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Calcium in the mineral nutrition of yellow passion fruit cultivated in lined pits and with saline water¹

Cálcio na nutrição mineral de maracujazeiro-amarelo produzido em covas protegidas e sob salinidade hídrica

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HIGHLIGHTS:

Irrigation with saline water interferes with the mineral nutrition of yellow passion fruit plants.

The increase in water salinity results in an increase in sodium content of leaf.

Calcium can be used as a salt stress attenuator in yellow passion fruit plants.

ABSTRACT: Nutritional status is an important tool in salinity management, because salt stress interferes with both the absorption and the assimilation of mineral nutrients by plants. The objectives of this experiment were to evaluate the effects of water salinity, lateral protection of pits against water losses and calcium doses on the leaf concentration of macronutrients and sodium of yellow passion fruit cv. BRS GA1. The treatments were arranged in a randomized block design in split plots in a $2 \times (2 \times 5)$ factorial scheme, corresponding to water salinity (0.3 and 4.0 dS m⁻¹) in the main plot, and the combinations between lateral protection of pits (without and with) and calcium doses (0, 30, 60, 90 and 120 kg ha⁻¹) in the subplots. Leaf concentrations of macronutrients and sodium were determined at the phenological stage of full flowering. Irrigation of yellow passion fruit with 4.0 dS m⁻¹ water decreased the leaf concentrations of macronutrients. The lining of the pits compromised macronutrient concentration in the plants. Calcium fertilization is recommended for yellow passion fruit cultivated in Entisol with low calcium concentration at the dose of 60 kg ha⁻¹, because it raises nitrogen and calcium concentrations in plants irrigated with non-saline water and magnesium and sulfur concentrations in those irrigated with saline water. Calcium attenuates salt stress because it promotes the accumulation of macronutrients in yellow passion fruit under saline conditions.

Key words: *Passiflora edulis* Sims, salt stress, calcium fertilization, plant nutrition

RESUMO: O estado nutricional constitui uma importante ferramenta no manejo da salinidade, devido ao estresse salino interferir tanto na absorção quanto na assimilação dos nutrientes minerais às plantas. Objetivou-se neste experimento avaliar os efeitos da salinidade da água, proteção lateral das covas contra as perdas hídricas e doses de cálcio nos teores foliares de macronutrientes e sódio do maracujazeiro-amarelo cv. BRS GA1. Os tratamentos foram arranjados em delineamento em blocos casualizados em parcelas subdivididas no esquema fatorial $2 \times (2 \times 5)$ correspondente à salinidade da água (0,3 e 4,0 dS m⁻¹) na parcela principal, e nas subparcelas as combinações entre proteção lateral das covas (sem e com) e doses de cálcio (0, 30, 60, 90 e 120 kg ha⁻¹). Foram determinados os teores foliares de macronutrientes e sódio no estágio fenológico de plena floração das plantas. A irrigação do maracujazeiro-amarelo com água de 4,0 dS m⁻¹ reduziu as concentrações foliares de macronutrientes. O revestimento das covas comprometeu os teores de macronutrientes nas plantas. A adubação calcítica é recomendada para o maracujazeiro-amarelo cultivado em Entisol com baixo teor de cálcio na dose de 60 kg ha⁻¹ de cálcio, por elevar os teores de nitrogênio e cálcio nas plantas irrigadas com água não salina, e de magnésio e enxofre sob irrigação com água salina. O cálcio atenua o estresse salino porque aumenta o acúmulo de macronutrientes em condições salinas no maracujazeiro-amarelo.

Palavras-chave: *Passiflora edulis* Sims, estresse salino, adubação calcítica, nutrição de plantas

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INTRODUCTION

The evaluation of the nutritional status of plant is an important tool under saline conditions, which may lead to ionic competition triggered by nutritional deficiencies and toxicity (Dias et al., 2016). Excess of salts in irrigation water can hamper the absorption of mineral nutrients by plants, including passion fruit (Freire et al., 2013; Souza et al., 2018; Lima et al., 2020), which can be grown with water of up to 2.3 dS m⁻¹ without significant losses (Holanda et al., 2016).

Increased sodium chloride concentration in irrigation water can reduce the absorption of NO₃⁻ and phosphorus (H₂PO₄⁻), due to the competition with chloride (Cl⁻) (Bar et al., 1997; Bünemann et al., 2011), as well as the absorption of potassium (K⁺), calcium (Ca²⁺) and magnesium (Mg²⁺), due to the antagonism with sodium (Freire et al., 2013; Lima et al., 2020).

One of the strategies to reduce exchangeable sodium is the application of calcium in the soil (Tavares Filho et al., 2012; Santos et al., 2019). The nutritional status of plants is affected by the supply of calcium, applied both in the soil (Silva Júnior et al., 2013) and through foliar sprays (Cavalcante et al., 2014; 2015), being an element considered mobile in the soil and immobile in the plant.

