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Salinity and cationic nature of irrigation water on castor bean cultivation

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Key words:
Ricinnus communis L.
semi-arid region
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A B S T R A C T

This study aimed to evaluate the water relations, cell damage percentage and growth of the castor bean cv. 'BRS Energia' as a function of salinity and cationic nature of the water used in irrigation. The experiment was conducted in drainage lysimeters under greenhouse conditions in eutrophic Grey Argisol of sandy loam texture. Six combinations of water salinity and cations were studied (S_1 - Control; S_2 - Na^+, S_3 - Ca^{2+}, S_4 - $Na^+ + Ca^{2+}$; S_5 - K^+ and S_6 - $Na^+ + Ca^{2+} + Mg^{2+}$), in a randomized block design with four replicates. In the control (S_1), plants were irrigated with 0.6 dS m^{-1} water, whereas the other treatments received 4.5 dS m^{-1} water, obtained by adding different salts, all in the chloride form. Higher relative water content in the leaf blade of plants irrigated with K^+-salinized water associated with leaf succulence are indicative of tolerance of the castor bean cv. 'BRS Energia' to salinity. Saline stress negatively affected castor bean growth, regardless of cationic nature of water. Among the ions studied, 'BRS Energia' castor bean was more sensitive to the presence of sodium in the irrigation water, in terms of both water relations and leaf succulence.

Palavras-chave:
Ricinnus communis L.
semiárido
escassez de água

Salinidade e natureza catiônica da água de irrigação no cultivo da mamoneira

R E S U M O

A presente pesquisa propôs avaliar as relações hídricas, o percentual de dano celular e o crescimento da mamoneira cv. BRS Energia em função da salinidade e da natureza catiônica da água utilizada na irrigação. O experimento foi desenvolvido em lisímetros de drenagem em condições de casa de vegetação em Argissolo Acinzentado Eutrófico de textura franco-arenosa. Foram estudadas seis combinações de salinidade da água (S_1 - Testemunha; S_2 - Na^+; S_3 - Ca^{2+}; S_4 - $Na^+ + Ca^{2+}$; S_5 - K^+ e S_6 - $Na^+ + Ca^{2+} + Mg^{2+}$), no delineamento em blocos casualizados com quatro repetições. Na testemunha (S_1), as plantas foram irrigadas com água de condutividade elétrica (CEa) de 0,6 dS m^{-1}, enquanto se utilizou nos demais tratamentos água com CEa de 4,5 dS m^{-1}, obtida a partir de diferentes cátions, todos na forma de cloreto. O maior teor relativo de água no limbo foliar nas plantas irrigadas com água de composição potássica associado à suculência foliar são indicativos de tolerância da mamoneira cv. BRS Energia à salinidade. O estresse salino afetou, de forma negativa, o crescimento da mamoneira, independentemente da natureza catiônica da água. Dentre os íons estudados, a mamoneira foi mais sensível à presença do sódio na água de irrigação, tanto em termos de relações hídricas como para a suculência foliar.

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Introduction

Belonging to the Euphorbiaceae family, castor bean (*Ricinus communis* L.) is an oilseed crop that stands out in Northeast Brazil due to its characteristics of xerophilism and heliophilism, besides good adaptation to different soil and management conditions. It is a rustic crop, with fast growth, high yield and various possibilities of use for the oil extracted from its seeds (Marinho et al., 2010).

Products and byproducts obtained from the castor bean crop have high socioeconomic value, with applications in the manufacture of nylon fabrics, in the steel industry as cutting oil for lamination, in the industry for the finishing of fine leather, paints and varnishes, perfumery. The oil extracted from the seeds has 90% ricinoleic acid, which promotes high economic value as lubricant for high-speed engines, being widely used in aviation, whereas in medicine it has been used for its purgative qualities (Silva et al., 2008).

Despite its importance for the semi-arid region of Northeast Brazil, the areas cultivated in this region are subject to agroclimatic variation, in which it is common the occurrence of high temperatures, low rainfall, irregular rainfall distribution and high evapotranspiration rates in most of the year, favoring the scarcity of surface waters. Thus, the irrigation practice is an important measure to guarantee water supply in moments of higher demands (Nobre et al., 2011).

