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Leaching of salts and production of sour passion fruit irrigated with low- and high-salinity water[1]

Lixiviação de sais e produção de maracujazeiro irrigado com água de baixa e alta salinidade

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HIGHLIGHTS:

Incorporation of biofertilizer contributes to increasing soil pH in the dry period.
Irrigation with water of 4.0 dS m^{-1} increases the saline character of the soil from moderately to strongly saline.
Leaching fraction of 10% was not sufficient to avoid salt accumulation, even in sandy soil.

ABSTRACT: The objective of this study was to evaluate the effect of irrigation with low- and high-salinity water on the increment of salts in the soil, the production components of sour passion fruit and the leaching of salts by rainfall and by leaching fraction of 10%. The treatments were arranged in randomized blocks, in a split-plot scheme, corresponding to three irrigation management practices [evaluation of soil chemical attributes before irrigation; and after irrigation with water of low electrical conductivity (0.35 dS m^{-1}), and high electrical conductivity (4.00 dS m^{-1}) in the main plot], and in the subplot two soil depths of evaluation (0-20 and 20-40 cm) and three soil sampling times (at 115 days after transplanting of seedlings (DAT) - beginning of flowering; at 199 DAT - end of the dry season; and at 379 DAT - end of the rainy season). Irrigation increased the electrical conductivity of the soil saturation extract, with higher values in the surface layer and at the end of the dry season. Rainfall during the rainy season reduced the saline character of soil from moderately saline and strongly saline, in treatments irrigated with water of low and high electrical conductivity, to non-saline and slightly saline, respectively. Irrigation with high-electrical conductivity water negatively affected the production components and yield of sour passion fruit.

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

RESUMO: O objetivo deste estudo foi avaliar o efeito da irrigação com água de baixa e alta salinidade sobre o incremento de sais no solo, os componentes de produção do maracujazeiro azedo e a lixiviação dos sais pela precipitação pluviométrica e pela fração de lixiviação de 10%. Os tratamentos foram dispostos em blocos ao acaso, em esquema de parcelas subdivididas, correspondendo a três práticas de manejo de irrigação [avaliação dos atributos químicos do solo antes da irrigação; e após irrigação com água de baixa (0,35 dS m^{-1}) e alta condutividade elétrica (4,00 dS m^{-1}) na parcela principal], e na subparcela duas profundidades de avaliação dos atributos químicos do solo (0-20 e 20-40 cm) e três épocas de amostragem de solo (aos 115 dias após o transplantio das mudas (DAT) - início do florescimento das plantas; aos 199 DAT - final do período de estiagem; e aos 379 DAT - final do período chuvoso). A irrigação elevou a condutividade elétrica do extrato de saturação do solo, com superioridade na camada superficial e no final do período seco. A precipitação pluviométrica durante a estação chuvosa reduziu o caráter salino do solo de medianamente e fortemente salino, nos tratamentos irrigados com água de baixa e alta condutividade elétrica, para não salino e ligeiramente salino, respectivamente. A irrigação com água de alta condutividade elétrica afetou negativamente os componentes de produção e produtividade do maracujazeiro azedo.

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

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Introduction

Passion fruit (*Passiflora edulis* Sims) stands out, especially in the Northeast region, which is the largest producer of this fruit in Brazil, despite having a low yield (IBGE, 2021). One of the factors that contribute to the low yield of passion fruit in the Northeast region is the quality of irrigation waters, which in this region, generally pose risks of soil salinization (Cavalcante et al., 2018; Souza et al., 2018; Lima et al., 2022).

In northeastern Brazil, the rise in soil salinity is related to high evaporation rates, rainfall irregularity, and inadequate management of fertilizers and irrigation and drainage, which contribute to a significant increase in salt-affected areas (Nunes et al., 2017; Lima et al., 2020a; Moura et al., 2020). However, in this region, the practice of irrigation is essential to increase crop yield.

Irrigation can increase crop production; however, this agricultural practice, even with water of low electrical conductivity, adds salts to the soil and contributes to the increase in salinized areas (Resende et al., 2014). Passion fruit is sensitive to salts present in the soil and irrigation water (Lima et al., 2020a; Moura et al., 2021), indicating the need for research aimed at knowing the dynamics of salts and their effects on crop yield.

