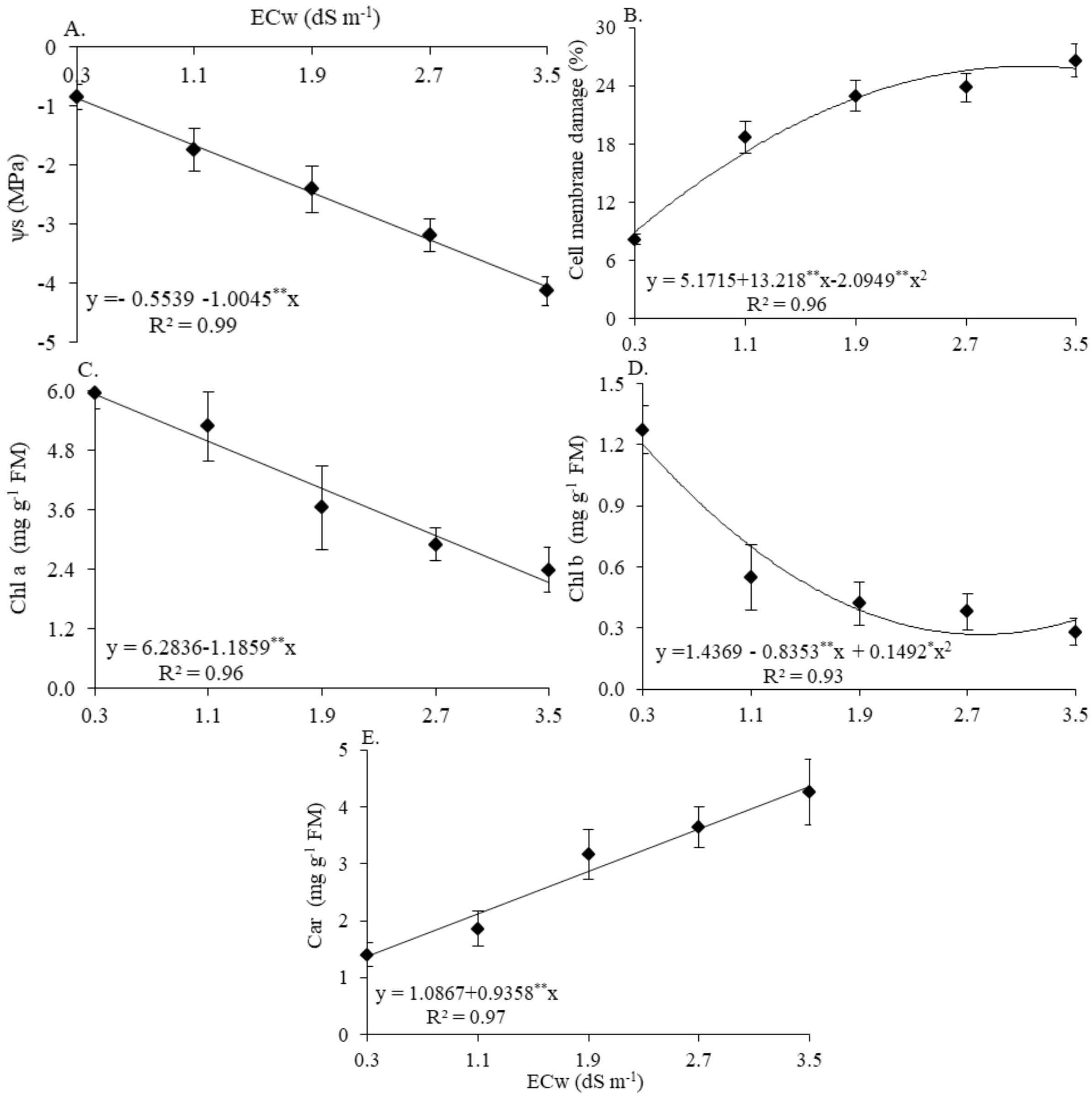
Salt stress caused by water salinity also inhibited chlorophyll b synthesis in sour passion fruit seedlings (Figure 1D). The maximum value for Chl b (1.199 mg g^{-1} FM) was estimated in seedlings irrigated with water of 0.3 dS m^{-1} and the minimum value (0.267 mg g^{-1} FM) in those under ECw of 2.8 dS m^{-1}. According to Cavalcante et al. (2011), salt stress inhibits the synthesis of 5-aminolevulinic acid, a chlorophyll precursor molecule, and induces the enzymatic activity of chlorophyll, which acts in the degradation of photosynthesizing pigment molecules and destroys the structure of chloroplasts, also causing imbalance and loss of activity of pigmentation proteins.

