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Tolerance of castor bean cultivars under salt stress

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Key words:
Ricinus communis L.
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A B S T R A C T

This study aimed to evaluate the tolerance of castor bean cultivars under salt stress during the initial growth stage. The experiment was set in randomized blocks, in a 5 x 4 factorial scheme, resulting in 20 treatments, 5 salinity levels (0.6-control, 1.2, 1.8, 2.4 and 3.0 dS m^{-1}) and 4 castor bean cultivars (BRS Energy, LA Guarani, BRS Gabriela and IAC 028)] with 3 replicates. At 30 days after sowing, plants were evaluated for growth, dry matter accumulation and salt tolerance. Increased salinity levels in the water used for irrigation reduced the growth of all the studied cultivars. The salt tolerance of the studied castor bean cultivars follows the following order: BRS Energia > BRS Gabriela = IAC 028 > LA Guarani.

Palavras-chave:
Ricinus communis L.
crescimento
seleção de germoplasma
qualidade da água

Tolerância de cultivares de mamoneira sob estresse salino

R E S U M O

Propôs, com este estudo, avaliar a tolerância de cultivares de mamoneira sob estresse salino durante a fase inicial de crescimento. Utilizou-se esquema fatorial 5 x 4, em delineamento em blocos casualizados, resultando em 20 tratamentos (5 níveis de salinidade (0,6 -controle; 1,2; 1,8; 2,4 e 3,0 dS m^{-1}) x 4 cultivares de mamoneira (BRS Energia; LA Guarani; BRS Gabriela e IAC 028)] com 3 repetições. Aos 30 dias após a semeadura as plantas foram avaliados para crescimento, acúmulo de matéria seca e tolerância à salinidade. O aumento dos níveis de salinidade da água usada na irrigação reduziu o crescimento de todas as cultivares estudadas; a tolerância à salinidade das cultivares de mamoneira obedece a seguinte sequência: BRS Energia > BRS Gabriela = IAC 028 > LA Guarani.

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Introduction

Castor bean (*Ricinus communis* L.), belonging to the *Euphorbiaceae* family, is an oilseed crop with high socioeconomic value that has stood out for its rusticity and good adaptation to adverse conditions of climate and soil, high production and high content of oil in its seeds (Santos et al., 2011).

The cultivation of oilseed species is an alternative for the support to family farming and one of the main alternatives for socioeconomic problems (Ramos et al., 2003; Severino et al., 2006). Their cultivation occurs mainly in semiarid climate areas of Northeast Brazil, in which problems such as water and soil salinity are limiting factors for crop development (Medeiros et al., 2003). Salinity problems in semiarid regions have increased along the years and water quality is one of the most limiting factors for crop development, since it affects plants from growth to production, because water is a component of plant tissues, constituting more than 90% of some plants. Hence, water deficit and saline stress directly affect crop development, which requires the incorporation of strategies of irrigation management, fertilization and identification of materials tolerant to salinity in order to obtain satisfactory crop yields under semiarid conditions (Ayers & Westcot, 1999; Medeiros et al., 2007; Souza et al., 2007; Diniz Neto et al., 2009; Sá et al., 2013; Lima et al., 2014).

Therefore, this study aimed to evaluate the tolerance of castor bean cultivars to saline stress during the initial development stage.

Material and Methods

The study was carried out from October to November 2013 in a greenhouse, at the Center of Human and Agricultural Sciences of the State University of Paraíba (CCHA-UEPB), *Campus* IV, in Catolé do Rocha-PB, Brazil (6° 20' 38" S; 37° 44' 48" W; 275 m).

Four castor bean cultivars (C) were evaluated (BRS Energia - C_1; LA Guarani - C_2; BRS Gabriela - C_3 and IAC 028 - C_4), under five levels of irrigation water salinity - ECw (S_1 = 0.6 (control); S_2 = 1.2; S_3 = 1.8; S_4 = 2.4 and S_5 = 3.0 dS m^{-1}), arranged in randomized blocks, with three replicates.

