Australian Journal of
Crop Science
AJCS

AJCS 16(02):307-314 (2022) ISSN:1835-2707
doi: 10.21475/ajcs.22.16.02.3456

Chemical composition of prickly pear cactus (*Opuntia stricta* Haw) irrigated with saline water in semi-arid soils

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Abstract

The objective of this study was to investigate the effect of application of saline water in different soils on the accumulation of sodium and potassium in different structures of prickly pear cactus (*Opuntia stricta* Haw) variety 'Orelha de elefante mexicana'. The experiment was laid out in a randomized-block design with treatments arranged in a 3 × 4 factorial arrangement (three soil types: chromic Luvisol, Solonetz and Fluvisol × four irrigation water salinity levels: 0.75, 3.0, 5.25 and 7.50 dS m^{-1}, at 25 °C), using three replicates. At 360 days after planting, the plants were harvested, dried in a forced-air oven, ground and digested. After the digested samples were obtained, the sodium and potassium contents of each plant structure were determined by flame emission spectrometry, using a flame photometer. The soil types significantly influenced the potassium content in the mother and primary cladodes, whereas the salinity levels did not influence the potassium content in any of the plant structures. Higher sodium contents were found in the roots as compared with the other structures, but which did not differ statistically between the soils. Under salt stress, sodium tended to accumulate in the roots and mother cladodes. Chromic Luvisol is the most recommended soil for growing prickly pear cactus 'Orelha de elefante Mexicano' in salt stress conditions.

Keywords: Cladodes; Luvisol; Neosol; *Opuntia*; Planosol; Potassium; Salt stress; Sodium.

Introduction

The Brazilian semi-arid region is characterized by having long periods of drought and poor rainfall distribution, which render irrigation a means of enabling agricultural production in the region. However, most waters available for irrigation purposes have a relatively moderate salt content that reaches an average of 5.0 dS m^{-1} (Nobre et al., 2013).

In most cases, irrigation with saline water causes adverse effects on soil-water-plant relationships, inducing severe restrictions on the physiological and productive activities of cultivated plants (Gheyi et al., 2016) by reducing the osmotic potential of the soil solution and/or specific-ion effects (Porto Filho et al., 2006).

The effect of salts on plants, via soil or irrigation water, is a complex phenomenon that involves morphological, growth, physiological, biochemical and nutritional changes (Garcia et al., 2008). The response of crops to the presence of salts in the soil differs between species, with a threshold value that does not affect their potential yields, called 'threshold salinity'. Any salinity value above threshold causes yield to decrease (Porto Filho et al., 2006). In addition, the response of plants to salinity depends not only on the species, but also on the genotype, phenological stage and time of exposure to salts (Munns and Tester, 2008). Prickly pear cactus stands out as an important forage resource in the semi-arid region of Brazil (Galvão Júnior et al., 2014), where it generally develops in all soil types. However, its growth is limited by the presence of sodium chloride (NaCl) in the root zone (Nobel and Bobich 2002). Meanwhile, potassium is the nutrient that the cactus extracts in largest quantity (Dubeux Jr and Santos, 2005), and its level in the soil and in the plant can be reduced due to excess sodium in the soil. Thus, elucidating the dynamics between sodium and potassium is of great importance in the production of this crop. In view of the above-described facts, this study was undertaken to examine the effect of applying saline water in different soils on the accumulation of sodium and potassium in different structures of prickly pear cactus (*Opuntia stricta* Haw) variety 'Orelha de elefante mexicana'.

Results and discussion

Effects of saline water irrigation in semi-arid soils on the potassium composition of prickly pear cactus

The soil types significantly influenced the potassium content in the mother and primary cladodes, whereas the salinity levels did not influence the potassium content in any of the plant structures. The interaction of these factors had no significant effect on the potassium levels (Table 1).

Although the soil significantly influenced the potassium content in the mother cladodes, Tukey's test showed no significant difference in the comparison of means (Table 1). According to Pimentel-Gomes (1985), it is seldom that the F test is significant without any difference being detected by Tukey's test. This may be associated with the acceptance of different hypotheses in theoretical deductions, although of little relevance.

The primary cladodes showed statistical superiority in the SN soil, which did not differ from the FS soil. It should be stressed that the SN soil exhibited the highest potassium concentration in the initial soil analyses and, consequently, the greatest export of this nutrient to the plant. According to Dubeux Jr and Santos (2005), potassium is the nutrient most exported by the cactus crop, followed by calcium.

The root, mother, primary and secondary cladode structures showed average potassium contents of 3.5, 24.3, 36.6 and 26.4 g kg^{-1}, respectively, i.e., this mineral is more concentrated in the primary cladodes and less concentrated in the roots (Fig. 1). Potassium values in the shoots were higher than the average of 22.9 g kg^{-1} found by Lemos (2016) in 'Orelha de elefante mexicana' irrigated with treated sewage water. Despite the existence of data from other researchers, including very close mean values, discussing them would be unfeasible, since most of them relate cladodes of the aerial part without distinction of the order of appearance.