The carotenoid contents of the seedlings of sour passion fruit cv. BRS RC increased linearly with water salinity (Figure 1E). The increase in carotenoid contents was equal to 218.99% (2.995 mg g^{-1} FM) between seedlings irrigated using water with electrical conductivity of 0.3 dS m^{-1} and those under irrigation with water of 3.5 dS m^{-1}. The increase in the synthesis of carotenoids in plants cultivated under salt stress stands out as a mechanism for dissipation of excess light energy and an alternative to maintain antioxidant agents protecting membrane lipids during oxidative stress (Falk & Munné-Bosch, 2010).

Table 2. Summary of the analysis of variance for leaf osmotic potential (Ψs), percentage of cell membrane damage (%D) and contents of chlorophyll a (Chl a), chlorophyll b (Chl b) and carotenoids (Car) of the sour passion fruit seedlings, cv. BRS RC, under irrigation with saline water and potassium doses at 60 days after sowing

Source of variation	DF	Mean squares				
		ψs	%D	Chl a	Chl b	Car
Water salinity levels (SL)	4	12.95**	417.37**	18.68**	1.26**	11.54**
Linear regression	1	51.66**	1415.04**	72.00**	3.68**	44.83**
Quadratic regression	1	0.02ns	201.32**	0.80ns	1.02ns	0.14ns
K dose (KD)	1	0.003ns	0.004ns	2.66ns	0.44ns	3.58ns
Interaction (SL x KD)	4	0.67ns	17.60ns	2.79ns	0.29ns	0.12ns
Blocks	3	0.45ns	21.97ns	0.71ns	0.14ns	0.03ns
Residual	27	0.32	10.25	1.07	0.07	0.66
CV (%)		23.27	15.98	25.74	48.82	28.53

CV - Coefficient of variation; DF - Degrees of freedom; ns, *, ** - Not significant, significant at $p \leq 0.05$ and at $p \leq 0.01$, respectively



* and ** - Significant at $p \leq 0.05$ and at $p \leq 0.01$ by F test, respectively; Vertical bars represent the standard error of the mean (n = 4)

Figure 1. Leaf osmotic potential - ψs (A), percentage of cell membrane damage (B), chlorophyll a - Chl a (C), chlorophyll b - Chl b (D) and carotenoids - Car (E) of the seedlings of sour passion fruit cv. BRS RC as a function of the electrical conductivity of irrigation water (ECw) at 60 days after sowing

There was no significant effect of the interaction between the factors (SL × KD) on any of the biometric variables and Dickson Quality Index of the sour passion fruit cv. BRS RC analyzed at 60 days after sowing (Table 3). Water salinity levels significantly affected plant height, stem diameter, leaf area, dry biomass of leaf, stem, root and total, and Dickson Quality Index of the sour passion fruit seedlings. K doses did not cause significant effect on any of the variables analyzed. In a study with the yellow passion fruit cv. BRS GA1 under water salinity management strategies and potassium doses,