Lateral lining of pits has also been used in order to reduce water losses (Lima Neto et al., 2013) and soil salinity (Cavalcante et al., 2005a). Despite the practice of protecting the pits, in yellow passion fruit, it is still incipient and inconclusive (Cavalcante et al., 2005a, b), so it is necessary to deepen the perspective of this practice.

Therefore, the objective of this study was to evaluate the combination of lateral lining of the pits associated with calcium application to mitigate the deleterious effects of increased water salinity on the concentrations of macronutrients and sodium in leaves of yellow passion fruit cv. BRS GA1.

MATERIAL AND METHODS

The study was conducted between November 2015 and July 2016 at the Macaquinhos Farm (07° 00' 08" South, 35° 47' 58" West, and at 564 m of altitude), in the municipality of Remígio, Paraíba State, Brazil. According to Köppen's classification, the municipality is within the climatic zone As', which means tropical climate with rains from March to August (Alvares, 2013).

The soil of the experimental area was classified as Entisol of a loamy sand texture, with 842, 92 and 66 g kg⁻¹ of sand, silt and

clay, respectively. Samples of this soil were randomly collected from the area in the 0-0.20 m layer of the profile and used to characterize both fertility and salinity (Table 1).

Treatments were arranged in a randomized block design, in a 2 × (2 × 5) split-plot and factorial scheme, corresponding to the electrical conductivity of irrigation water (0.3 and 4.0 dS m⁻¹) as the main plot and the combination between lateral lining of pits against water losses (without and with) and calcium doses (0, 30, 60, 90 and 120 kg ha⁻¹) in the subplot, with four repetitions. The subplot for data collection was constituted by four plants. Fertilization with calcium and its splitting were based on the absorption rate of the yellow passion fruit (Haag et al., 1973).

The experiment with yellow passion fruit cv. BRS GA1 was installed at the density of 1,666 plants per hectare, with 2 m between rows and 3 m between plants. The plant training system was a single wire trellis with a flat wire no. 12 installed at 2.2 m height at the top of the posts. The pits were protected laterally using high-strength plastic film (320 μ). This protection was installed at a distance of 0.50 m from the center of the pit and to a depth of 0.45 m, aiming to reduce water losses by lateral infiltration.

Fertilization followed the recommendations of Borges & Souza (2010). In total, 233 kg ha⁻¹ of N, 338 kg ha⁻¹ of K₂O and 167 kg ha⁻¹ of P₂O₅ were applied. The pits were opened with dimensions of 0.40 x 0.40 x 0.40 m and prepared with a mixture of the material removed from the pits, 20 L of decomposed bovine manure, 15 g of N, 18 g of K₂O, 12 g of P₂O₅, 4 g of Zn, 2.7 g of Mg and 5.7 g of S.

During the plant growth stage, 53 g of N, 65 g of K₂O, 28 g of P₂O₅ were applied per plant in four monthly applications plus one application with 18 g of magnesium sulfate at 90 days after transplantation. In the production stage, 72 g of N, 120 g of K₂O were supplied in four monthly applications, plus 60 g of P₂O₅ in two portions applied with the first and third fertilizations with nitrogen and potassium and 18 g of magnesium sulfate at 150 days after transplantation.

Calcium doses were split into five equal portions, with the first one applied upon the preparation of the pits and the remainder at 60, 90, 120 and 150 days after transplantation. The fertilizers used were urea (45% N), calcium nitrate (15.5% N and 19% Ca), potassium chloride (60% K₂O), monoammonium phosphate (11% N and 50% P₂O₅), zinc sulfate (20% Zn and 9% S) and magnesium sulfate (9% Mg and 13% S).

Irrigation was based on crop evapotranspiration (ETc), calculated by the product of reference evapotranspiration

Table 1. Chemical attributes (fertility and salinity) in the 0-0.20 m layer of the Entisol, before cultivation with yellow passion fruit cv. BRS GA1, in the municipality of Remígio, Paraíba State, Brazil

pH	P	K	Na ⁺	Ca ²⁺	Mg ²⁺	Al ³⁺	H ⁺ + Al ³⁺	SB	CEC	V	ESP	OM
	(mg dm ⁻³)		(cmol _c dm ⁻³)									
4.58	10.60	31.28	0.05	1.92	0.48	0.00	1.30	2.53	3.83	66.10	1.31	5.10
Salinity (saturation extract) ²												
pH	EC _{se}	K ⁺	Na ⁺	Ca ²⁺	Mg ²⁺	SO ₄ ²⁻	CO ₃ ²⁻	HCO ₃ ⁻	Cl ⁻	SP	SAR	Classification
	(dS m ⁻¹)	(mmol _c L ⁻¹)							(%)			
7.14	0.82	0.73	1.97	7.5	2.75	2.99	0.00	2.5	2.5	18.11	0.87	non-saline