The predominance of K^+ in the shoots may be related to the fact that it is a "mobile" element in plants and participates in essential functions, such as stomatal opening and closure through guard cells, regulation of cell osmotic potential, in addition to activating numerous enzymes involved in respiration and photosynthesis (Taiz and Zeiger, 2017). The vast majority of these activities take place in the plant shoots.

Irrigation water salinity affected the potassium content in the cactus variety 'Orelha de elefante mexicana' only in primary cladodes (Table 1). With the increase in electrical conductivity in the irrigation water (ECiw), the potassium content in the primary cladodes (Fig. 2) rose by around 16.5% from the lowest (0.75 dS m^{-1}) to the highest (7.5 dS m^{-1}) salinity level.

Nobre et al. (2013) observed a 33.2% increase in potassium content in castor leaf tissues, when contrasting the levels of 0.4 and 4.4 dS m^{-1}. According to these authors, the increase in NaCl concentration in the soil solution impairs the uptake of some elements such as K^+ and Ca^{2+} and the ability to maintain high K^+ and Na^+ concentrations in the tissues, thus proving to be one of the key mechanisms of tolerance to saline environments. Therefore, with the higher concentration of sodium in the roots and in the mother cladode (as shown more clearly later), the cactus favored the concentration of K^+ in the primary cladodes to maintain the ideal level of this element in the shoot tissues.

Nevertheless, several other authors obtained results contradictory to those found in this study. Miranda et al. (2005) worked with Moringa in nutrient solution with increasing addition of NaCl and observed a negative linear relationship with the potassium content in the stems and leaves. Viana et al. (2001), on the other hand, studied rootstocks of vines irrigated with five levels of NaCl (0, 5, 10, 15 and 20 mmol L^{-1}) and found that the K^+ concentration showed an increasing quadratic response in the lower leaves and a linear increase in the roots. In maize, Azevedo Neto and Tabosa (2000) described a linear decrease in all parts of the plant.

All these results show that crops interact with the potassium element under salt stress in different ways, depending on the stage of development, salt concentration, exposure time and metabolism employed. In other words, they exhibit different mechanisms of tolerance (or lack thereof) to saline conditions.

Effects of saline water irrigation in semi-arid soils on the sodium composition of prickly pear cactus

Fig. 3 displays the comparisons of the average sodium (Na^+) content between the soils used, in each structure of prickly pear cactus. Even though no sodium was found in the plant tissues of the primary and secondary cladodes, they are presented in the graph to provide an overview of the content of this element in the plant.

High Na^+ contents were found in the roots as compared with the other structures (Fig. 3), but these values did not differ statistically between the soils (Table 1).

The Na^+ content in the roots (Fig. 4) showed a linear response salinity (CEiw levels), ranging from 3.31 (0.75 dS m^{-1}) to 7.01 g kg^{-1} (7.50 dS m^{-1}), which represents a 111.89% increase in the concentration of this element in the roots.

Azevedo Neto and Tabosa (2000) obtained similar results working with maize and increasing levels of NaCl, which ranged from 0 to 100 mol m^{-3} in the nutrient solution. The authors observed a greater accumulation in the roots up to the concentration of 25 mol m^3, from which point the concentration of this ion in the shoot tissues started to increase. Maize is a C4 plant and, according to Taiz and Zeiger (2017), the use of sodium in CAM and C4 plants is similar, since both use the sodium ion (Na^+) for the regeneration of phosphoenolpyruvate, the substrate for the first carboxylation. In plant tissues, Na^+ stimulates plant growth via leaf expansion and may partially replace potassium ions as an osmotically active solute.

The Soil × Salinity Treatment interaction significantly influenced the sodium content in the mother cladodes (Table 1), as shown in Fig. 5. In the basal cladodes, the sodium levels did not differ between the soils for the saline treatments of 0.75 and 3.00 dS m^{-1}. For the saline treatments of 5.25 and 7.50 dS m^{-1}, the SN and FS soils showed statistical superiority. The lack of effects at the first two levels of ECiw applied is mainly due to the absence and low concentrations of Na^+ in the plant structure at the levels of 0.75 and 3.00 dS m^{-1}, respectively. The lower concentration of Na^+ ions in the basal cladodes of the CL soil at all levels was likely due to the lower retention of soluble sodium in the solution and, consequently, its lower uptake. In the initial analysis, the CL soil showed higher Ca^{2+} and Mg^{2+} contents (Table 2), which are preferential elements to occupy the exchange complex, as they are bivalent, leaving sodium in a soluble form and more likely to have been leached throughout the irrigation events. Fig. 6 illustrates the average sodium content in the basal cladodes as a function of the increasing ECiw levels, for each soil.