Various studies highlight the castor bean crop as moderately sensitive to salinity (Babita et al., 2010; Nobre et al., 2013; Santos et al., 2013). However, crop tolerance to salinity may vary between species and cultivars of the same species, besides other factors such as type of salt, time of exposure to stress, phenological stage, edaphoclimatic factors and interaction between them (Munns & Tester, 2008).

In this context, various studies have found negative effects of salinity on castor bean growth and development (Campos et al., 2009; Alves et al., 2012; Nobre et al., 2013; Santos et al., 2013; Lima et al., 2014). Nevertheless, these studies are limited to evaluating only the use of waters with different salinity levels, and new studies become necessary, especially to assess the effects of using waters with different cationic compositions on the castor bean cultivar 'BRS Energia' under semi-arid conditions in Northeast Brazil.

In this context, this study aimed to evaluate the water relations, percentage of cell membrane damage and growth of the castor bean cultivar 'BRS Energia', as a function of salinity and cationic nature of the irrigation water.

Material and Methods

The study was carried out in drainage lysimeters under greenhouse conditions, at the Center of Technology and Natural Resources of the Federal University of Campina Grande (CTRN/UFCG), municipality of Campina Grande-PB, Brazil (7° 15' 18" S; 35° 52' 28" W; ~ 550 m).

Treatments consisted in six types of salinity (S_1 - Control; S_2 - Na^+; S_3 - Ca^{2+}; S_4 - $Na^+ + Ca^{2+}$; S_5 - K^+ and S_6 - $Na^+ + Ca^{2+} + Mg^{2+}$), in such a way to have equivalent proportions of 1:1 for Na:Ca in S_4 and 7:2:1 for Na:Ca:Mg in S_6, respectively. Water with electrical conductivity (ECw) of 0.6 dS m^{-1} was used to irrigate plants in the control treatment (S_1), whereas the other types of water had ECw of 4.5 dS m^{-1}, prepared by adding compound(s) of different cations, in chloride form. The experiment was set in randomized blocks with six treatments and four replicates, totaling 24 experimental plots.

Plants were grown in drainage lysimeters with capacity for 100 L (50 cm height, 30 cm bottom diameter and 33 cm top diameter) with 2 holes at the bottom to allow drainage, attached to a 4-mm-diameter drain. The tip of the drain inside the lysimeter was involved in nonwoven geotextile (Bidim OP 30).

The lysimeters were filled with a 2 kg layer of crushed stone (nº zero) followed by 54 kg of soil material (properly pounded to break up clods and homogenized) and 76 kg of the same soil mixed with aged bovine manure to achieve 1% organic matter content, and its quantity was determined based on soil volume.

The soil used in the experiment was collected in the 0-30 cm layer (A horizon) of a Eutrophic Grey Argisol, from the district of São José da Mata (Campina Grande, PB), and its chemical and physical-hydraulic characteristics were obtained according to the methodologies described by Claessen (1997).

Based on soil analysis data, pH was corrected by adding 49.25 g of dolomitic limestone in the soil of each lysimeter (130 kg of soil), quantity required to neutralize Al^{3+} and increase the contents of Ca^{2+} and Mg^{2+} to 70%. After correction, the soil showed the following chemical characteristics: Ca^{2+} = 1.14 $cmol_c$ kg^{-1}; Mg^{2+} = 1.36 $cmol_c$ kg^{-1}; Na^+ = 0.30 $cmol_c$ kg^{-1}; K^+ = 0.14 $cmol_c$ kg^{-1}; H^+ = 0.11 $cmol_c$ kg^{-1}; Al^{3+} = 0 $cmol_c$ kg^{-1}; CEC = 3.05 $cmol_c$ kg^{-1}; Organic matter = 1.08 dag kg^{-1}; P = 47.80 mg kg^{-1} and pH in water (1:2.5) = 6.42.

Water salinity levels were obtained by dissolving the chloride salt of the respective cations, according to the preestablished treatments in water from the local supply system (Campina Grande, PB). The quantity of the compound was determined based on the equation of Richards (1954), considering the relationship between ECw and concentration of salts (10 * $mmol_c$ L^{-1} = 1 dS m^{-1}).