Table 3. Summary of the analysis of variance for plant height (PH), stem diameter (SD), leaf area (LA), dry biomass of leaf (LDB), stem (StDB), root (RDB), and total (TDB) and Dickson Quality Index (DQI) of the seedlings of sour passion fruit cv. BRS RC cultivated with saline waters and potassium doses at 60 days after sowing

Source of variation	DF	Mean squares							
		PH	SD	LA	LDB	StDB	RDB	TDB	DQI
Water salinity levels (SL)	4	1267.17*	3.19*	87189.50*	3.17*	3.48**	0.12*	15.86**	0.02**
Linear regression	1	5000.70**	7.75**	290482.12*	12.45**	12.92**	0.46**	60.30**	0.07*
Quadratic regression	1	53.62^{ns}	0.65^{ns}	118.36^{ns}	0.48^{ns}	0.68^{ns}	0.01^{ns}	2.70^{ns}	0.009^{ns}
K dose (KD)	1	555.02^{ns}	0.25^{ns}	12744.90^{ns}	1.38^{ns}	0.31^{ns}	0.005^{ns}	3.26^{ns}	0.002^{ns}
Interaction (SL x KD)	4	262.60^{ns}	0.28^{ns}	38229.60^{ns}	0.30^{ns}	0.24^{ns}	0.04^{ns}	1.01^{ns}	0.002^{ns}
Blocks	3	672.31^{ns}	0.30^{ns}	43880.29^{ns}	0.44^{ns}	0.28^{ns}	0.03^{ns}	0.83^{ns}	0.003^{ns}
Residual	27	217.41	0.41	28290.46	0.57	0.30	0.01	1.10	0.003
CV (%)		33.55	17.24	31.02	32.24	36.00	24.89	24.24	21.78

CV - Coefficient of variation; DF - Degrees of freedom; $^{ns, *, **}$ - Not significant, significant at $p \leq 0.05$ and at $p \leq 0.01$ by F test, respectively

Lima et al. (2020) also verified that there was no significant effect of the interaction between the sources of variation on gas exchange, growth and production.