The CL soil did not influence the sodium content in the mother cladodes, in addition to showing the lowest means. However, in the SN and FS soils, the average sodium contents in these cladodes better fit the linear and quadratic regression models, where the highest sodium contents were obtained at the levels of 7.5 and 5.25 dS m^{-1}, respectively. In the SN soil, the effect indicates that up to the level of

Table 1. Summary of analysis of variance for the potassium content in the roots and mother, primary (PC) and secondary (SC) cladodes; sodium content in the roots and mother cladode; and sodium/potassium ratio in the roots and mother cladode of prickly pear cactus 'Orelha de elefante mexicana' grown in three soils and subjected to increasing levels of salinity (electrical conductivity) in the irrigation water.

Source of variation	DF	Mean square							
		K^+ roots		K^+ mother		K^+ PC		K^+ SC	
Soil (A)	2	771.5	ns	30,701.70	*	98,991.20	**	25,932.00	ns
Salinity (B)	3	1,315.00	ns	15,748.20	ns	39,473.10	ns	17,741.70	ns
(A) × (B)	6	155.8	ns	4,251.30	ns	16,386.20	ns	3,831.20	ns
Block	2	934.4	ns	15,869.50	ns	21,358.40	ns	23,157.80	ns
Residual	22	674.1		8,526.40		14,658.80		9,885.90	
Linear r. (B)			ns		ns		*		ns
Quadratic r. (B)			ns		ns		ns		ns
CV (%) =		37.46		18.97		16.55		18.64	
		Na^+ roots¹		Na^+ mother²		Na^+/K^+ roots		Na^+/K^+ mother	
Soil (A)	2	6,012.900	ns	28,252.00	**	0.239	ns	0.095	**
Salinity (B)	3	7,933.800	*	22,476.90	**	0.445	*	0.08	**
(A) × (B)	6	1,207.900	ns	4,479.20	*	0.082	ns	0.014	*
Block	2	282.600	ns	2,857.00	ns	0.113	ns	0.008	ns
Residual	22	1,945.500		1,621.40		0.126		0.005	
Linear r. (B)			**		**		**		**
Quadratic r. (B)			ns		*		ns		*
CV (%) =		41.26		63.82		21.33		60.53	

CV - coefficient of variation; DF - degrees of freedom; **, * and ^{ns} - significant by the F test at 1%, 5% and not significant, respectively. ¹BoxCox-transformed. ² √X- transformed.

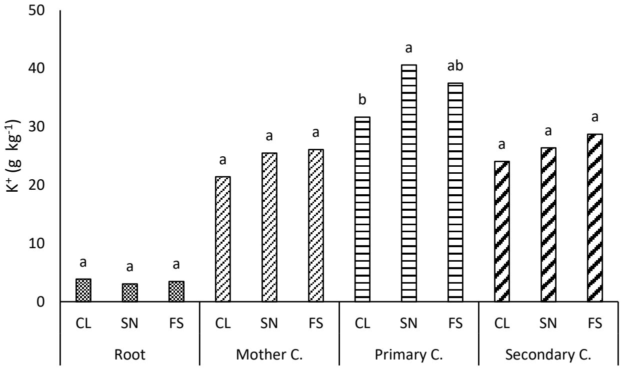

Fig 1. Potassium content in each structure of prickly pear cactus 'Orelha de elefante mexicana' as a function of the soils (chromic Luvisol [CL], Solonetz [SN] and Fluvisol ([FS]) used. Common letters between columns, within each plant structure, do not differ by Tukey's test at 5% probability.

Table 2. Physicochemical characterization and salinity of samples of the soils used (chromic Luvisol [CL], Solonetz [SN] and Fluvisol [FS]).