¹pH (hydrogen potential) in water; P (phosphorus), K⁺ (potassium) and Na⁺ (sodium) with Mehlich 1 extractant; Ca²⁺ (calcium), Mg²⁺ (magnesium) and Al³⁺ (aluminum) with 1 M KCl extractant; H⁺ + Al³⁺ (hydrogen plus aluminum) with 0.5 M calcium acetate extractant at pH 7.0; SB (sum of bases) = K⁺ + Na⁺ + Ca²⁺ + Mg²⁺; CEC (cation exchange capacity) = SB + H⁺ + Al³⁺; V (base saturation) = (SB/CEC) × 100; ESP (exchangeable sodium percentage) = (Na⁺/CEC) × 100; OM (organic matter) = organic carbon × 1.724, Walkley-Black method; ²EC_{se} (electrical conductivity of the soil saturation extract at 25 °C); SO₄²⁻ (sulfate); CO₃²⁻ (carbonate); HCO₃⁻ (bicarbonate); Cl⁻ (chloride); SAR (sodium adsorption ratio) = Na⁺/[0.5(Ca²⁺+Mg²⁺)]^{0.5}; SP (sodium percentage)

(ET_o), crop coefficient at each phenological stage (k_c) and area reduction coefficient (k_r) (ET_c = ET_o × k_c × k_r). Reference evapotranspiration was obtained by the product of the readings of evaporation of the class A pan, installed near the experimental site, and the pan correction factor of 0.75 (Steduto et al., 2012). The crop coefficients were 0.43 at the vegetative stage, 0.94 at flowering and 1.04 at fruiting. The reduction coefficient was based on the decrease in the wetting area of the localized irrigation (Steduto et al., 2012).

Water was supplied through four pressure-compensating drippers per plant, with individual flow rate of 10 L h⁻¹, working at the operating pressure of 0.15 MPa. Non-saline water (EC_{iw} - electrical conductivity of 0.3 dS m⁻¹ and sodium adsorption ratio of 0.56 (mmol L⁻¹)^{0.5}) was pumped from a surface reservoir, while saline water (EC_{iw} of 4.0 dS m⁻¹) was obtained by dissolution of non-iodized NaCl in low-salinity water. Saline water was prepared a day before irrigation. In the treatments with saline water, 10% additional depth was added as leaching fraction to prevent excessive accumulation of salts in the soil.

The leaf concentrations of macronutrients and sodium were evaluated at full flowering of passion fruit plants at 142 days after transplanting, in the third or fourth leaf collected from the apex of the branch, which contained a floral bud in its axil, from a central branch on both sides of the plants. The concentrations of macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium and sulfur) and sodium were determined according to Tedesco et al. (1995).

The data were subjected to analysis of variance. The effects of irrigation water electrical conductivity and pit protection were compared by the F test ($p \leq 0.05$), while calcium doses were fitted by polynomial regression, when F test was significant ($p \leq 0.10$). The analyses were performed in the software program SAS® University Edition.

RESULTS AND DISCUSSION

The effects of irrigation water electrical conductivity, lateral protection of pits and calcium fertilization on leaf concentrations of macronutrients and sodium can be observed in Table 2.

Leaf nitrogen concentration in yellow passion fruit was influenced by the interactions between water salinity and

protection, water salinity and calcium and between protection and calcium, so in the interpretation of the data it was considered as a triple interaction (Table 2). In pits that were not laterally protected, an increase in salinity from 0.3 to 4.0 dS m⁻¹ reduced leaf nitrogen concentration on average from 48.4 to 44.1 g kg⁻¹ (-9%), respectively, with no satisfactory fit of the regressions as a function of calcium doses (Figure 1A).

In laterally protected pits, the data for plants irrigated with saline water did not vary with calcium doses, having a mean value of 45.4 g kg⁻¹ (Figure 1B). On the other hand, in plants irrigated with good quality water (0.3 dS m⁻¹) N concentration increased from 44.0 to 48.5 g kg⁻¹, decreasing to 42.2 g kg⁻¹ in plants without and with the Ca doses of 55 and 120 kg ha⁻¹, respectively.

The variations observed in leaf nitrogen did not cause deficiency, and the concentrations were considered adequate as N is between 41.2 and 50.2 g kg⁻¹ (Carvalho et al., 2011). These results differ from those reported by Freire et al. (2013) and Lima et al. (2020), who concluded that salinity reduced leaf nitrogen concentration in yellow passion fruit. In a saline environment there may be lower sap flow and NO₃⁻ flow in the xylem, causing a reduction in nitrate reductase activity (Aragão et al., 2010). Under these conditions there is also competition in the absorption between nitrate and chloride, which results in a decreased concentration of nitrogen (Bar et al., 1997), besides the higher energy expenditure in the assimilation of nitrate in comparison to ammonium (Marschner, 2012).