Ten seeds of the castor bean cv. 'BRS Energia' were planted in each lysimeter, 2 cm deep and equidistantly distributed. Ten days after sowing (DAS), thinning was performed to leave only one plant per pot. After sowing, the soil was maintained at field capacity with daily irrigations, and the volume to be applied was determined according to the methodology previously cited by Lima et al. (2014).

Based on recommendations of Novais et al. (1991), 40.62 g of potassium nitrate and 75 g of monoammonium phosphate, corresponding to 100, 150 and 300 mg kg^{-1} of soil of N, K_2O and P_2O_5, respectively, were provided in four applications via fertigation, at 10-day intervals, with the first application at 15 DAS. To present probable deficiencies of nutrients, the castor bean plants received 7 L of a solution containing 2.5 g L^{-1} of Ubyfol [(N (15%); P_2O_5 (15%); K_2O (15%); Ca (1%); Mg (1.4%); S (2.7%); Zn (0.5%); B (0.05%); Fe (0.5%); Mn (0.05%); Cu (0.5%); Mo (0.02%)] sprayed on the leaves, at 30 and 60 DAS.

Effects of salinity and cationic nature of irrigation water on the castor bean cv. 'BRS Energia' were determined at 80 DAS based on the percentage of cell membrane damage (%D), relative water content (RWC) in the leaf blade, leaf succulence (SUC), plant height (PH), stem diameter (SD) and leaf area (LA). The percentage of cell membrane damage was evaluated as recommended by Campos & Thi (1997). RWC was determined according to Weatherley (1950).

Leaf succulence was determined based on the relationship proposed by Mantovani (1999): (Fresh phytomass - Dry phytomass/Leaf area). Plant height was measured from the base to the apical meristem. Stem diameter was measured 5 cm above the base of the plant. Leaf area was obtained by measuring the midrib length of all leaves, using the methodology described by Severino et al. (2005).

The obtained data were evaluated through analysis of variance by F test. When significant, treatment means were compared by Tukey test at 0.05 probability level, using the statistical program Sisvar (Ferreira, 2011). For comparison between treatments, the respective standard error of each mean was calculated. The contrasts were defined as follows: $\hat{y}_1$ (S_1 vs S_2; S_3; S_4; S_5; S_6); $\hat{y}_2$ (S_2 vs S_3); $\hat{y}_3$ (S_2 vs S_6); $\hat{y}_4$ (S_2 vs S_5) and $\hat{y}_5$ (S_5 vs S_2; S_3; S_4; S_6).

Results And Discussion

According to the analysis of variance summary (Table 1), the cationic composition of the irrigation water had significant effect ($p < 0.01$) on the percentage of cell membrane damage (%D), relative water content in the leaf blade (RWC), leaf succulence (SUC), plant height (PH), stem diameter (SD) and leaf area (LA) of the castor bean cv. 'BRS Energia'.

According to the means comparison test (Figure 1A) for the percentage of damage to the cell membrane of the leaf tissue, the use of K^+-salinized water (S_5) in irrigation led to statistically superior values of %D in comparison to calcium salt (S_3). Among the other treatments (S_1; S_2; S_4; S_5 and S_6), castor bean plants irrigated with S_3 water deserve attention due to the lower %D, evidencing lower damages to the leaf tissue membrane.