Physical characterization													
Soil	Sand	Silt	Clay	Text. class				SD	PD	Porosity		Moisture (%)	
	--------g kg^{-1}--------							--- g/cm³ ---		%	Nat.	1	15
												atm	atm
CL	607.5	232.9	159.6	Sandy loam				1.34	2.7	50.37	0.44	15.1	7.95
SN	830	71	99	Loamy sand				1.49	2.65	43.77	0.36	8.65	3.9
FS	759.3	141.8	98.9	Sandy loam				1.38	2.68	48.5	0.71	8.49	4.47
Chemical characterization													
Soil	Ca	Mg	Na	K	S	H	Al	CEC	OC	OM	N	P	pH
	-----------------------$cmol_c$ kg^{-1} of soil -------------------									---------- % ----------		mg kg^{-1}	H_2O
													(1:2.5)
CL	6.53	6.1	3.19	0.18	16	1.1	0	17.1	0.42	0.72	0.04	33	6.86
SN	3.06	1.82	0.35	0.67	5.9	0	0	5.9	0.38	0.66	0.04	30.3	7.37
FS	3.4	2.22	0.12	0.58	6.32	0	0	6.32	0.45	0.78	0.05	32.2	7.00
Salinity													
Soil	ECse	Cl^-	CO_3^{-2}	HCO_3^-	SO_4^{-2}	Ca	Mg	K	Na	SP	SAR	ESP	SC
		-------------------------------- meq/L --------------------------------										%	
CL	7.64	85.75	0	3	Abs.	18	26.8	0.18	33.1	26.66	6.98	18.65	SS
SN	0.28	1.5	0	4.2	Abs.	1.25	0.75	0.48	2.19	23.33	2.19	5.93	Normal
FS	0.46	2.75	0	3.1	Abs.	2.88	0.49	0.65	0.9	27	0.69	1.89	Normal

SD: soil density; PD: particle density; Nat.: natural; CEC: cation-exchange capacity at pH 7.0; OC: organic carbon; OM: organic matter; ECse: electrical conductivity in the saturation extract; SP: saturation percentage; SAR: sodium adsorption ratio; ESP: exchangeable sodium percentage; Abs.: absent; SC: soil class; SS: sodium saline. Source: Irrigation and Salinity Laboratory (LIS/UFCG).

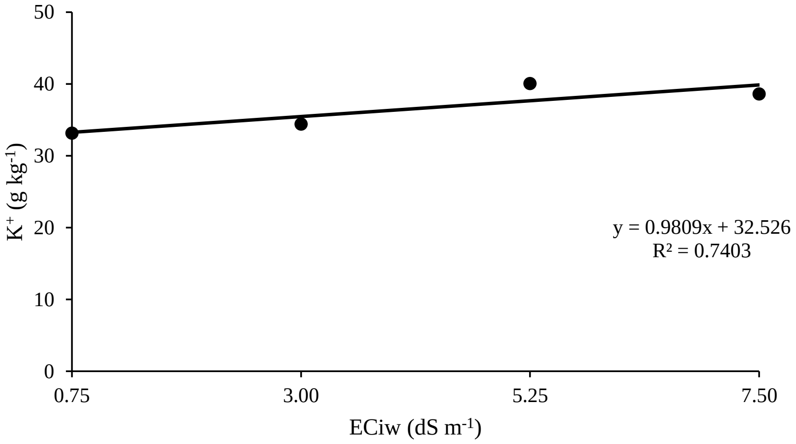

Fig 2. Potassium (K^+) content in primary cladodes of prickly pear cactus 'Orelha de elefante mexicana' as a function of increasing electrical conductivity values in the irrigation water (ECiw).

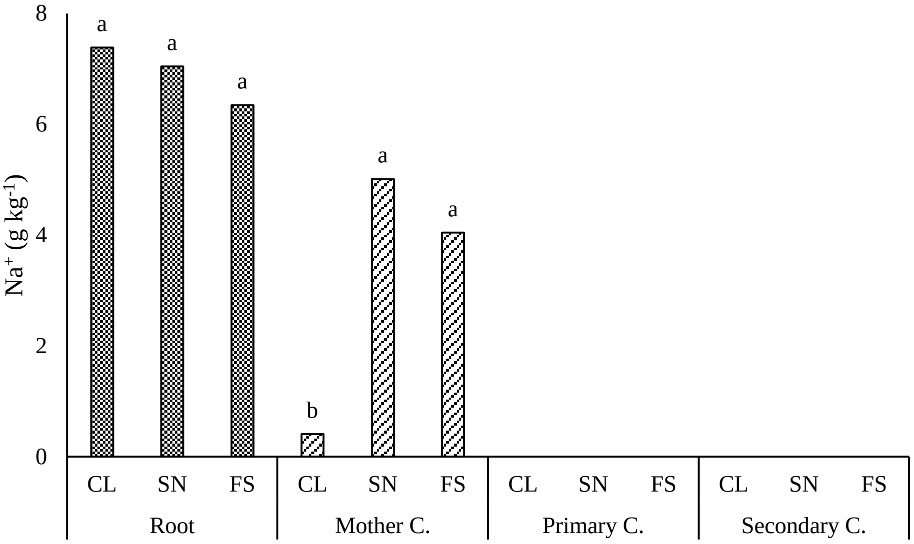

Fig 3. Mean sodium content (Na^+) in each structure of prickly pear cactus 'Orelha de elefante mexicana' as a function of the soils (chromic Luvisol [CL], Solonetz [SN] and Fluvisol [FS]) used. Common letters between columns, within each plant structure, do not differ by Tukey's test at 5% probability.