The deleterious effects of salts on plants have been reported in the national and international literature (Bonifácio et al., 2018; Arif et al., 2020; Lima et al., 2020b; Zhao et al., 2020). Although there are studies in the northeastern semi-arid region evaluating irrigation with saline water in passion fruit (Souza et al., 2018; Lima et al., 2020a; Moura et al., 2021); however, these studies do not evaluate the effect of rainfall on the leaching of salts accumulated in the soil under field conditions.

In this context, the objective of this study was to evaluate the effect of irrigation with low- and high-salinity water on the increment of salts in the soil, the production components of sour passion fruit and the leaching of salts by rainfall and by leaching fraction of 10%.

Material and Methods

The experiment was carried out at the Sítio Macaquinhos farm in the municipality of Remígio, PB, Brazil (7° 00' 15" S, 35° 47' 55" W and an altitude of 561.7 m), from May 2013 to August 2014. According to Köppen's classification, the climate of the municipality is As', which means hot and dry, with the rainy season starting in March and ending in August (Alvares et al., 2013). The minimum and maximum values of rainfall, air temperature, and relative humidity of air during the experimental period, obtained from pluviometer and Datalogger HT-70 Instrutherm®, were 520 and 637 mm (Figure 1A), 24.9 and 26.6 °C, and 71.8 and 76.9% (Figure 1B), respectively.

Before setting up the experiment, soil samples were collected at depths of 0-20 and 20-40 cm for chemical characterization with respect to salinity (Table 1) according to Richards (1954), fertility (Table 2), and physical attributes (Table 1) following methodologies recommended by Teixeira et al. (2017). The soil of the experimental area was classified as

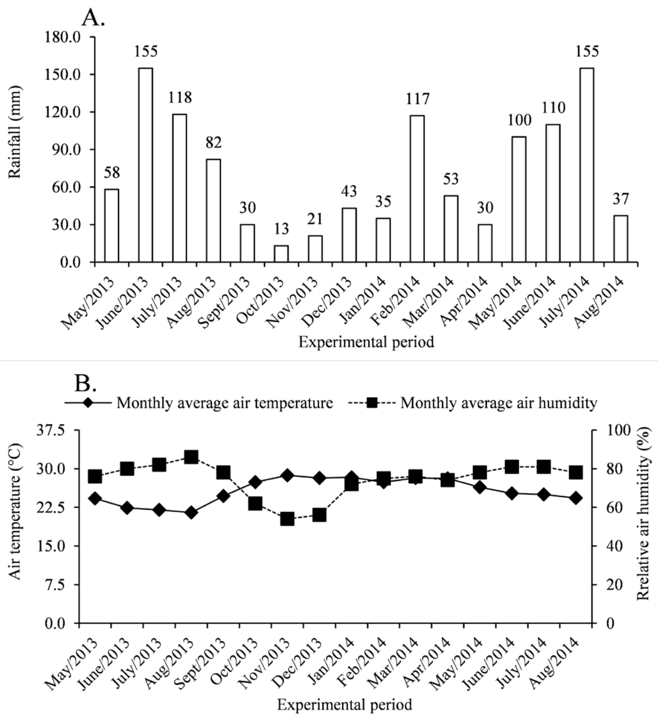

Figure 1. Monthly rainfall (A), monthly average air temperature, and relative humidity of air (B) at the Sítio Macaquinhos, PB, Brazil, during the experimental period

Table 1. Chemical attributes - salinity, and physical attributes of the soil before the beginning of the experiment, in the 0-20 and 20-40 cm layers (mean of three replicates)