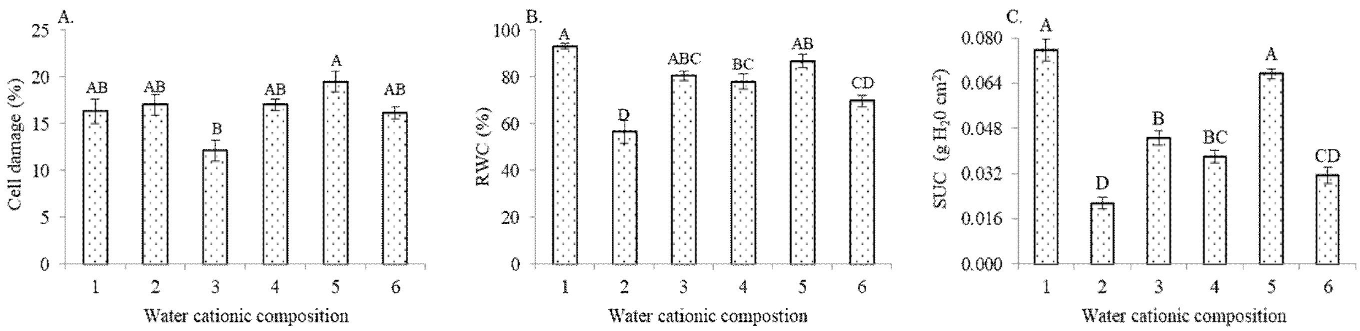
Based on the contrasts of means obtained for the percentage of damage to leaf tissue membrane (Table 2), significant effect occurred only in the comparison between plants irrigated using waters from the treatments S_2 vs S_3 ($\hat{y}_2$) and S_5 vs S_2; S_3; S_4; S_6 ($\hat{y}_5$). According to the estimate of the mean, there was an increment of 4.89% in the mean %D of plants irrigated using S_2 water, compared with those under S_3 water. Comparing S_5 vs the other salts (S_2; S_3; S_4; S_6), it is noted that the %D obtained in the S_5 treatment was 3.89% higher than that of plants subjected to different cations in the irrigation water.

The lower %D observed in plants irrigated using water prepared with Ca^{2+} demonstrates the lower damages to the membrane integrity of castor bean leaf tissue. According to Mengel & Kirkby (2000), this occurs because Ca participates in cell membrane integrity, regulation of cell membrane functionality and activation of various enzymatic systems. In addition, the increment in the percentage of cell membrane damage observed in plants irrigated using K^+-salinized water (S_5) may have occurred due to the increase in the amount of reactive oxygen species (superoxides), free radicals and

Table 1. Summary of analysis of variance for percentage of cell membrane damage (%D), relative water content (RWC) in the leaf blade, leaf succulence (SUC), plant height (PH), stem diameter (SD) and leaf area (LA) of the castor bean cv. 'BRS Energia' irrigated using water with different cationic compositions, at 80 days after sowing

SV/Contrasts#	DF	Mean squares					
		%D	RWC	SUC	PH	SD	LA
Blocks	3	0.27^{ns}	23.26^{ns}	0.00005^{ns}	14.11^{ns}	7.71^{ns}	637005.56^{ns}
Water cationic composition	(5)	22.82**	675.14**	0.001**	487.24**	47.06**	84121507.71**
$\hat{y}_1$	1	0.007^{ns}	1197.00**	0.004**	2200.77**	200.61**	412616054.56**
$\hat{y}_2$	1	47.96*	1152.00**	0.001**	0.14^{ns}	0.08^{ns}	32701.09^{ns}
$\hat{y}_3$	1	1.42^{ns}	351.12*	0.0001*	37.77^{ns}	0.14^{ns}	1037113.22^{ns}
$\hat{y}_4$	1	12.02^{ns}	1830.12**	0.004**	166.37*	25.22*	6174110.29*
$\hat{y}_5$	1	48.44*	775.01*	0.003**	175.97*	31.90*	6796829.74*
Residual	15	4.93	35.89	0.00002	14.99	2.79	440766.11
CV (%)		13.57	7.74	9.96	6.76	9.69	15.16

$\hat{y}_1$ (S_1vs S_2; S_3; S_4; S_5; S_6); $\hat{y}_2$ (S_2 vs S_3); $\hat{y}_3$ (S_2 vs S_6); $\hat{y}_4$ (S_2 vs S_5); $\hat{y}_5$ (S_5vs S_2; S_3; S_4; S_6); Subscripts 1, 2, 3, 4, 5 and 6 represent the waters S_1 = Control; S_2 = Na^+; S_3 = Ca^{2+}; S_4 = Na^+ + Ca^{2+}; S_5 = K^+; S_6 = Na^+ + Ca^{2+} + Mg^{2+}; SV - Source of variation; DF - Degree of freedom; CV - Coefficient of variation; (*) and (**) Significant at 0.05 and 0.01 probability levels, respectively; (ns) Not significant



1= Control; 2 = Na^+; 3 = Ca^{2+}; 4 = Na^+ + Ca^{2+}; 5 = K^+; 6 = Na^+ + Ca^{2+} + Mg^{2+}
Bars represent standard error of the mean (n = 4). Means followed by different letters differ by Tukey test ($p < 0.05$)