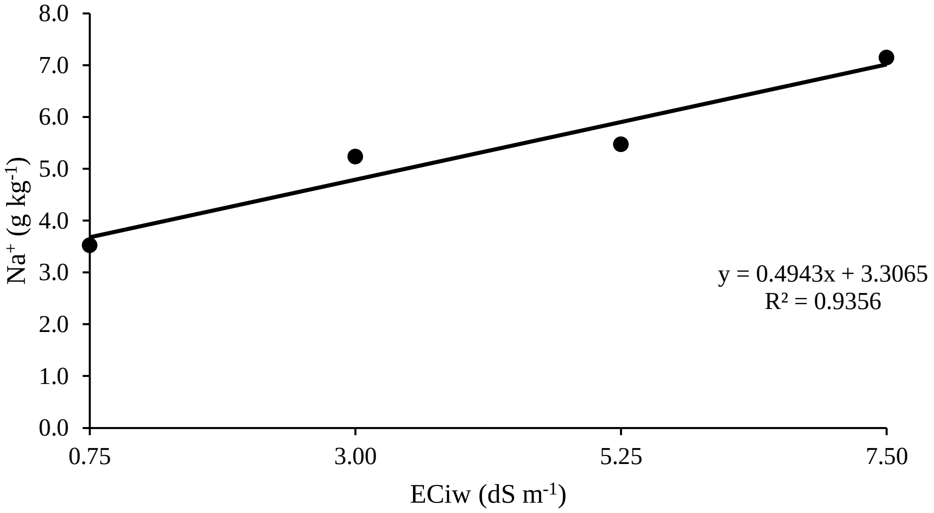

Fig 4. Sodium (Na^+) content in the roots of prickly pear cactus 'Orelha de elefante mexicana' as a function of increasing levels of electrical conductivity in the irrigation water (ECiw).

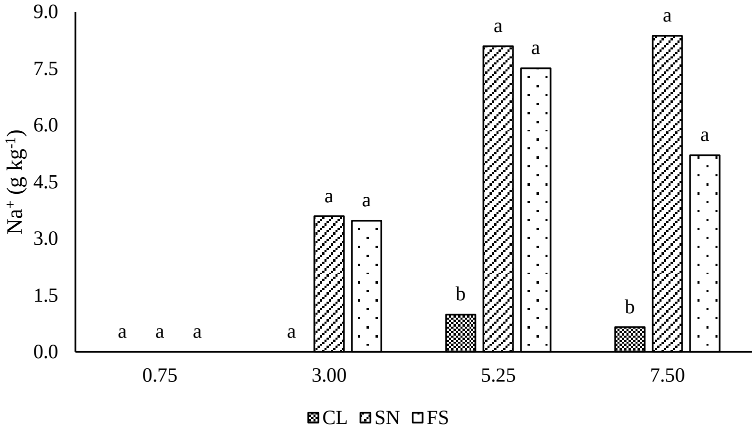

Fig 5. Sodium content in mother cladodes of prickly pear cactus 'Orelha de elefante mexicana' as a function of the soil (chromic Luvisol [CL], Solonetz [SN] and Fluvisol [FS]) used, for each level of electrical conductivity in the irrigation water. Common letters between columns, within each plant structure, do not differ by Tukey's test at 5% probability.

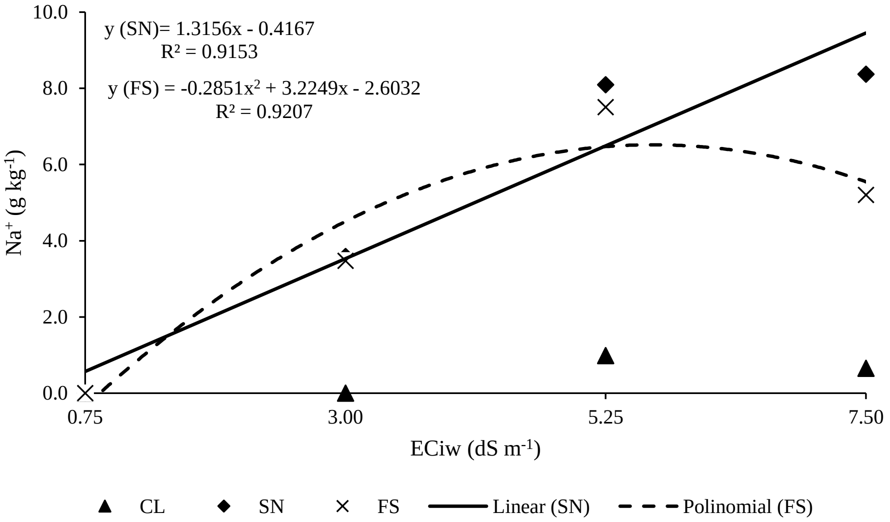

Fig 6. Mean sodium content in mother cladodes of prickly pear cactus 'Orelha de elefante mexicana' as a function of increasing levels of electrical conductivity in the irrigation water (ECiw).