Chemical attributes	0-20 cm	20-40 cm	Physical attributes	0-20 cm	20-40 cm
EC_{se} at 25 °C (dS m^{-1})	0.43	0.29	Soil bulk density (kg dm^{-3})	1.61	1.59
pH (H_2O)	6.93	6.67	Particle density (kg dm^{-3})	2.66	2.65
Ca^{2+} ($mmol_c$ L^{-1})	0.87	0.72	Total porosity (m^3 m^{-3})	0.39	0.40
Mg^{2+} ($mmol_c$ L^{-1})	0.78	0.55	Sand (g kg^{-1})	847	821
Na^+ ($mmol_c$ L^{-1})	2.11	1.32	Silt (g kg^{-1})	102	124
K^+ ($mmol_c$ L^{-1})	0.56	0.34	Clay (g kg^{-1})	51	55
Cl^- ($mmol_c$ L^{-1})	2.66	1.93	WDC (g kg^{-1})	13	13
CO_3^{2-} ($mmol_c$ L^{-1})	0.00	0.00	DF (%)	74.5	76.4
HCO_3^- ($mmol_c$ L^{-1})	0.89	0.61	DI (%)	25.5	23.6
SO_4^{2-} ($mmol_c$ L^{-1})	0.67	0.31	Ufc (g kg^{-1})	98.1	99.1
SARse (mmol L^{-1})$^{0.5}$	2.32	1.66	Upwp (g kg^{-1})	43	45
ESP (%)	1.59	1.54	AW (g kg^{-1})	55.1	54.1
Classification	NS	NS	Textural classification	Loamy sand	Loamy sand

EC_{se} - Electrical conductivity of saturation extract; SARse - Sodium adsorption ratio = $Na^+[(Ca^{2+} + Mg^{2+})/2]^{0.5}$; ESP - Exchangeable sodium percentage = 100 (Na^+/CEC); NS - Non-saline; WDC - Water-dispersible clay; DF - Degree of flocculation; DI - Dispersion index = 100 - DF; Ufc - Soil moisture at field capacity; Upwp - Soil moisture at the permanent wilting point; AW - Available water

Table 2. Soil chemical attributes - fertility, in the 0-20 and 20-40 cm layers

Soil depths (cm)	pH_{H_2O}	P (mg dm^{-3})	K^+	Na^+ (cmol$_c$ dm^{-3})	$H^+ + Al^{3+}$	Al^{3+}	Ca^{2+}	Mg^{2+}	SB	CEC	V (%)	OM (g kg^{-1})
0-20	6.00	23.51	81.34	0.07	1.32	0	2.45	0.35	3.08	4.40	70.00	6.41
21-40	6.21	12.06	76.04	0.07	1.48	0	2.20	0.60	3.05	4.54	67.18	4.14

SB - Sum of bases (Ca^{2+} + Mg^{2+} + K^+ + Na^+); CEC - Cation exchange capacity [SB + (H^+ + Al^{3+})]; V - Percentage of base saturation [V = (SB/CEC)×100]; OM - Organic matter - Walkley-Black method

non-saline Neossolo Regolítico Eutrófico (EMBRAPA, 2018), which corresponds to Entisol - Psamments (United States Soil Survey Staff, 2014).

The treatments were arranged in randomized blocks, in split plots, corresponding to three irrigation management practices [evaluation of soil chemical attributes before irrigation - BI; and after irrigation with low-salinity water - LSW (EC - 0.35 dS m^{-1}) and high-salinity water - HSW (4.00 dS m^{-1}) in the main plot], and in the subplot the combination of two depths of evaluation of soil chemical attributes (0-20 and 20-40 cm) and three soil sampling times (at 115 days after transplanting of seedlings (DAT), i.e., beginning of flowering; at 199 DAT, i.e., end of the dry season; and at 379 DAT, i.e., end of the rainy season), with three replicates and four plants per plot.

Seedlings of passion fruit were obtained by the seminiferous method for the cultivar 'BRS GA1' with a germination rate of 87%. Polyethylene bags with a capacity of 1.5 L were used, and five seeds were sown in each bag. At 15 days after emergence, the seedlings were thinned, keeping the most vigorous plant. Before transplanting, the seedlings were standardized, considering the criteria of seedlings with height of 25-35 cm and five to six pairs of leaves that were producing the first tendrils.

The holes for planting the seedlings were opened with the dimensions and depth of 0.40 × 0.40 × 0.50 m, with a spacing of 3 m between plants and 2 m between rows, relative to a density of 1,666 plants ha^{-1}. The material of the first 20 cm of each hole received a mixture (100 g) containing 75% of calcitic limestone (48% CaO, 4.5% MgO, and 78% relative neutralizing value - RNV) and 25% of agricultural gypsum - $CaSO_4.2H_2O$ (24% CaO, 16% S, 0.81% P_2O_5, and 14% moisture), along with 10 L of dry bovine manure (C/N = 18:1), as recommended by Borges et al. (2002).