Soil was used as substrate in pots with capacity for 2 dm^3 and its chemical characterization showed: pH = 7.02; P and K = 53 and 297 mg dm^{-3}; Na^+ = 0.3; Ca^{2+} = 4.63; Mg^{2+} = 2.39; Al^{3+} = 0.0, H+ = 0.0 and CEC = 8.08 $cmol_c$ dm^{-3}, respectively; base saturation (V) = 100% and OM = 1.8% and was classified as eutrophic Fluvic Neosol, with sandy loam texture, according to the methodologies suggested by EMBRAPA (2011). One additional fertilization was performed using the solution proposed by Hoagland & Arnom (1950), composed of: N = 15; P = 1; K = 6; Ca = 5; Mg = 2; S = 2; Fe = 0.0625; Mn = 0.01; B = 0.05; Cu = 0.003; Zn = 0.008 and Mo = 0.001 mmol L^{-1}, at the proportion of 5% of the volume of the substrate, 10 days after sowing (DAS).

Sowing was performed using four seeds per pot, distributed equidistantly at the depth of 1 cm. After emergence, thinning was performed when plantlets showed two definitive leaves, leaving only one plant in each pot.

Irrigations were daily performed in order to bring the soil close to the maximum holding capacity, based on the method of drainage lysimetry, and in the applied water depth was added a leaching fraction (LF) of 20%. The volume applied (Va) in each pot was obtained by the difference between the previously applied water depth (La) minus the mean drainage (d), divided by the number of pots (n): Va = [La - (D/n)]/(1-LF).

The solutions used in irrigation were prepared with the addition of sodium chloride (NaCl) salts, which constitute 70% of the salt ions in the water sources used for irrigation in small farms of Northeast Brazil (Medeiros et al., 2003). The solutions with different electrical conductivities (EC) were prepared by adding the salts to the water until the desired EC level and the values were confirmed using a portable conductivity meter adjusted to the temperature of 25 °C.

At 30 DAS, the following variables were evaluated: plant height (PH, cm), considered as the distance between the base and the apical meristem of the plants, stem diameter (SD, mm), measured at 1 cm above the soil, and the number of leaves (NL), considering the count of photosynthetically active leaves. Also at 30 DAS, castor bean plants were collected and shoots and roots were separated, dried in a forced-air oven at 65 °C for 72 h and weighed on an analytical scale. Using this data, it was possible to calculate shoot dry matter (SDM, g), root dry matter (RDM, g) and total dry matter (TDM, g).

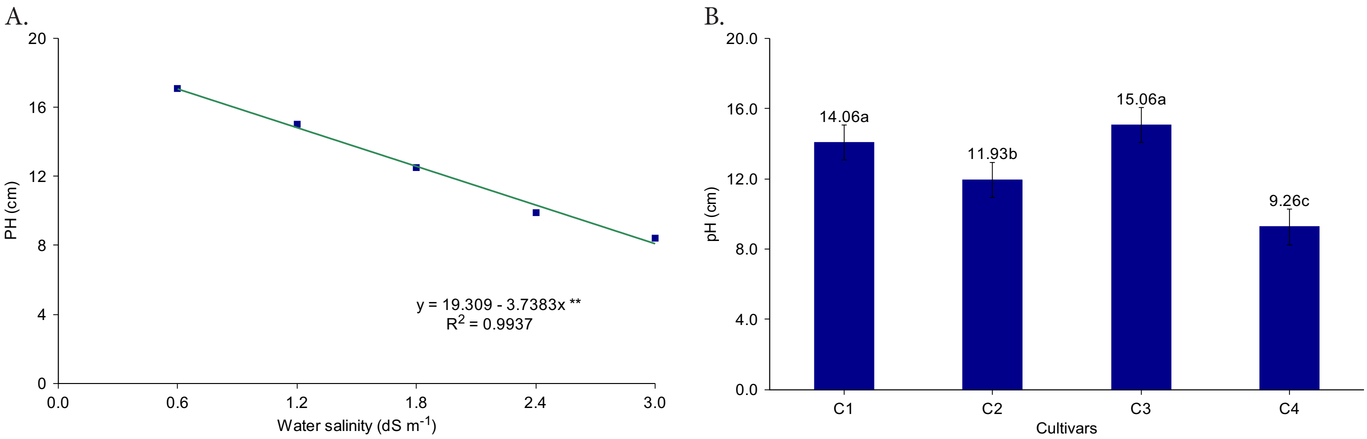
The data of total dry matter production were used to calculate the percentages partitioned between vegetative organs and the index of tolerance to salinity (IT), through the comparison between the data of the saline treatments and those of the control (ECw = 0.6 dS m^{-1}): IT = [(TDM production in the saline treatment/TDM production in the control treatment)*100] (Aquino et al., 2007). The total dry matter production of the cultivars was used as the main parameter for the determination of tolerance to saline stress.