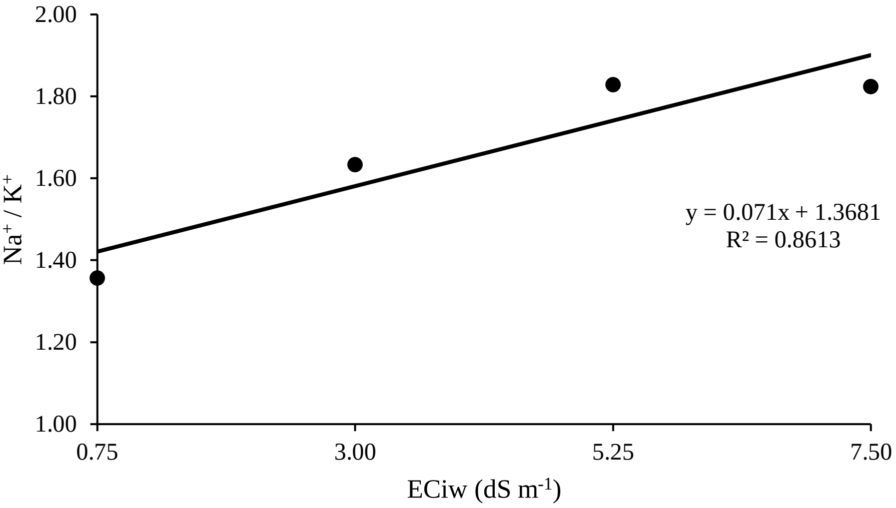

Fig 8. Sodium/potassium ratio in the roots of prickly pear cactus 'Orelha de elefante mexicana' subjected to increasing levels of electrical conductivity in the irrigation water (ECiw).

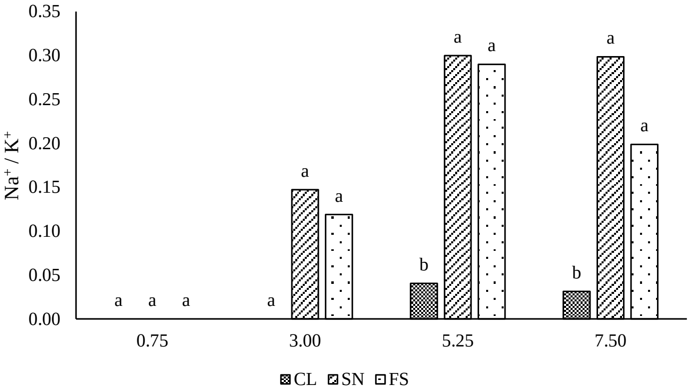

Fig 8. Sodium/potassium ratio in mother cladodes of prickly pear cactus 'Orelha de elefante mexicana' as a function of the soil used for each saline level. Common letters between columns, within each plant structure, do not differ by Tukey's test at 5% probability.

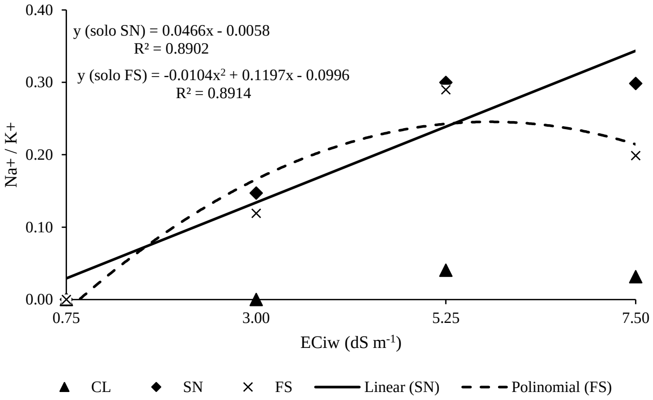

Fig 9. Sodium/potassium ratio in mother cladodes of prickly pear cactus 'Orelha de elefante mexicana' as a function of increasing levels of electrical conductivity in the irrigation water (ECiw) in the chromic Luvisol (CL), Solonetz (SN) and Fluvisol (FS) soils.

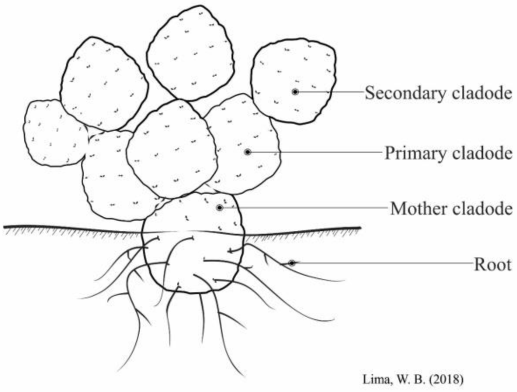

Fig 10. Exemplification of the structures of prickly pear cactus variety 'Orelha de elefante mexicana' with the positioning of cladodes by order of appearance.