Plants were trained on a trellis system, installed at 2.2 m height from the ground, using smooth wire nº 12 at the top of the posts. The seedlings were grown supported by a stake and, after reaching 15 cm above the support wire, they were pruned to stimulate the emergence of two lateral branches (secondary branches), which were trained in opposite directions and pruned when they reached 1.5 m of the main branch, originating the tertiary branches (curtain), which were pruned at 30 cm above the ground. Cultural and phytosanitary management practices were performed according to the crop requirement, based on visual monitoring.

Water with the respective salinity level (Table 3) was prepared weekly by dissolving non-iodized sodium chloride in low-salinity water (C_1S_1) from a dam. For plant fertilization, 670 kg ha^{-1} per year of urea (45% N), 880 kg ha^{-1} per year of single superphosphate (18% P_2O_5, 20% Ca, 12% S), and 476 kg ha^{-1} per year of potassium chloride (60% K_2O) were applied, as recommended by Souza et al. (2018). Urea and potassium

Table 3. Chemical composition of irrigation waters and bovine biofertilizer in terms of salinity

Variables	Type of water LSW	Type of water HSW	Bovine biofertilizer (Pure)
pH	6.12	6.25	7.68
EC_{iw} (dS m^{-1})	0.35	4.00	4.55
SAR (mmol L^{-1})$^{0.5}$	1.57	12.83	1.92
Ca^{2+} (mmol$_c$ L^{-1})	1.19	2.51	10.26
Mg^{2+} (mmol$_c$ L^{-1})	0.59	7.92	13.02
Na^+ (mmol$_c$ L^{-1})	1.48	29.31	6.56
K^+ (mmol$_c$ L^{-1})	0.19	0.38	15.53
SC (mmol$_c$ L^{-1})	3.45	40.12	45.37
CO_3^{2-} (mmol$_c$ L^{-1})	Absent	0.11	Absent
HCO_3^- (mmol$_c$ L^{-1})	0.54	2.85	6.79
Cl^- (mmol$_c$ L^{-1})	2.51	36.56	32.02
SO_4^{2-} (mmol$_c$ L^{-1})	0.36	0.24	6.67
SA (mmol$_c$ L^{-1})	3.41	39.65	45.48
Classification (Richards, 1954)	C_1S_1	C_4S_1	

EC_{iw} - Electrical conductivity of irrigation water; LSW - Low-salinity water from the surface dam; HSW – High-salinity water obtained by addition of sodium chloride; SAR = $Na^+/[(Ca^{2+} + Mg^{2+})/2]^{0.5}$; SC - Sum of cations; SA - Sum of anions; C_1 and C_4 – Water with low and very high risk of soil salinization; S_1 - Low risk of soil sodification

chloride were applied monthly, and phosphate fertilization was applied every two months. In addition to mineral fertilization, 15 L m^{-2} of pure bovine biofertilizer (Santos, 1992) was applied to the soil one day before planting and every 90 DAT (Table 3).

Irrigation with both types of water was performed every two days by the localized drip irrigation method, using two drippers per plant, each with a flow rate of 10 L h^{-1}. The irrigation depth was calculated based on the maximum daily depth of potential evapotranspiration (ETo) of 14 L per plant per day obtained by the product of evaporation from the class A pan (ETa), installed at the experiment site (ETo = ETa × 0.75), and crop coefficient - Kc of 0.4, 0.8, and 1.2 (Souza et al., 2018) to calculate crop evapotranspiration - ETc (ETc = ETo × Kc), respectively referring to the first 60 DAT, from 60 to 90 DAT, and from flowering to the end of harvest.