The obtained data were evaluated through analysis of variance by F test. In cases of significance, a means-grouping test (Scott & Knott, at 0.05 probability level) was applied for the factor Cultivars, while the levels of irrigation water salinity were subjected to polynomial regression analysis (linear or quadratic, at 0.05 probability level) using the program Sisvar (Ferreira, 2011).

Results and Discussion

There was no significant effect ($p > 0.05$) of the interaction between the studied factors (Cultivars x Salinity) on plant height; however, there was significant effect of the isolated factors. The cultivars BRS Energia and BRS Gabriela showed higher values of plant height, regardless of the salinity levels, with mean heights of 14.06 and 15.06 cm, respectively, while the cultivar IAC 028 showed the lowest height (Figure 1B).

The increase in irrigation water salinity linearly reduced plant growth in height for all studied castor bean cultivars, with reductions of 3.73 cm per unit increase in irrigation water salinity, possibly due to specific ionic interactions caused by NaCl ions, which reduce soil osmotic potential and thus limit the absorption of water and nutrients, such as nitrogen, compromising photosynthetic activity and, consequently, plant



*C1 - BRS Energia; C2 - LA Guarani; C3 - BRS Gabriela and C4 - IAC 028

Figure 1. Plant height (PH) (A and B) of castor bean cultivars subjected to different levels of irrigation water salinity

growth (Figure 1A). The decrease in castor bean height as a function of the increment in irrigation water salinity was also reported by Lima et al. (2012), who evaluated the initial growth of the cultivar BRS Energia under water salinity and N doses, and observed that fertilization intensified castor bean growth.

As observed for the variable plant height, the stem diameter of the castor bean cultivars was reduced by 0.455 mm per unit increase in irrigation water salinity, with total reduction of 18.1% in plants cultivated between the highest (3.0 dS m^{-1}) and the lowest (0.6 dS m^{-1}) salinity level studied (Figure 2).

The growth in stem diameter in young plants is directly related to the cell expansion influenced by cell turgor or the water content present in the cell (Taiz & Zeiger, 2013). Hence, it is believed that the decrease in stem diameter is related to the restriction of water absorption by the castor bean cultivars due to the reduction of soil osmotic potential, through the increase in the concentration of salts (Ayers & Westcot, 1999). Similar tendency was also reported by Santos et al. (2013), who studied the effects of different water salinity levels (0.12 to 4.8 dS m^{-1}) on growth components of BRS Energia in different development stages and observed decrease in growth in diameter as water salinity increased, for all evaluated periods.

There was significant effect ($p < 0,05$) of the interaction between the studied factors (Cultivars x Salinity) for the number of leaves, the cultivar BRS Energia showed a quadratic response to the salinity levels, with maximum number of leaves (5.5 leaves $plant^{-1}$) when subjected to the salinity level

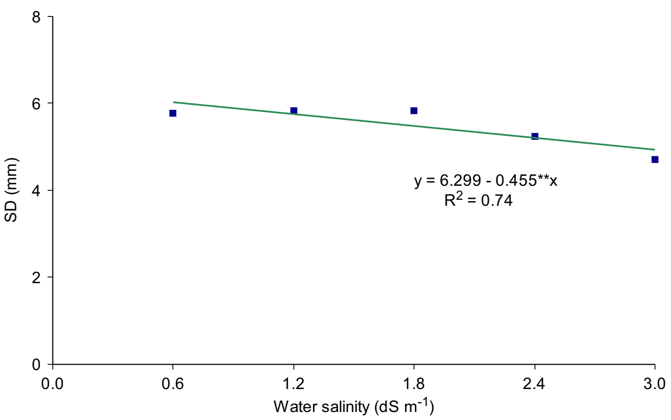


Figure 2. Stem diameter (SD) of castor bean cultivars subjected to different levels of irrigation water salinity at 30 days after sowing

of 1.38 dS m^{-1} (Figure 3A). Therefore, it is supposed that the increase in the number of leaves in this cultivar until this level is due to a mechanism of tolerance, which tries to increase plant leaf area and produce a higher number of photosynthetically active leaves, stimulating plant growth.

Different response was reported by Costa et al. (2013), who observed no significant effect of different treatments of saline water management on the growth of the castor bean cultivar BRS Energia 100 days after sowing. However, these authors evaluated only three water salinity levels (0.53, 2.09 and 3.66 dS m^{-1}) under field condutions, where the effect of salt concentrations are lower than those in the pots.