7.5 dS m^{-1}, the accumulation of sodium ions increased. This is contrary to what was seen in the FS soil, where maximum accumulation occurred at the ECiw concentration of 6.50 dS m^{-1} and Na^+ concentration of 6.32 g kg, after which level there was a reduction in the sodium content.

Overall, we may state that the plant does not possess mechanisms for the exclusion of toxic ions, such as sodium. Sodium tends to accumulate in the roots and older cladodes, which, in the case of this study, occurred in the mother cladode (seed cladodes used for planting). The primary and secondary cladodes, in turn, did not show concentrations of this element in their tissues, considered the plant shoots. These are precisely the cladodes that carry the active photosynthetic apparatus, which suggests a mechanism for their tolerance to salt stress.

According to Azevedo Neto and Tabosa (2000), the tendency for the sodium concentration in the roots in medium and high saline conditions to stabilize, with the ions being transferred to the shoots, may indicate a limitation of this organ for the sodium retention mechanism under salt stress. Because there was an increasing accumulation of sodium in the roots and in the mother cladodes of the cactus, it is inferred that the application of higher concentrations of NaCl in the irrigation water allowed the accumulation of sodium ions to reach the plant shoots after saturating the maximum limit of the basal structures the roots and mother cladodes, in the present case.

Previous studies had already reported a lack of sodium in cactus shoots. This was highlighted by Sampaio (2005), who stated that animals fed a diet based on prickly pear cactus require salt supplementation, since the crop has a low sodium content in the cladodes. Some plants tend to retain sodium ions in older tissues, preventing their translocation to younger tissues, which are more sensitive to salt stress (Alves, 2015).

Effects of saline water irrigation in semi-arid soils on the Na^+/K^+ ratio composition of prickly pear cactus

The Na^+/K^+ ratio in the roots was significantly affected by the electrical conductivity levels of the irrigation water (ECiw) applied ($P < 0.05$), increasing linearly. In other words, the Na^+/K^+ ratio increased with the increase in ECiw in the root structure (Fig. 7).

This ratio demonstrates the amount of sodium present in the structure relative to the potassium content. Additionally, this ratio is used to relate the degree of tolerance of plants to salinity. Therefore, it can be used as a sodium ion toxicity index, considering that it can inhibit the activity of enzymes that need potassium for their maintenance (Azevedo Neto and Tabosa, 2000; Garcia et al., 2008).

There was an interaction effect for the Na^+/K^+ ratio in the mother cladode. Fig. 8 shows the mean values of this ratio between the tested soils. At the salinity levels of 5.25 and 7.50 dS m^{-1}, the mean comparison between soils reveals the same behavior: statistical superiority in the SN and FS soils. As explained above, the lower sodium uptake by plants grown in the CL soil and the lack of differentiation in potassium uptake resulted in a lower Na^+/K^+ ratio in the mother cladode in the CL soil.

In the SN and FS soils, the Na^+/K^+ ratio differed significantly between the ECiw levels applied, with linear and quadratic responses, respectively (Fig. 9). Results for the sodium/potassium ratio were similar to those identified for the sodium ion concentration in the mother cladode, as shown in Fig. 7.

Some authors relate these ions in the inverse direction, with the expression 'K^+/Na^+', as was the case with Silva et al. (2009). However, the most important thing is to present the relationship between these ions in the plant. In the case of the aforementioned authors, the jatropha plant showed a decrease in this ratio with increasing salinity, that is, there was a reduction in the difference between the potassium and sodium contents, which was the same ratio identified in the mother cladodes of the cactus plant.

The ratios of sodium to potassium ions showed different responses in the different parts of the cactus. Potassium occupied all of the plant structures, whereas sodium was limited to the roots and the mother cladode. In both structures (root and mother cladode), the increasing ECiw levels induced an increase in the Na^+/K^+ ratio. In the primary cladodes, there was an increase in the potassium content, even in the absence of Na^+, but which was possibly influenced by the presence of sodium in the lower structures. For Flowers (2004), each species has different strategies to maintain acceptable levels of K^+ and Na^+ ions in the cytosol, which also happens to be a ratio used as a physiological marker in the selection of more salinity-resistant plants.