In the treatments irrigated with water of 4.0 dS m^{-1}, despite the sandy texture of the soil (Table 1), a leaching fraction of 10% was adopted, resulting in an applied irrigation depth 10% higher than that estimated, in order to reduce the accumulation of salts in the soil by leaching from the root zone (Ayers & Westcot, 1999). From the transplanting of seedlings to the beginning of flowering, the plants were irrigated for a period of 71 days (01/09/2013 to 10/11/2013); from the beginning of flowering to the end of the dry season, the plants were irrigated for a period of 82 days (11/11/2013 to 31/01/2014), totaling 153 days of irrigation. Rainfall during the rainy season, from March to August 2014, was equal to 485 mm (Figure 1).

Collection of soil samples to evaluate salinity was performed at 115 DAT (beginning of flowering), 199 DAT (end of the dry season), and 379 DAT (end of the rainy season). Single samples were collected from each quadrant, in relation to the plant stem, in the 0-20 and 20-40 cm layers, in the third plant of each treatment to evaluate the pH of the saturated paste and electrical conductivity of the saturation extract, using the methodology of Richards (1954).

During the two production cycles (first - 16/12/2013 to 20/02/2014; second - 12/03/2014 to 12/05/2014), fruit harvests were carried out three times a week, collecting the fruits with at least 20% of their peel area with yellowish color (Diniz et al., 2022). Then, the fruits were placed in a plastic box, counted to obtain the number of fruits per plant, and weighed to obtain the average fruit mass (g per fruit) and production per plant (kg per plant). Yield (t ha^{-1}) was obtained by the product between the mass of fruits per plant and the number of plants per hectare (1,666 plants ha^{-1}) divided by 1,000.

The results were subjected to analysis of variance by the F test, and the means were compared by the Tukey test at $p \le 0.01$ and $p \le 0.05$. SAS® software version 9.3 (SAS®, 2011) was used for data processing.

Results and Discussion

The triple interaction (irrigation management practice × depth of evaluation of soil chemical attributes × evaluation time) had a significant effect on the pH and electrical conductivity values of the saturation extract (EC_{se}) in soil cultivated with BRS GA1 passion fruit plants (Table 4). The pH of the saturated paste was influenced by the simple factors - soil depth and evaluation time, and by the interactions - irrigation management × soil depth of evaluation and irrigation management × evaluation time. Except for blocks, the electrical conductivity of the saturation extract was influenced by the simple factors and by the double and triple interactions between the studied sources of variation. The similar behavior of the significant effects observed for pH and EC_{se} evidences the action of irrigation water in adding salts to the soil and the benefits of salt leaching to the deeper layers in sandy-textured soils, promoted by rainwater.

Table 4. Summary of the analysis of variance of pH of saturated paste (pH_{sp}) and electrical conductivity of saturation extract (EC_{se}) in soil cultivated with BRS GA1 passion fruit

Source of variation	DF	Mean squares	
		pH_{sp}	EC_{se}
Blocks	2	0.590^{ns}	0.375^{ns}
Irrigation management (I)	2	2.057^{ns}	111.407**
Residual (a)	4	0.437	0.0952
Depth (D)	1	0.433**	11.592**
Interaction I × D	2	0.651**	2.149**
Time (T)	2	3.286**	37.032**
Interaction I × T	4	0.932**	12.857**
Interaction D × T	2	0.164^{ns}	0.902**
Interaction I × D × T	4	0.271**	0.428**
Residual (b)	30	0.056	0.007
Total	53		
CV (a) - %		10.24	10.63
CV (b) - %		3.68	3.07

DF - Degrees of freedom; CV (a) - Coefficient of variation of the residual a; CV (b) - Coefficient of variation of the residual b; ^{ns} - Not significant; * - Significant at $p \le 0.05$; ** - Significant at $p \le 0.01$

When soil samples were collected at the beginning of flowering (115 DAT) of BRS GA1 passion fruit plants, regardless of the soil depth, there was no difference in the pH values of the saturated paste before irrigation and after irrigation with water of low and high electrical conductivity (Table 5). However, regardless of the electrical conductivity of the irrigation water and soil depth, the pH values of the saturated soil at 115 DAT were higher than those recorded at the end of the rainy season, at 379 DAT (Table 5).

When comparing the soil pH_{sp} values of 6.57 and 6.99, in the subsurface layer (20-40 cm) with the values of 5.62 and 6.50 in the surface layer (0-20 cm), under irrigation with water of low and high electrical conductivity, respectively, at the end of the dry season, it is observed that the pH values of the subsurface layer are 19.02 and 7.54% higher.