The number of leaves of the cultivars BRS Gabriela and IAC 028 decreased linearly as the salinity level increased, with respective reductions of 0.44 and 0.55 leaves $plant^{-1}$ for each unit increase in irrigation water salinity (Figure 3C and D), which is related to the excessive increase in water salinity levels, promoting higher concentration of salts in the soil and, therefore, greater absorption of salts by the plant. This causes toxicity through specific ions (Flowers & Flowers, 2005), especially in more sensitive cultivars, as observed in IAC 028.

For the cultivar LA Guarani, water salinity did not affect its emission of leaves and it showed a mean of 4.26 leaves $plant^{-1}$ (Figure 3B). However, this cultivar obtained the highest reductions in shoot dry matter, which indicates that, even maintaining the number of leaves, it drastically reduced its photosynthetic potential under saline conditions, affecting the synthesis of biomass (Figure 4B), possibly due to damages caused to the photosynthetic apparatus, consequently restricting the synthesis of carbohydrates (Silva et al., 2014).

There were linear reductions in the accumulation of shoot dry matter of approximately 0.2517, 0.2306, 0.1978 and 0.1561 g $plant^{-1}$ with per unit increase in irrigation water salinity for the cultivars LA Guarani, BRS Gabriela, IAC 028 and BRS Energia, respectively (Figura 4A, B, C e D). Thus, the cultivar BRS Energia showed the lowest reductions in shoot dry matter accumulation in response to the increase in water salinity, indicating its higher capacity to maintain photosynthesis. These plants are able to regulate the synthesis and accumulation of photosynthates under saline conditions, denoting the potential of this material for the cultivation in semiarid regions that face qualitative scarcity of water resources (Medeiros et al., 2003).