Figure 1. Percentage of damage to leaf tissue membrane - %D (A), relative water content (RWC) in the leaf blade (B) and leaf succulence - SVC (C) of the castor bean cv. 'BRS Energia' under different cationic composition of the irrigation water, at 80 days after sowing

Table 2. Estimate of the mean for percentage of cell membrane damage (%D), relative water content (RWC) in the leaf blade, leaf succulence (SUC), plant height (PH), stem diameter (SD) and leaf area (LA) of the castor bean cv. 'BRS Energia' irrigated using waters of different cationic compositions, at 80 days after sowing

Contrasts#	Estimate of mean					
	%D	RWC (%)	SUC (g H_2O cm^2)	PH (cm)	SD (mm)	LA (cm^2)
$\hat{y}_1$	ns	18.95	0.03	25.69	7.75	11125.86
$\hat{y}_2$	4.89	-24.00	-0.02	ns	ns	ns
$\hat{y}_3$	ns	-13.25	-0.009	ns	ns	ns
$\hat{y}_4$	ns	-30.25	-0.04	-9.12	-3.55	-1757.00
$\hat{y}_5$	3.89	15.56	0.03	7.41	3.15	1457.39

$\hat{y}_1$ (S_1 vs S_2; S_3; S_4; S_5; S_6); $\hat{y}_2$ (S_2 vs S_3); $\hat{y}_3$ (S_2 vs S_6); $\hat{y}_4$ (S_2 vs S_5); $\hat{y}_5$ (S_5 vs S_2; S_3; S_4; S_6); Subscripts 1, 2, 3, 4, 5 and 6 represent the waters S_1 = Control; S_2 = Na^+; S_3 = Ca^{2+}; S_4 = Na^+ + Ca^{2+}; S_5 = K^+; S_6 = Na^+ + Ca^{2+} + Mg^{2+}, respectively

enzymes, which lead to membrane rupture and increase permeability and, often, to irreversible damages in the organelles and molecules present inside the cells (Alonso et al., 1997).

According to the comparison of means test for relative water content in the leaf blade (Figure 1B), 'BRS Energia' castor bean plants irrigated with Na^+-salinized water (S_2) differed statistically from those subjected to the treatments S_1, S_3, S_4 and S_5. On the other hand, only plants subjected to irrigation using water prepared with Na^+ (S_2, S_4 and S_6) significantly stand out from the control treatment (S_1), and lowest RWC (56.50%) was found in plants irrigated with NaCl (S_2). In contrast, plants irrigated using Ca^{2+} water (S_3) and K^+ water (S_5) did not differ from those subjected to the lowest ECw level-control (S_1).

Table 2 shows the summary for the contrasts of means referring to RWC in the leaf blade. Based on the contrasts of means referring to the RWC, plants irrigated with ECw = 0.6 dS m^{-1} (S_1) significantly differed from those under ECw = 4.5 dS m^{-1} (S_2; S_3; S_4; S_5; S_6). According to the estimate of mean, in plants irrigated using 0.6 dS m^{-1} water, RWC increased by 18.95% compared with those subjected to ECw = 4.5 dS m^{-1}.

Comparing the data of treatments S_2 vs S_3 (Table 2), when Na^+-salinized water was used in irrigation, RWC was 24% lower in the plants, in comparison to S_3. On the other hand, plants subjected to irrigation with Na^+-salinized water (S_2) showed reduction of 13.25% in RWC, compared with those irrigated with S_6 (Na^+ + Ca^{2+} + Mg^{2+}). For the treatments S_2 vs S_5, when Na^+-salinized water was applied, plants showed a decrease of 30.25% in RWC, compared with those under the S_5 treatment (K^+).

For leaf succulence (SUC), according to the means comparison test (Figure 1C), in the treatment that used low-salinity water (control) and K^+-salinized water (S_5), SUC was statistically higher compared with plants irrigated using water prepared with the other salts (S_2; S_3; S_4 and S_6). Nonetheless, castor bean plants irrigated with Ca^{2+}-salinized water were statistically different from those under salinity of the water prepared with Na^+ (S_2) and Na^+ + Ca^{2+} + Mg^{2+}(S_6).