When comparing the pH values of the soil saturated paste at the end of the dry season with those at the end of the rainy season, in the layer of 20-40 cm, the former were higher, under any salinity level of the irrigation water (Table 5). The higher values of pH_{sp} at the end of the dry period highlight the increase of ions transported to the soil by the irrigations using both types of water, especially in treatments irrigated with water of higher salinity (Table 3), along the 153 days of irrigation (01/09/2013 to 31/01/2014). On the other hand, the lower values observed at the end of the rainy season show that there was solubilization and leaching of the salts, promoted by rainfall of 485 mm (Figure 1A), which is associated with soil texture (Table 1) and contributed to increasing the pH_{sp} values in the subsurface layer (Table 5). In addition to these factors, the monthly application of urea may have contributed to the decrease in soil pH during the rainy season, through the release of H^+ in the nitrification process (Pires et al., 2008). The

Table 5. Mean values of pH of saturated paste (pH_{sp}) and electrical conductivity of soil saturation extract (EC_{se}) before irrigation (BI) and after irrigation with water of low (LSW) and high electrical conductivity (HSW) at different evaluation times, in the 0-20 and 20-40 cm soil depths

Soil depth (cm)	Evaluation times								
	115 DAT (Beginning of flowering)			199 DAT (End of the dry season)			379 DAT (End of the rainy season)		
	BI	LSW	HSW	BI	LSW	HSW	BI	LSW	HSW
					pH_{sp}				
0-20	6.93 aAα	6.57 aAα	6.97 aAα	6.93 aAα	5.62 bBβ	6.50 aBα	6.93 aAα	5.59 bAβ	5.28 bBβ
20-40	6.67 aAα	6.94 aAα	6.93 aAα	6.67 aAα	6.57 aAα	6.99 aAα	6.67 aAα	5.44 cAβ	6.05 bAβ
					EC_{se} (dS m^{-1})				
0-20	0.43 cAα	3.47 bAβ	6.44 aAβ	0.43 cAα	5.28 bAα	9.19 aAα	0.43 cAα	2.11 bAγ	2.52 aAγ
20-40	0.29 cAα	2.33 bBβ	5.43 aBβ	0.29 cAα	3.74 bBα	6.57 aBα	0.29 cAα	1.18 bBγ	1.84 aBγ

DAT - Days after transplanting of seedlings; Means followed by the same lowercase letters in the rows for the different irrigation managements (BI, LSW, HSW) at the same evaluation time and soil depth do not differ statistically from each other by Tukey test ($p \le 0.05$); Means followed by the same uppercase letters in the columns between the different soil depths at the same evaluation time and irrigation management do not differ statistically from each other by Tukey test ($p \le 0.05$); Means followed by the same Greek letters in the rows under the same irrigation management and soil depth at different evaluation times do not differ statistically from each other by Tukey test ($p \le 0.05$)

chemical composition of the biofertilizer applied to the soil, with pH of 7.68 (Table 3), may also have influenced the pH values of the saturated paste, as observed by Cavalcante et al. (2019). However, despite the variation of pH values throughout the passion fruit cultivation period, they are within the range recommended for the crop.

In the 0-20 cm layer, irrigations with water of low and high electrical conductivity increased soil salinity from 0.43 dS m^{-1} to 3.47 and 6.44 dS m^{-1}, from the transplanting of the seedlings to the beginning of flowering, respectively (Table 5). In the 20-40 cm layer, during the same period, soil salinity was increased from 0.29 dS m^{-1} in the samples collected before irrigation to 2.33 and 5.43 dS m^{-1} in treatments irrigated with water of low electrical conductivity (0.35 dS m^{-1}) and high electrical conductivity (4.00 dS m^{-1}), respectively. Regardless of the irrigation management practice and the time of collection of soil samples for chemical evaluation, it is observed that the agricultural practice increased the concentration of salts in the soil at the evaluated depths. Similar results were also reported by Cavalcante et al. (2018).