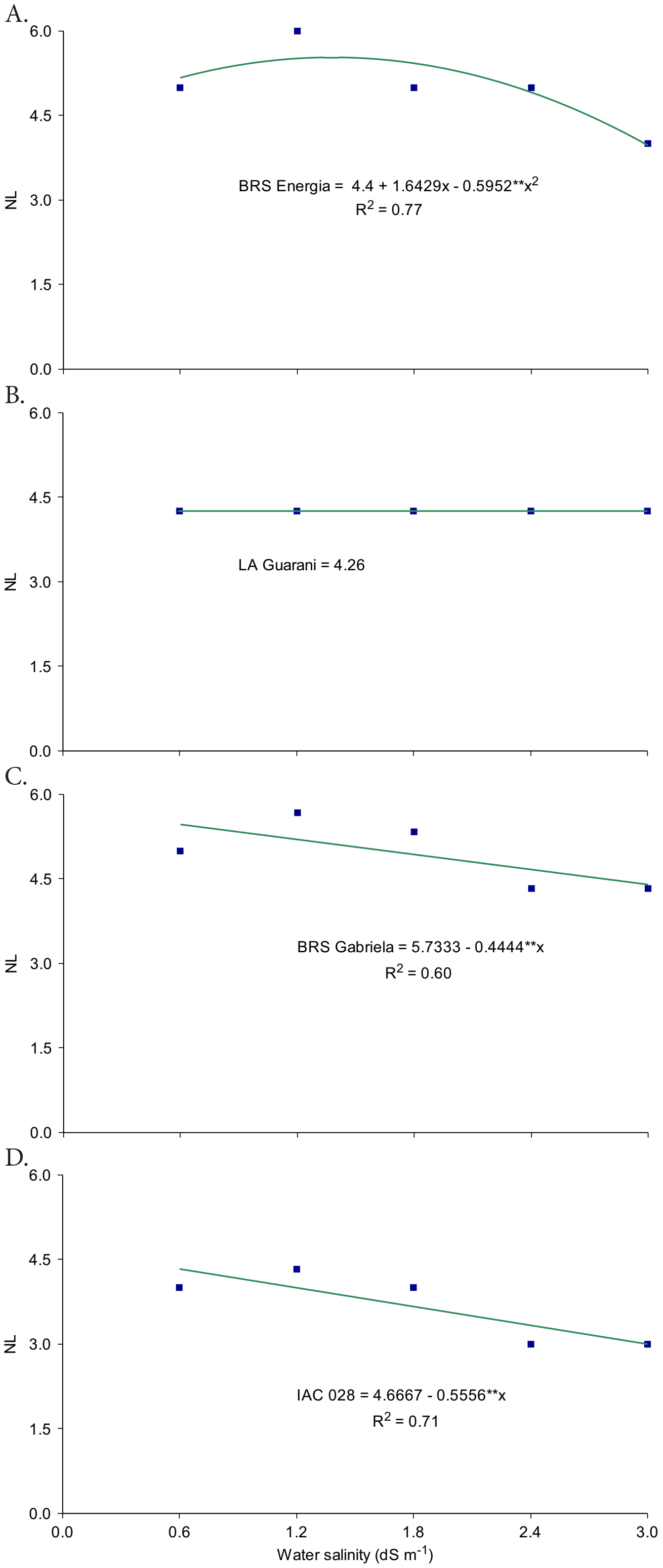


Figure 3. Number of leaves (NL) of the castor bean cultivars BRS Energia (A), LA Guarani (B), BRS Gabriela (C) and IAC 028 (D) subjected to different levels of irrigation water salinity at 30 days after sowing

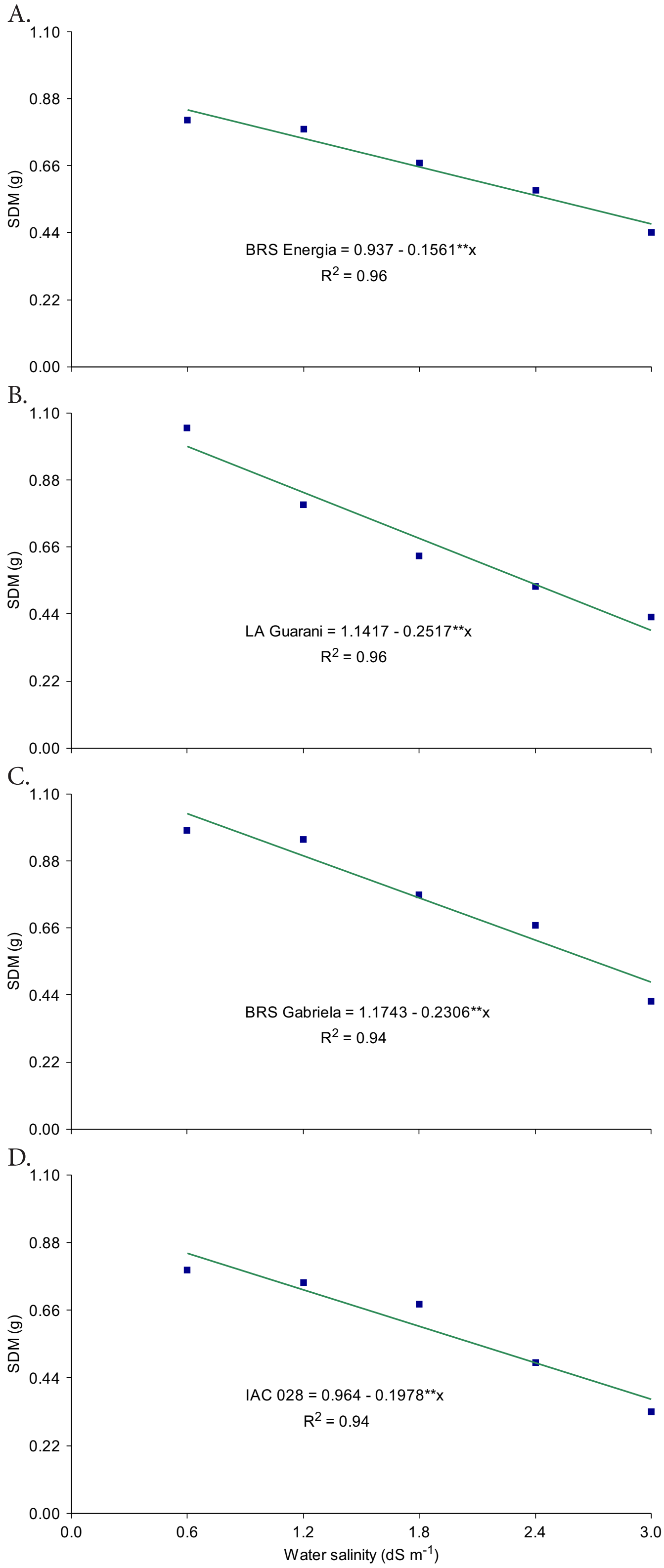


Figure 4. Shoot dry matter (SDM) of the castor bean cultivars BRS Energia (A), LA Guarani (B), BRS Gabriela (C) and IAC 028 (D) subjected to different levels of irrigation water salinity at 30 days after sowing

There was no significant interaction ($p < 0.05$) between the studied factors for root dry matter, but the variable responded to the isolated factors (Figure 5A and B). The cultivar BRS Gabriela showed the highest root dry matter accumulation (Figure 5B). For the water salinity levels, there was a linear decrease in root dry matter accumulation, regardless of the studied cultivar, of 0.1317 g plant^{-1} for each unit increase in water salinity and total reduction of 53% from 0.6 to 3.0 dS m^{-1}. The reduction in the root system may be related to the mechanism of tolerance to saline stress of this species, since the decrease in root surface also reduces the absorption of water and ions by plants, including the toxic ones (Sá et al., 2013).