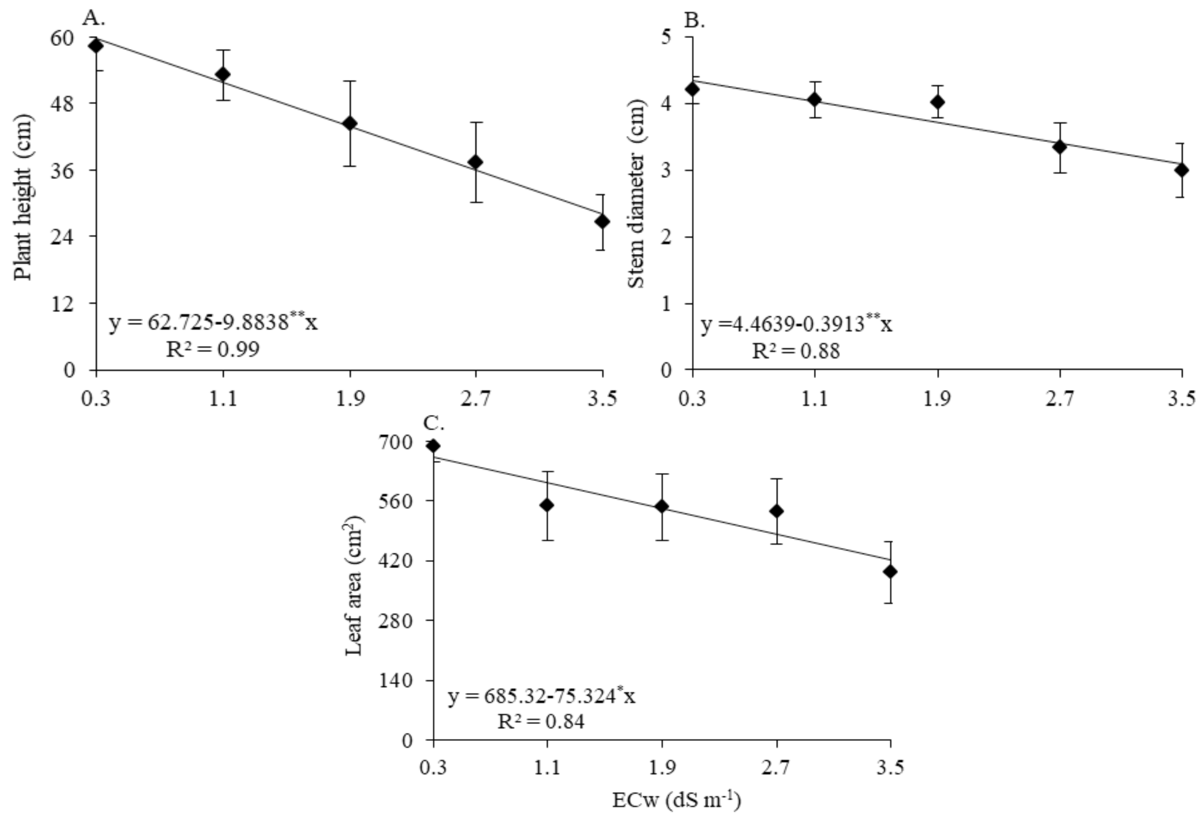
As irrigation water salinity increased, the height of the sour passion fruit cv. BRS RC was reduced (Figure 2A), decreasing by 15.75% per unit increase in ECw, that is, plants under irrigation with the highest salinity level (3.5 dS m^{-1}) had a decrease of 31.62 cm (52.91%) in their PH compared to those subjected to ECw of 0.3 dS m^{-1}. The decrease in the growth in height observed in the seedlings reflects the effect of the reduction in the osmotic potential of the soil solution caused by the high concentrations of salts, which hampers the absorption of water and nutrients by plants and, as a consequence, causes loss of turgor pressure in cells, which compromises plant growth (Oliveira et al., 2013).

The stem diameter of the sour passion fruit seedlings was negatively affected by irrigation with saline water (Figure 2B). According to Figure 2B, stem diameter was reduced by 8.76% per unit increase in ECw. A decrease of 28.80% (1.25 mm) was observed between the SD values of seedlings cultivated under ECw of 3.5 and 0.3 dS m^{-1}. Effects of water salinity on the diameter growth of yellow passion fruit seedlings were observed by Mesquita et al. (2012), who found that the salinity of irrigation water inhibited the absolute and the relative growth rate in stem diameter.

The leaf area of passion fruit plants was linearly reduced with the increase in water salinity, decreasing by 10.99% per unit increment in ECw (Figure 2C). Plants grown under the highest level of ECw (3.5 dS m^{-1}) showed a reduction of 36.37% (241.03 cm^2) compared to those receiving water of 0.3 dS m^{-1}. The reduction in leaf area of plants under salt stress conditions occurs because of the restriction in the absorption of water and nutrients due to the accumulation of salts in the soil and the decrease in cell turgor pressure, standing out as one of the mechanisms of adaptation of plants to salt stress, decreasing the transpiration surface and maintaining a high water potential inside the plants through the decrease in transpiration (Oliveira et al., 2013).