Irrigation was started on 01/09/2013 and, based on the results, in the period of 71 days, which corresponds to the beginning of flowering (115 DAT), it was observed that low-salinity water (LSW) and high-salinity water (HSW) increased the initial values of electrical conductivity of soil saturation extract (ECse) by 707 and 1,398% and by 703 and 1,772%, in surface (0-20 cm) and subsurface (20-40 cm) layers, respectively. This level of soil salinity has restrictions for the cultivation of passion fruit and indicates that the leaching fraction adopted (10%) was not sufficient to avoid salt accumulation, even in sandy soil (Table 1), probably due to the preferential paths of the water movement in the soil.

In salt-sensitive crops, such as yellow passion fruit, which do not tolerate soil salinity in saturation extract above 1.3 dS m^{-1} (Ayers & Westcot, 1999) without significant production losses, the values of 3.47 and 6.44 dS m^{-1} and 2.33 and 5.43 dS m^{-1}, obtained in treatments irrigated with water of low and high electrical conductivity, at soil depths of 0-20 and 20-40 cm, respectively (Table 5), may compromise the absorption of water and nutrients and production capacity of passion fruit plants (Lima et al., 2020a). This increase in salinity of an initially non-saline soil, irrigated with water of no restrictions to agriculture, was also evidenced by Souza et al. (2018) and Souza et al. (2020). It is also noticed that the intensity of stress is aggravated with the increase in water salinity in the soils irrigated with water of higher electrical conductivity, exceeding by 86 and 133% the increase of salts in the soil caused by irrigation with water of low electrical conductivity, respectively in the layers of 0-20 and 20-40 cm, where most of the active roots of passion fruit plants are concentrated (Sousa et al., 2002).

After the evaluation of the soil concerning salinity at the beginning of flowering, irrigation with the same waters continued for more 82 days (11/11/2013 to 31/01/2014), totaling 153 days of irrigation until the end of the dry season (199 DAT). In this period, the initial values of soil salinity were increased by 1,128 and 2,037% and by 1,190 and 2,166% with the waters of low and high electrical conductivity, respectively, in the surface and subsurface layers of the soil (Table 5).

A comparison of the values of electrical conductivity of soil between the first two evaluation times showed, according to Richards (1954), that irrigation with water of low electrical conductivity ($ECiw = 0.35$ dS m^{-1}), from flowering to the end of the dry season, increased the saline character of the soil from slightly saline ($2 < ECse < 4$ dS m^{-1}) to moderately saline ($4 < ECse < 8$ dS m^{-1}) in the 0-20 cm layer. When comparing the soil electrical conductivity value of 5.28 with 3.47 dS m^{-1}, it was observed that irrigation, even with water without any restrictions to the crop, for 81 days, increased the salinity level of the soil by 52.3% (Table 5). In the same period, the water of high electrical conductivity ($ECiw = 4.00$ dS m^{-1}) increased the saline character of the soil from moderately saline to strongly saline ($8 < ECse < 16$ dS m^{-1}) in the same soil depth (Richards, 1954). Although the increase in ECse from 6.44 to 9.19 dS m^{-1} expresses in the same period a smaller increment of salts in the soil (42.7%), this does not mean that the stress was less harmful to plants. Under such situations, stress intensity should be evaluated based on the absolute value of salinity indicated by the electrical conductivity of the saturation extract of the soil (Richards, 1954).

In the 20-40 cm soil layer, the increase in the concentration of salts, caused by irrigation with water of low electrical conductivity in the two periods evaluated, was from 2.33 to 3.74 dS m^{-1}, keeping the soil as slightly saline (ECse between 2 and 4 dS m^{-1}), despite the 60.5% increment (Table 5). When irrigation was carried out with water of high electrical conductivity, the increase was from 5.43 to 6.57 dS m^{-1} in the flowering period of the crop at the end of the dry season, but maintaining the soil, despite the lower salt increment of 21%, as moderately saline ($4 < ECse < 8$ dS m^{-1}). In the subsurface layer, the values of ECse increased significantly, which is due to the physical conditions, such as sandy texture and macropore space for drainage (Table 1), along the soil profile.