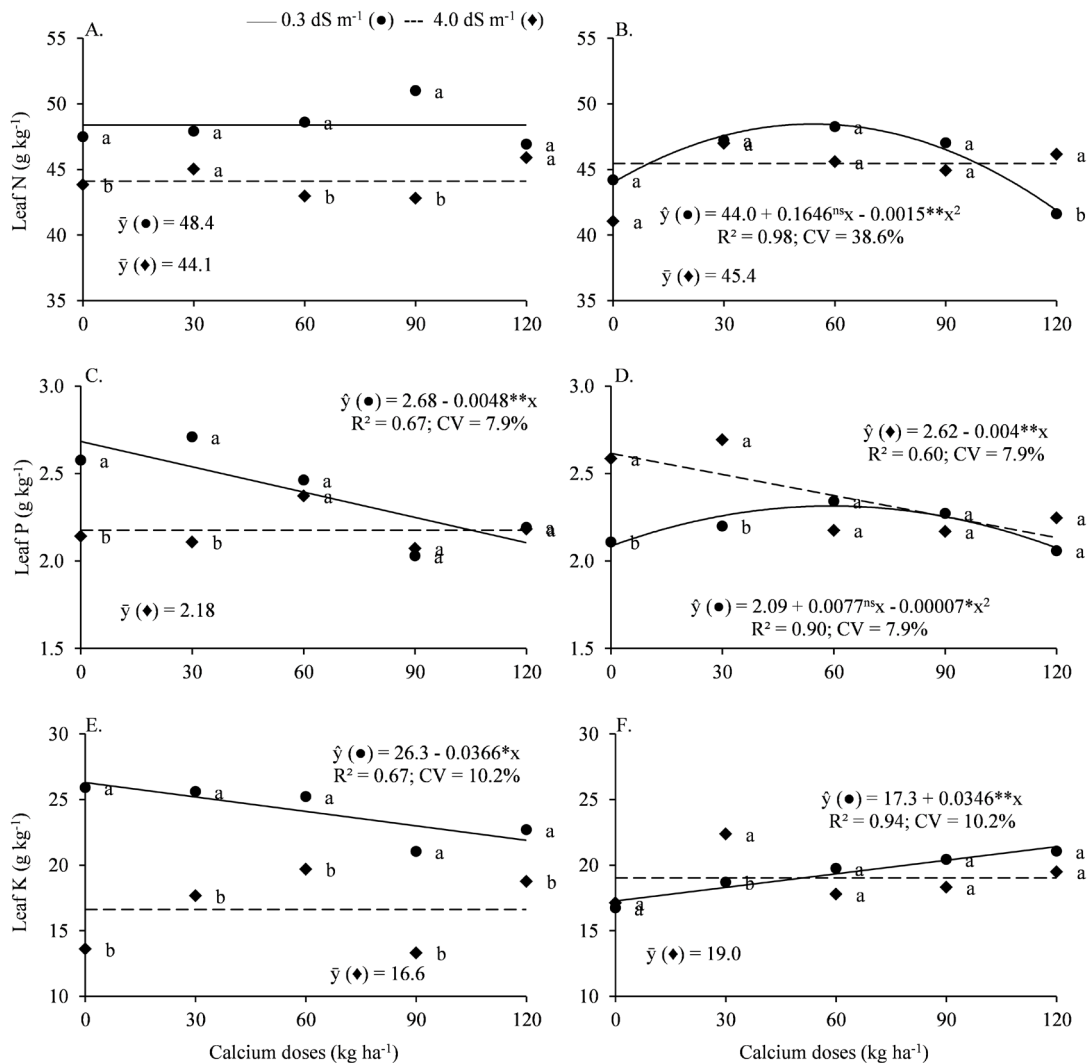
The increase in leaf nitrogen concentration associated with certain doses of calcium fertilization, supplied via calcium nitrate, is probably related to the increase in nitrate availability and decrease in chloride absorption due to the competition with nitrate (Bar et al., 1997). Cavalcante et al. (2014; 2015) found that foliar application of nitrate or calcium chloride stimulated the leaf concentration of nitrogen in passion fruit. The increase in leaf nitrogen concentration may also be a response to the higher activity of nitrate reductase and carbonic anhydrase (Naeem et al., 2009).