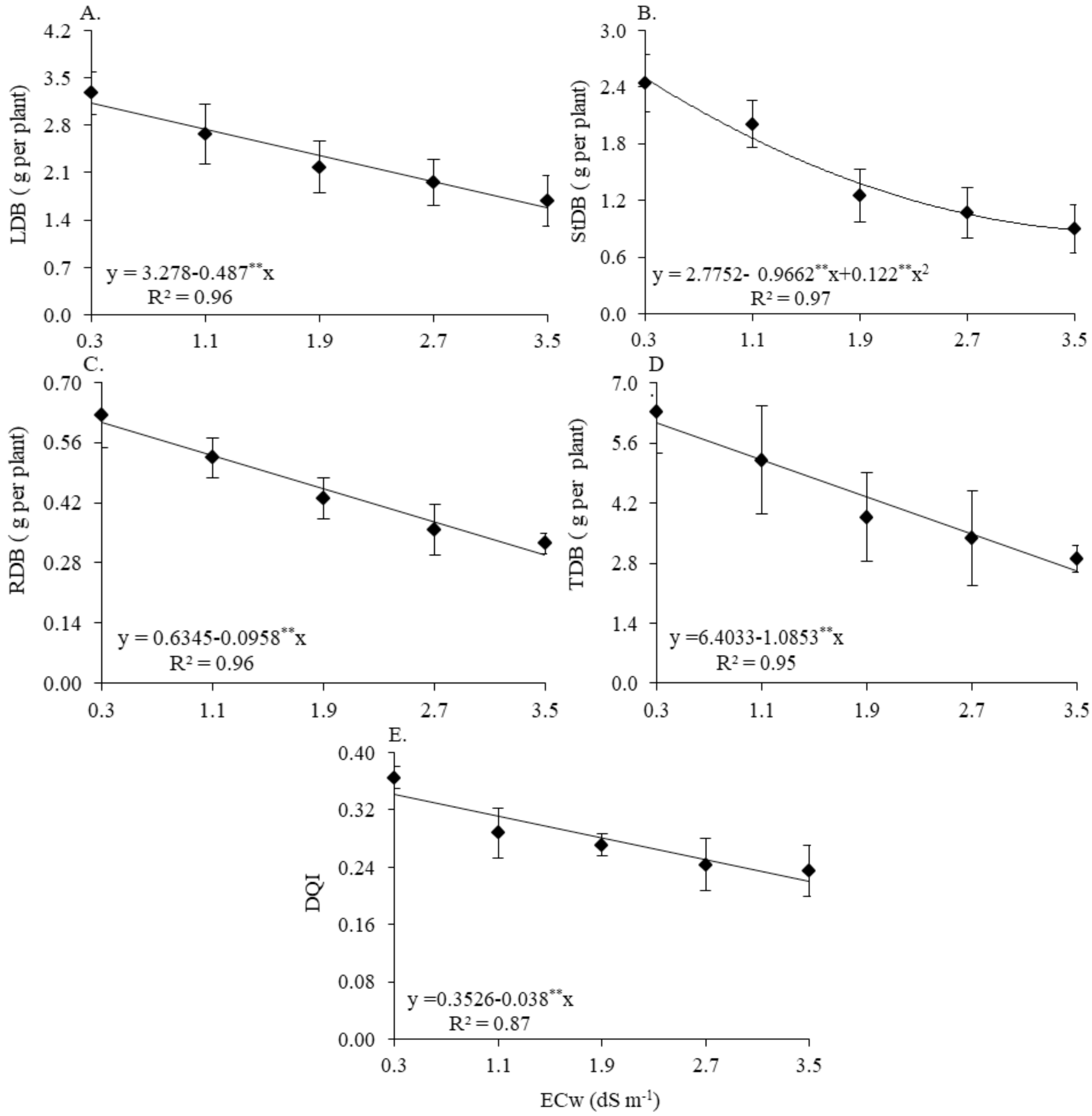
With the increase in water salinity, the leaf dry biomass of the seedlings of sour passion fruit cv. BRS RC decreased linearly by 14.85% per unit increase in ECw (Figure 3A). When seedlings under ECw of 3.5 dS m^{-1} were compared to those subjected to the lowest salinity level (0.3 dS m^{-1}), there was a reduction of 49.75% (1.55 g per plant) in LDB. Stem dry biomass was also negatively affected by the increase in the electrical conductivity of irrigation water (Figure 3B) and there was a reduction from 2.49 to 0.88 g per plant in seedlings irrigated with ECw of 0.3 and 3.5 dS m^{-1}, respectively.