In the rainy season, from March to July 2014, rainfall was equal to 485 mm and the electrical conductivity of soil saturation extract (ECse) obtained during the dry season was reduced to the values of 2.11 and 2.52 dS m^{-1} in the 0-20 cm layer and 1.18 and 1.84 dS m^{-1} in the 20-40 cm layer, in treatments irrigated with water of low and high electrical conductivity, respectively (Table 5).

When comparing the electrical conductivity of the soil saturation extract obtained at the end of the rainy season with that corresponding to the dry season, it can be observed that the rainfall of 485 mm (Figure 1) during the rainy season, regardless of the treatment, reduced electrical conductivity by 60 and 72.6% and by 68.4 and 72%, in the soil depths of 0-20 and 20-40 cm, compared to the values obtained with the salts accumulated by irrigations with water of low and high electrical conductivity during the dry season. These large reductions, in both soil depths, express the efficiency of the leaching of salts promoted in each layer by rainfall (Figure 1A) and the positive action of the sandy texture (Table 1) in the recovery of saline soils. These values indicate that, in situations in which the soil has physical attributes for air permeability and root growth, the rainwater leaches more than half of the salts accumulated in the soils by irrigation and enables the use of restrictive waters for plants sensitive and moderately sensitive to salinity (Cavalcante et al., 2018).

Table 6. Mean values ± standard error of number of fruits (NF), average fruit mass (AFM), production per plant (PP) and fruit yield (YLD) of BRS GA1 passion fruit plants (sum of two production cycles) irrigated with water of low electrical conductivity (LSW) and high electrical conductivity (HSW)

EC_{iw} ($dS\ m^{-1}$)	NF (fruits per plant)	AFM (g per fruit)	PP (kg per plant)	YLD ($t\ ha^{-1}$)
0.35	112.25 ± 2.75	403.35 ± 3.32	22.15 ± 0.59	36.92 ± 0.99
4.00	99.00 ± 12.10	384.51 ± 7.06	18.94 ± 2.22	31.57 ± 3.7
Mean	105.63	393.93	20.54	34.25

EC_{iw} - Electrical conductivity of irrigation water

As for the production and its components, only the average values are presented, due to the impossibility of statistically evaluating the variables of production according to the sources of variation studied (Table 6). It was found that irrigation with water of high electrical conductivity (4.00 $dS\ m^{-1}$) reduced the number of fruits per plant, average fruit mass, production per plant, and yield of BRS GA1 passion fruit (Table 6). When comparing the values obtained in the treatments irrigated with water of low and high electrical conductivity, the reductions were 11.8, 4.7, 14.5, and 14.5%, respectively. Despite these reductions, even in treatments irrigated with water of high electrical conductivity, the number of fruits per plant was higher than the average of 54.27 fruits per plant obtained by Souza et al. (2020), when evaluating soil salinity and the production of the same crop irrigated with saline water and under organomineral fertilization.

According to Cavalcante et al. (2018), the average fruit mass of both treatments is adequate for commercialization, as the values are above 180 g. Morais et al. (2020), evaluating the production per plant of passion fruit irrigated with saline water (3.4 $dS\ m^{-1}$) in different spatial arrangements in the absence and presence of pruning, recorded an average value (17.6 kg per plant) lower than that obtained in the present study. The average yield values recorded in the experiment (34.25 $t\ ha^{-1}$) are above the national average (15.2 $t\ ha^{-1}$) and that of the Southern Brazil (20.3 $t\ ha^{-1}$), which has the highest national yield (IBGE, 2021). Moreover, they exceed the average (9.5 $t\ ha^{-1}$) reported by Pinheiro et al. (2022), when evaluating the production of yellow passion fruit under different irrigation strategies using low- and high-salinity water in the semi-arid region of Paraíba state. However, these values are lower than the potential of the crop, which is around 50 $t\ ha^{-1}$ (Meletti, 2011).

Conclusions

1. Irrigation water increases the electrical conductivity of the soil saturation extract, with higher values in the surface layer and at the end of the dry season.

2. Rainfall of 485 mm during the rainy season reduces the saline character of soil irrigated with water of low and high salinity, respectively from moderately and strongly saline to slightly saline.

3. Irrigation with water of high electrical conductivity reduces the yield of BRS GA1 passion fruit by 14.5%.

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