Rodrigues et al. (2012) evaluated jatropha in a nutrient solution and identified a strong antagonism between sodium and potassium. The high concentration of potassium in the external environment was able to reduce the transport and toxic effects of sodium in the plant, and the opposite was also true. In this respect, the increase in the potassium content in the cactus shots and the accumulation of sodium in the lower structures demonstrate a tolerance mechanism of the plant to salt stress, with a possible reduction of the toxic effects of sodium.

Material and methods

Experimental site

The experiment was conducted in a 202.80-m² greenhouse at the Prof. Ignacio Salcedo Unit at the National Institute of the Semi-Arid (INSA), located in the municipality of Campina Grande, Paraíba, Brazil (7°16'34.9" S; 35°57'53.3" W; 542 m asl). Minimum and maximum temperatures recorded in the greenhouse ranged between 15 and 22 °C and 37.5 and 46 °C, respectively.

Experimental setup and development

A randomized-block design was adopted in which treatments were evaluated in a 3 × 4 factorial arrangement (three soil types: chromic Luvisol [CL]; Solonetz [SN]; and Fluvisol [FS] × four irrigation water salinity levels: 0.75, 3.0, 5.25 and 7.50 dS m^{-1} at 25 ºC). Three replicates were used, totaling 12 treatments and 36 experimental units.

We analyzed variety 'Orelha de Elefante Mexicana' of the species *Opuntia stricta* Haw, which was grown in plastic pots with a capacity of 40-L and arranged at a spacing of 0.8 × 0.8 m. In these pots, the cladodes were planted by burying the basal third and maintaining the planting position at 45° relative to the longitudinal axis.

The soil samples used in the production of prickly pear cactus (CL, SN and FS) were collected in three different municipalities of Paraíba (Juazeirinho, Soledade and São João do Cariri) and characterized physically and chemically according to methodologies proposed by Richards (1954) and Teixeira et al. (2017) (Table 2). Based on the chemical analysis of the soil samples, 50 g K_2O were applied per plant, at planting, for the CL soil only.

To apply the water volumes, a drip irrigation system was employed with pressure-compensating emitters (flow of 10 L h^{-1}) spaced 0.8 m apart, which were previously evaluated under normal operating conditions.

At 90 days after planting (DAP), the saline treatments were applied and the irrigation water was prepared by adding commercial NaCl (without iodine) to rainwater, by multiplying the desired electrical conductivity value (dS m^{-1}) by 640, following Richards (1954). Irrigation was always carried out in the early morning and based on the water consumption of the plants in the previous irrigation event. The amount was calculated by dividing the estimated volume by the factor of 0.8, thus restoring the soil moisture to field capacity and obtaining a leaching fraction (LF) of approximately 0.2:

$$\mathrm{VL\ (mL)} = [\frac{(\mathrm{VP} - \mathrm{VD})}{(1 - \mathrm{LF})}] \qquad \text{Eq. 1}$$

Where VL: water volume to be applied in irrigation; VP: water volume applied in the previous irrigation (mL); and VD: water volume drained in the previous irrigation (mL).

Prior to planting, a Bordeaux mixture and a 10% neutral detergent and water solution were applied to prevent fungi and cactus scale (*Diaspis echinoccati*).

Variables analyzed

At 360 days after planting (DAP), the plants were harvested, dried in a forced-air oven at 65 ºC, ground and digested, following an adapted version of the methodology proposed by Fernandes (2011). The analyzed samples were subdivided according to their position on the plant, as follows: roots, mother cladode, primary cladode and secondary cladode (Fig. 10).

After the digested samples were obtained, the sodium (Na^+) and potassium (K^+) contents for each plant structure were determined by emission flame spectrometry, using a flame photometer. The sodium/potassium ratio in the plant structures was calculated by dividing the sodium content by the potassium content.

Data analysis

Results were subjected to analysis of variance, by comparing the salinity levels in the irrigation water (quantitative factor) by regression analysis; and the soil types (qualitative factor) by the test of means (Tukey's) at the 5% probability level, using SISVAR statistical software version 5.2 (Ferreira, 2011). For the purposes of normality, transformations were performed to meet the Anova assumptions. Accordingly, the sodium content in the root was BoxCox-transformed and the sodium content in the mother cladode was √X-transformed.

Conclusions

Under salt stress, sodium tended to accumulate in the roots and mother cladodes of prickly pear, which reduced the presence of these ions in the shoots, where the photosynthetic apparatus of the plant is located. The increasing concentrations of salts in the irrigation water favored the accumulation of potassium, at higher levels, in the primary cladodes. Between the three soils used in this study, chromic Luvisol is the most recommended for growing prickly pear cactus, since the cactus grown in this soil showed less sodium accumulation in its structures.

Acknowledgments

Thanks are due to Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Universidade Federal de Campina Grande (UFCG), Fundação de Apoio à Pesquisa do Estado da Paraíba (FAPESQ) and Instituto Nacional do Semiárido (INSA).

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