The reduction in biomass accumulation in sour passion fruit plants results from the decrease in water availability due to the reduction in the osmotic potential of the soil solution, because the high concentration of salts causes the closure of stomata, reducing the photosynthetic rate and, consequently, the growth and biomass accumulation (Willadino et al., 2011), because biomass production results from the translocation of photoassimilates to the different organs of the plants (Cavalcante et al., 2008). Evaluating the effects of irrigation water salinity on the growth of yellow passion fruit (*Passiflora edulis* f. flavicarpa), Cavalcante et al. (2002) concluded that the increase in water salinity inhibited the accumulation of shoot and root dry matter.



* and ** - Significant at $p \leq 0.05$ and at $p \leq 0.01$ by F test, respectively; Vertical bars represent the standard error of the mean (n = 4)

Figure 2. Plant height (A), stem diameter (B) and leaf area (C) of the seedlings of sour passion fruit cv. BRS RC as a function of the electrical conductivity of irrigation water (ECw) at 60 days after sowing



* and ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by F test, respectively; Vertical bars represent the standard error of the mean (n = 4)

Figure 3. Dry biomass of leaf - LDB (A), stem - StDB (B), root - RDB (C), total - TDB (D) and Dickson Quality Index - DQI (E) of the seedlings of sour passion fruit cv. BRS RC as a function of the electrical conductivity of irrigation water (ECw) at 60 days after sowing

The salinity of irrigation water caused a marked reduction in root and total dry biomass, respectively equal to 15.09 and 16.94% per unit increment in ECw (Figure 3C and D). When the RDB and TDB values of passion fruit seedlings cultivated under water salinity of 3.5 dS m^{-1} were compared to those of seedlings subjected to 0.3 dS m^{-1}, there were reductions of 0.306 and 3.472 g per plant, respectively.

The decrease in biomass accumulation may result from the effects of osmotic nature, which reduce the water available to plants, causing decrease in cell elongation, besides reducing stomatal opening, net CO_2 assimilation, photosynthetic efficiency and, consequently, plant growth (Oliveira et al., 2018). Bezerra et al. (2016), when evaluating two genotypes of yellow passion fruit (cvs. BRS SC and BRS RA) cultivated under salt stress, verified that the increase in irrigation water salinity reduced biomass accumulation.

Dickson Quality Index was negatively affected by the increase in irrigation water salinity (Figure 3E), with a decrease of 10.77% per unit increment in ECw. Passion fruit plants irrigated with high-salinity water (3.5 dS m^{-1}) showed a decrease in DQI of 35.63% (0.1216) compared to those receiving the lowest value of ECw (0.3 dS m^{-1}). It is worth pointing out that, although the DQI was reduced by salt stress, seedlings under water salinity of up to 3.5 dS m^{-1} were still suitable to be transplanted to the field, because they showed DQI of 0.2196, being considered of acceptable quality (Diniz et al., 2020b). According to Dickson et al. (1960), DQI indicates the sturdiness and balance of biomass distribution in the plant.

Conclusions

1. Electrical conductivity of irrigation water from 0.3 dS m^{-1} reduces the chlorophyll synthesis and growth of seedlings of sour passion fruit cv. BRS RC.

2. Despite the reduction in growth, water with electrical conductivity of up to 3.5 dS m^{-1} can still be used in the formation of passion fruit seedlings with acceptable quality for the field.

3. Potassium does not attenuate the deleterious effects of salt stress in the formation of seedlings of sour passion fruit cv. BRS RC.

4. The interaction between electrical conductivity of irrigation water and potassium doses does not affect any of the analyzed variables of sour passion fruit cv. BRS RC at 60 days after sowing.

Acknowledgments

To the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) for providing the financial support (Proc. CNPq 429732/2018-0) and research productivity grant (Proc. CNPq 309127/2018-1) to the first author.

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