Leaf phosphorus concentration in yellow passion fruit was influenced by the interaction between salinity, pit protection and calcium (Table 2). In unlined pits, irrigation with saline water reduced phosphorus concentration by 13 and 22% without and with application of 30 kg ha⁻¹ of calcium,

Table 2. Summary of analysis of variance (mean square) for leaf concentrations of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S) and sodium (Na) in yellow passion fruit cv. BRS GA1 plants, at full flowering, as a function of the electrical conductivity of irrigation water (EC_{iw}), lateral protection of pits (Pp) and calcium doses (Ca)

Sources of variation	DF	N	P	K	Ca	Mg	S	Na
Block	3	1.106 ^{ns}	0.0097 ^{ns}	2.7491 ^{ns}	2.9330 ^{ns}	0.0725 ^{ns}	0.3107*	2.3801 ^{ns}
EC _{iw}	1	101.701*	0.0083 ^{ns}	254.8980**	10.5706 ^{ns}	1.4187 ^{ns}	0.4601*	449.4152**
Residual (a)	3	6.424	0.0310	1.6121	5.6991	1.5196	0.0199	3.9836
Ca	4	25.717**	0.2532**	22.5002**	61.4096**	0.8608*	0.0532 ^{ns}	15.6856**
Pp	1	9.494 ^{ns}	0.0000 ^{ns}	14.3369 ^{ns}	1.2533 ^{ns}	0.0072 ^{ns}	0.6313**	0.5622 ^{ns}
Pp × Ca	4	19.049*	0.0567 ^{ns}	23.3228**	25.4551**	1.1980**	0.1072*	12.6762**
EC _{iw} × Ca	4	33.131**	0.0264 ^{ns}	17.6664**	94.6196**	3.9850**	0.3749**	11.0891**
EC _{iw} × Pp	1	82.175**	0.7814**	211.6836**	55.7557**	0.5099 ^{ns}	0.0125 ^{ns}	0.8080 ^{ns}
EC _{iw} × Pp × Ca	4	5.309 ^{ns}	0.3270**	17.0563**	4.8008 ^{ns}	0.8878*	0.1351*	2.8724 ^{ns}
Residual (b)	54	313.702	0.0327	4.0158	5.5759	0.2473	0.0410	1.5263
CVa (%)		5.52	7.67	6.47	14.18	31.37	5.04	37.87
CVb (%)		38.58	7.90	10.22	14.02	12.65	7.23	23.44
Means (g kg ⁻¹)		45.91	2.29	19.60	16.84	3.93	2.80	5.27

^{ns}, * and ** - Not significant and significant at $p \leq 0.05$ and $p \leq 0.01$ by F test, respectively



Means followed by the same letter, at each calcium dose, do not differ by F test ($p \leq 0.05$); ns, * and ** - Not significant and significant at $p \leq 0.05$ and $p \leq 0.01$ by F test, respectively

Figure 1. Leaf concentrations of nitrogen (N), phosphorus (P) and potassium (K) in yellow passion fruit cv. BRS GA1 as a function of calcium doses, cultivated in pits without (A, C and E) and with (B, D and F) lateral protection and irrigated using water with electrical conductivity of 0.3 (●) and 4.0 dS m⁻¹ (◆)

respectively (Figure 1C). When irrigation was performed using water of 0.3 dS m⁻¹, the phosphorus concentration decreased by 4.8 mg kg⁻¹ per kg ha⁻¹ of calcium.

In lined pits, without and with the application of 30 kg ha⁻¹ of calcium, water salinity increased the concentration of this mineral by 20 and 8%, respectively (Figure 1D). However, when saline water was used in irrigation, calcium doses reduced phosphorus concentration from 2.62 to 2.14 g kg⁻¹ in plants not fertilized and under 120 kg ha⁻¹, respectively. With non-saline water, there was an increase in phosphorus concentration up to the fertilization with 55 kg ha⁻¹ of calcium, which led to a concentration of 2.30 g kg⁻¹.

The P concentration in yellow passion fruit, during full flowering, was below the adequate range, which is between 2.68 and 2.90 g kg⁻¹ (Carvalho et al., 2011). An increase in chloride in the saline water (Bar et al., 1997; Lucena et al., 2012), and calcium-associated nitrate, may have an antagonistic effect on the absorption of phosphorus, predominantly available as orthophosphate, H₂PO₄⁻ (Bünemann et al., 2011), because NO₃⁻ and PO₄⁻ can compete for the same absorption sites. Foliar application of calcium, via chloride and nitrate, also reduced

phosphorus concentration in passion fruit leaves (Cavalcante et al., 2014; 2015).

Potassium concentration in yellow passion fruit leaves was influenced by the interaction between salinity, lining, and calcium (Table 2). In non-lined pits, saline water reduced leaf potassium concentration, with higher intensity at the lowest doses of calcium (Figure 1E). The functional relationship between calcium doses and leaf potassium was observed only under irrigation with non-saline water (Figures 1E, F). Leaf potassium concentration in passion fruit decreased by 36.6 mg kg⁻¹ in plants grown in unprotected pits (Figure 1E) and increased by 34.6 mg kg⁻¹ in plants grown in protected pits (Figure 1F), per unit increase in calcium fertilization.