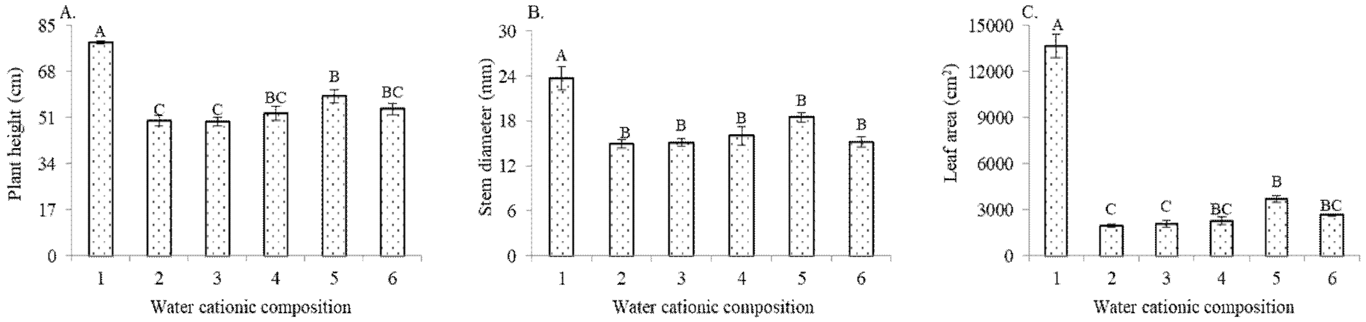
Based on the superiority of SUC data in the S_5 treatment, compared with the other types of salts (S_2; S_3; S_4 and S_6), when K^+-salinized water was used in irrigation, 'BRS Energia' castor bean plants experienced lower deleterious effect caused by water salinity. Silva et al. (2009), evaluating jatropha under salt stress conditions (0, 25, 50, 75 and 100 $mmol_c$ L^{-1} of NaCl), also found increments in leaf succulence. These authors also pointed out that such increment in SUC played an effective role in plant osmotic adjustment, a fact observed in the present study in plants irrigated using water prepared with K^+.

The analysis of the contrasts between means for SUC (Table 2) shows a significant difference for all contrasts and, based on the estimate of mean, castor bean plants irrigated with water of lowest ECw (0.6 dS m^{-1}) increased SUC by 0.03 g H_2O cm^2, compared with those irrigated with ECw = 4.5 dS m^{-1} (S_2; S_3; S_4; S_5 and S_6). According to Table 2, plants irrigated with Na^+-salinized water (S_2) showed reduction of 0.02 g H_2O cm^2 in SUC, compared with those irrigated with the S_3 treatment. Based on the means obtained in the different treatments (S_2 vs S_6; S_2 vs S_5; S_5 vs S_2; S_3; S_4; S_6), plants irrigated with K^+-salinized water (S_5) showed statistically superior SUC values in comparison to those under the other types of salts.

Increased SUC in plants grown using K^+-salinized water may be an indication that osmotic adjustment occurred in stressed plants (Silva et al., 2009), which is considered as important because succulence is a parameter that allows to regulate the concentration of salts in the leaf tissues and directly depends on absorption, transport and accumulation of ions in the leaf tissues, possibly contributing to reducing the effect of salts on plant growth (Trindade et al., 2006). Hence, the saline stress caused by the high K^+ concentrations in the irrigation water possibly had a negative effect on the hydration level of the leaf tissues.

The comparison of means test for plant height (PH) (Figure 2A) shows that castor bean plants cultivated under irrigation with low-salinity water (S_1) grew more in PH, significantly differing from those irrigated with the other types of water, ECw = 4.5 dS m^{-1}, containing Na^+ (S_2), Ca^{2+} (S_3), Na^+ + Ca^{2+} (S_4), K^+ (S_5) and Na^+ + Ca^{2+} + Mg^{2+} (S_6). Additionally, in the comparison of means obtained in the different treatments (Figure 2A), plants subjected to irrigation with K^+-salinized water (S_5) were statistically different from those irrigated with S_2 and S_3, but were similar to those irrigated with S_4 and S_6.

For stem diameter (Figure 2B), except in the control (S_1), there were no significant differences between the different types of irrigation water salinity. In S_1, mean SD was equal to 23.71 mm, while the other treatments showed an average SD of 15.96 mm (32.68% lower). However, it is important to point out that plants irrigated with S_5 water showed less accentuated reductions, in comparison to the other types of salts. This fact must be associated with the functions of K, because this macronutrient participates in the maintenance of ionic balance and turgor of the cells, by controlling stomatal opening and closure (Gurgel et al., 2010).



1- Control; 2 = Na^+; 3 = Ca^{2+}; 4 = Na^+ + Ca^{2+}; 5 = K^+; 6 = Na^+ + Ca^{2+} + Mg^{2+}
Bars represent the standard error of the mean (n = 4). Means with different letters differ by Tukey test ($p < 0.05$)

Figure 2. Plant height (A), stem diameter (B) and leaf area (C) of 'BRS Energia' castor bean under different cationic composition of irrigation water, at 80 days after sowing

As observed for PH (Figure 2A), castor bean leaf area (LA) was significantly superior in plants subjected to irrigation using low-salinity water (S_1), with mean value of 13651.63 cm^2, statistically differing from the other treatments (S_2; S_3; S_4; S_5 and S_6), which showed 81.4% lower LA (on average 2525.76 cm^2). As shown in Figure 2C, the LA of plants using K^+-salinized water (S_5) was significantly superior to those of the other treatments with Na^+ (S_2) and Ca^{2+} (S_3), which did not differ from Na^+ + Ca^{2+} (S_4) and Na^+ + Ca^{2+} + Mg^{2+} (S_6).

Based on the contrasts of means shown in Table 2, plant height, stem diameter and leaf area of castor bean plants irrigated with ECw = 0.6 dS m^{-1} (S_1) significantly varied in comparison to those under ECw = 4.5 dS m^{-1} (S_2; S_3; S_4; S_5 and S_6) and, based on the estimate of mean (Table 2), the values of PH, SD and LA in the plants subjected to these treatments were 25.69 cm, 7.75 mm and 11125.86 cm^2 lower, respectively. The reduction in castor bean growth, evidenced by the decrease in plant height, stem diameter and leaf area, due to the use of waters with different ionic compositions, may also be related to the genetics of the plant, osmotically adjusting in the initial development stage, allocating greater amount of energy for the accumulation of sugars, organic acids and ions in the vacuole, energy that could be used for plant growth (Santos et al., 2012).

A joint analysis of the results obtained (%D, RWC, SUC, PH, SD and LA) reveals that the greater growth of castor bean plants in the treatments S_1 and S_5 may be related to the higher relative water content in the leaf blade, which led to high succulence in the leaf tissues, suggesting a strategy of osmotic adjustment by the crop. In this case, greater growth of the castor bean crop may also be related to cell wall extensibility, which is determined by the positive turgor pressure inside the cells. The results obtained in the present study agree with those of Lima et al. (2014), who found that increased irrigation water salinity (ECw varying from 0.3 to 3.9 dS m^{-1}) significantly reduced plant height, stem diameter and leaf area of 'BRS Energia' castor bean plants, at 30, 60 and 120 DAS.

Based on the contrasts S_2 vs S_3 and S_2 vs S_6, there was no significant influence ($p > 0.05$) on PH, SD and LA. It can be seen from the mean estimation data (Table 2) that the plants irrigated with sodium (S_2) water had PH, SD and LA, respectively 9.12 cm, 3.55 mm and 1757.00 cm^2 less in comparison to those receiving water prepared with potassium (S_5). While comparing the castor bean plants irrigated with water of potassium ion composition in relation to the other cations (S_2, S_3, S_4 and S_6), there was superiority in PH, SD and LA, with a mean value of 7.41 cm, 3.15 mm and 1457.39 cm^2, respectively.

Conclusions

1. Higher relative water content in the leaf blade of plants irrigated using K^+-salinized water associated with leaf succulence are indicative of tolerance to salinity by the castor bean cv. 'BRS Energia'.

2. Salt stress negatively affects castor bean growth, regardless of the cationic nature of the water.

3. The castor bean cv. 'BRS Energia' is more sensitive to the presence of sodium in the irrigation water, in terms of both water relations and leaf succulence.

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