The nutritional status of passion fruit at full flowering revealed potassium deficiency, with concentration below the adequate range from 23.7 to 30.1 g kg⁻¹ (Carvalho et al., 2011). This situation may be related to the competition between sodium and calcium for the absorption sites of potassium. In this context, Freire et al. (2013) and Lima et al. (2020) also found that the increase in salinity reduced leaf concentration of potassium in passion fruit.

Similar behavior was recorded by Lucena et al. (2012), who found reduction of potassium concentration in mango roots and leaves caused by the increase in sodium in irrigation water. However, the foliar application of nitrate or calcium chloride, depending on the applied concentration (threshold 1 g L^{-1} of calcium), allows both the increase and the reduction of leaf potassium (Cavalcante et al., 2014; 2015).

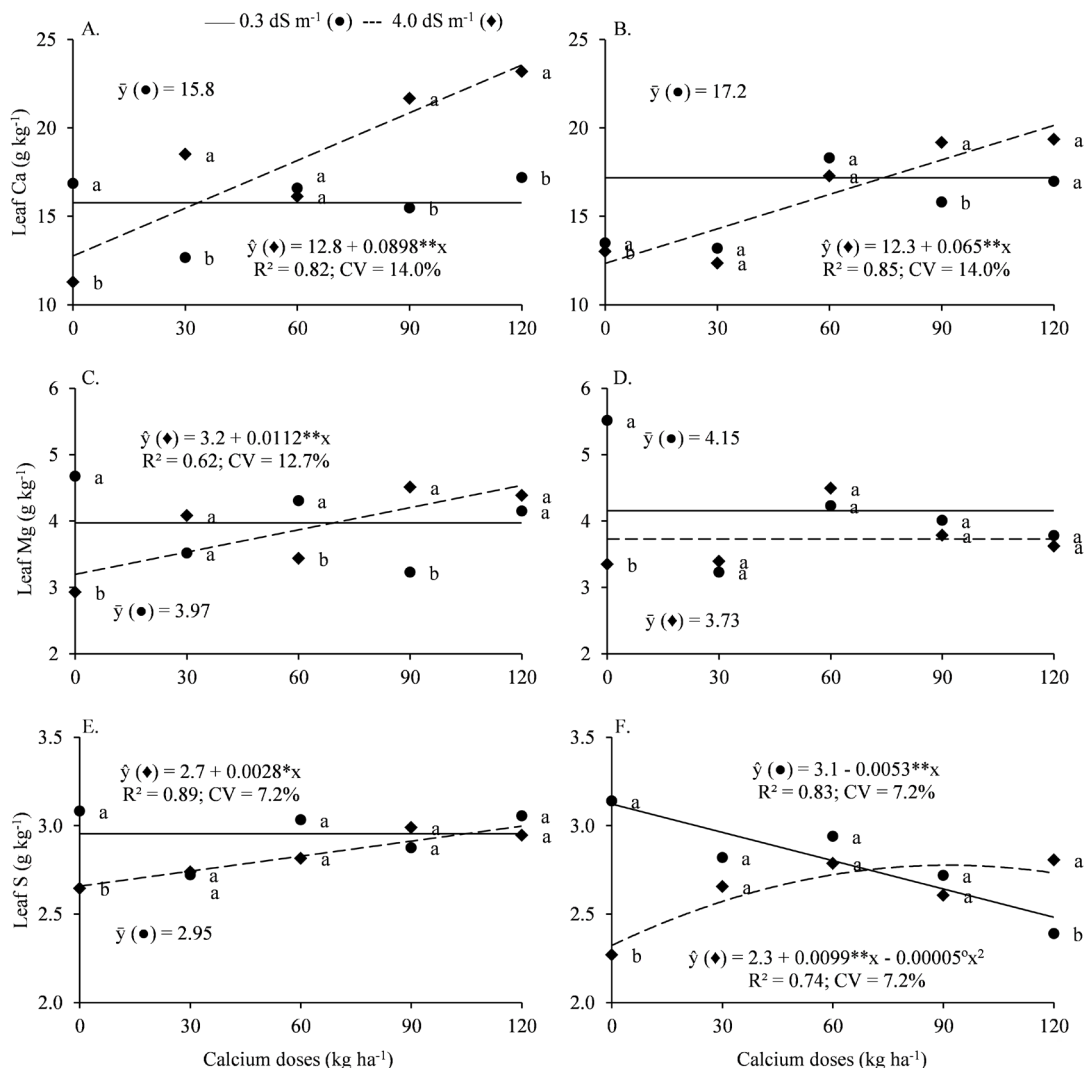
Leaf calcium in yellow passion fruit was affected by the interactions between salinity and lining, salinity and calcium and between lining and calcium, so in the interpretation of the data it was considered as a triple interaction (Table 2). Leaf calcium concentration in yellow passion fruit was reduced by saline water, but only in plants grown in pits without lining and without calcium fertilization (Figures 2A, B). In relation to calcium doses, under irrigation with saline water, there were increments of 89.8 (Figure 2A) and 65.0 mg kg^{-1} (Figure 2B) of calcium per unit increase in calcium fertilization. Under irrigation with non-saline water, there was no functional relationship between calcium fertilization and leaf calcium concentration (Figures 2A, B).

Considering that yellow passion fruit, according to Carvalho et al. (2011), requires between 9.2 and 11.2 g kg^{-1}

of Ca, it was concluded that the plants at flowering were adequately supplied. However, according to Malavolta et al. (1997), yellow passion fruit plants require from 15 to 20 g kg^{-1} of calcium and were therefore deficient in the element. The increase in leaf calcium in plants irrigated with saline water may result from the greater availability of the nutrient due to the addition of 10% in the irrigation depth to promote leaching of excess of salts from the root environment, since calcium is more strongly adsorbed to soil colloids than sodium, mainly due to the difference between the valences of these elements.

Calcium application in the soil increases calcium accumulation in the leaf, as reported by Silva Júnior et al. (2013), who applied dolomitic limestone in soil cultivated with passion fruit. Foliar application can also increase the leaf concentration of calcium, up to 1.3 mg L^{-1} of calcium (Cavalcante et al., 2014; 2015), because although it is considered immobile in the plants, foliar absorption can occur.

Leaf magnesium concentration was influenced by the interaction between salinity, lining, and calcium (Table 2). Without calcium fertilization, saline water reduced leaf concentration of magnesium in plants grown in pits both without (Figure 2C) and with lateral protection (Figure 2D).



Means followed by the same letter, at each calcium dose, do not differ by F test ($p \leq 0.05$). °, * and ** - Significant at $p \leq 0.10$, $p \leq 0.05$ and $p \leq 0.01$ by F test, respectively

Figure 2. Leaf concentrations of calcium (Ca), magnesium (Mg) and sulfur (S) in yellow passion fruit cv. BRS GA1 as a function of calcium doses, cultivated in pits without (A, C and E) and with (B, D and F) lateral protection and irrigated using water with electrical conductivity of 0.3 (●) and 4.0 dS m^{-1} (◆)

The functional relationship between calcium doses and leaf magnesium in passion fruit was observed only when plants were cultivated in non-lined pits and irrigated with saline water (Figure 2C). In this situation, the unit increase in calcium fertilization increased the leaf concentration of magnesium by 11.2 mg kg⁻¹.

The leaf concentration of magnesium was above the adequate range from 2.53 to 2.99 g kg⁻¹ for passion fruit (Carvalho et al., 2011). However, according to the intervals of optimum range (3 to 4 g kg⁻¹) established by Malavolta et al. (1997), these concentrations were slightly below adequate. Silva Júnior et al. (2013) observed that dolomitic limestone in the soil increased the leaf concentration of calcium without interfering with magnesium concentration. The relationship between the concentrations of calcium and magnesium in the soil interfered with the absorption of these elements (Salvador et al., 2011). Foliar application of calcium can also increase the leaf concentration of magnesium depending on the concentration used (Cavalcante et al., 2014; 2015).

Leaf concentration of sulfur in passion fruit was influenced by the interaction between water salinity, pit lining and calcium doses (Table 2). Without calcium application, the leaf concentration of sulfur in yellow passion fruit decreased with the use of saline water when cultivated both without (Figure 2E) and with (Figure 2F) protection.

In pits lined and irrigated with non-saline water, the increase in calcium doses reduced leaf sulfur by 5.3 mg kg⁻¹ per kilogram of calcium, from 3.12 (without calcium fertilization) to 2.48 g kg⁻¹ (with 120 kg ha⁻¹ of calcium) (Figure 2F). On the other hand, with saline water the sulfur concentration increased by 2.8 mg kg⁻¹ with each unit increase in calcium dose, for pits without lining (Figure 2E), and up to the dose of 99 kg ha⁻¹ of calcium, in protected pits (Figure 2F).

Leaf sulfur was below the range from 3.79 to 4.21 g kg⁻¹ obtained in a high-yield population of yellow passion fruit, which indicates that the plants were under sulfur deficiency (Carvalho et al., 2011). Such deficiency can be caused by the high concentration of chloride in the saline water used in irrigation and of nitrate supplied by calcium fertilization, because sulfur is absorbed in anionic form (SO₄²⁻) and there may be antagonism between chloride and nitrate (Marschner, 2012; Taiz et al., 2017).

Reduction in leaf sulfur concentration in yellow passion fruit irrigated with saline water has also been reported by

Freire et al. (2013) and Souza et al. (2018). Cavalcante et al. (2014; 2015), applying nitrate and calcium chloride through the leaves, observed that the leaf sulfur concentration increased up to the average dose of 1.1 g L⁻¹ of calcium, with reduction of sulfur after this dose.

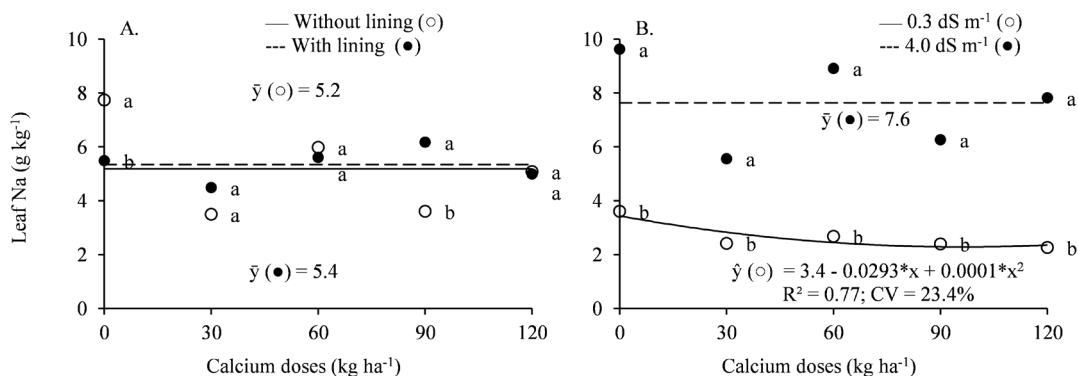
Sodium concentration in yellow passion fruit leaves was affected by the interactions between water salinity and calcium doses and between pit lining and calcium doses (Table 2). The functional relationship between calcium doses and leaf concentration of sodium did not fit (Figure 3A). It was also observed that, in the absence of calcium fertilization, the leaf concentration of sodium was higher in plants grown in non-lined pits, while under the dose of 90 kg ha⁻¹ of calcium the highest leaf concentration of sodium was observed in passion fruit grown in lined pits.

Regarding the interaction between calcium and salinity, it was observed that leaf sodium decreased up to the dose of 120 kg ha⁻¹ of calcium under irrigation with non-saline water (Figure 3B). With saline water in the irrigation of passion fruit, the model of sodium leaf concentration as a function of calcium doses was not significant. It was also observed that, at all calcium doses, the highest leaf concentration of sodium was found in plants irrigated with saline water (4.0 dS m⁻¹).

According to the values established by Carvalho et al. (2002), 1.22 to 3.06 g kg⁻¹, the leaf concentrations of sodium in yellow passion fruit in the present study were high. Lucena et al. (2012) observed that the increase in sodium chloride concentration intensified the accumulation of sodium in the roots, stem, shoots and leaves of mango. The accumulation rate was higher in the leaves compared to the other parts, thus implying absorption and transport of this element in the xylem.

Irrigation with saline water increases sodium concentration in both soil and leaves of yellow passion fruit (Freire et al., 2015). These authors found increments in sodium concentration from 0.34 to 0.70 cmol_c dm⁻³, 106% increase in the soil, and from 5.15 to 6.41 g kg⁻¹, 24% increase in the leaf, as the electrical conductivity of irrigation water increased from 0.5 to 4.5 dS m⁻¹, respectively.

The use of saline water has effects not only on the mineral nutrition of yellow passion fruit, but also on its physiological and productive aspects (Bezerra et al., 2019, 2020). These authors observed reduction in the net photosynthetic rate and consequently in the yield of the crop irrigated with saline water, indicating the application of 60 kg ha⁻¹ of calcium in



Means followed by the same letter, at each calcium dose, do not differ by F test ($p \leq 0.05$); * - Significant at $p \leq 0.05$ by F test

Figure 3. Leaf concentration of sodium in yellow passion fruit cv. BRS GA1, as a function of calcium doses in pits without lining (○) and with lining (●) (A) and irrigation using water with electrical conductivity of 0.3 (○) and 0.4 (●) dS m⁻¹ (B)

Entisol with low concentration of this nutrient as a mitigator of salt stress.

CONCLUSIONS

1. Irrigation of yellow passion fruit with saline water (4.0 dS m^{-1}) reduces the leaf concentrations of macronutrients and increases sodium concentration, so irrigation with non-saline water is recommended.
2. Lining of pits is not indicated in the cultivation of passion fruit because it reduces the concentrations of nutrients.
3. Calcium can be used to mitigate salt stress mainly because it promotes the accumulation of macronutrients under saline conditions, in soil with low concentration of calcium in the cultivation of yellow passion fruit.
4. It is recommended to apply 60 kg ha^{-1} of calcium in Entisol under irrigation with saline or non-saline water.

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