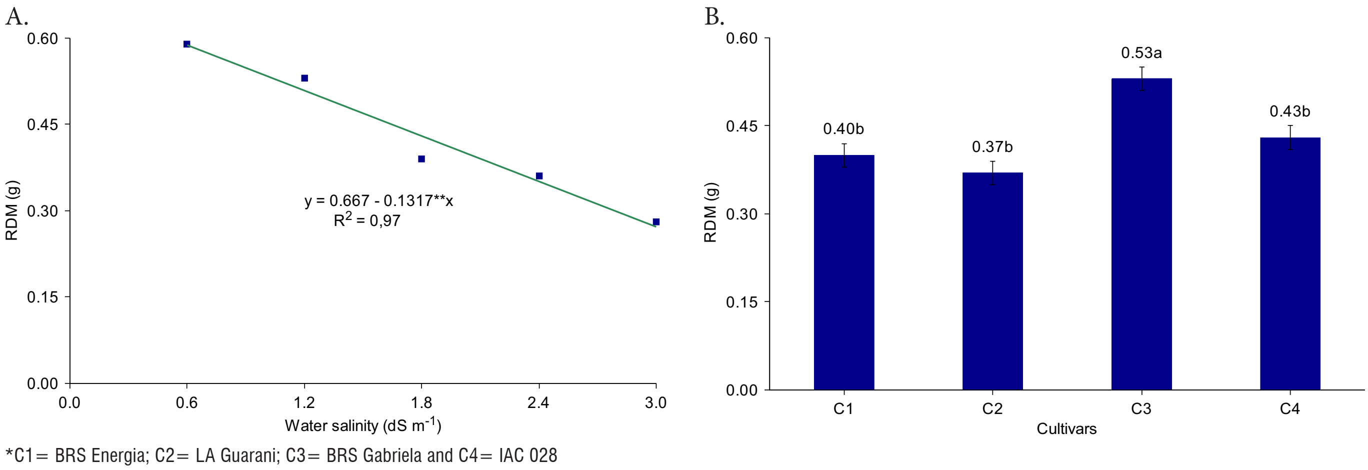


Figure 5. Root dry matter (RDM) of castor bean cultivars subjected to different levels of irrigation water salinity at 30 days after sowing

The highest reduction in total dry matter production under saline conditions was observed for the cultivar LA Guarani (0.3961 g plant^{-1}), followed by BRS Gabriela and IAC 028, with reductions of 0.3844 and 0.3189 g plant^{-1}, respectively, for each unit increase in water salinity (Figure 6A, B, C and D). In addition, the cultivar BRS Energia showed the lowest reduction (0.2717 g plant^{-1}) per unit increase in water salinity. Total dry matter reflects the gain of mass, i.e., the accumulation of photosynthates from the photosynthetic process of the plant as a whole. Hence, the highest reductions observed in the cultivar LA Guarani are indicative of greater influence of the saline stress on this cultivar, which is probably the most sensitive among the studied materials. The decrease in dry matter accumulation in castor bean plants under saline conditions was also reported by Lima et al. (2014), who evaluated the growth of the castor bean cultivar BRS Energia under water salinity conditions from 0.3 to 3.9 dS m^{-1}.

There were linear reductions in the index of salt tolerance of all the cultivars as a function of the increment in irrigation water salinity (Figure 7). With the increase in salinity to 1.8 dS m^{-1}, the index of salt tolerance of the cultivar LA Guarani decreased to 63.82%, while it was 79.80, 75.51 and 77.91% for the cultivars BRS Energia, BRS Gabriela and IAC 028, respectively. Thus, the level of 1.8 dS m^{-1} can be considered as favorable for the cultivation of BRS Energia, BRS Gabriela and IAC 028 in regions with limitations due to problems in the salinity of water used for irrigation.

Additionally, at the two highest salinity levels (2.4 and 3.0 dS m^{-1}), there were the most drastic reductions in the indices

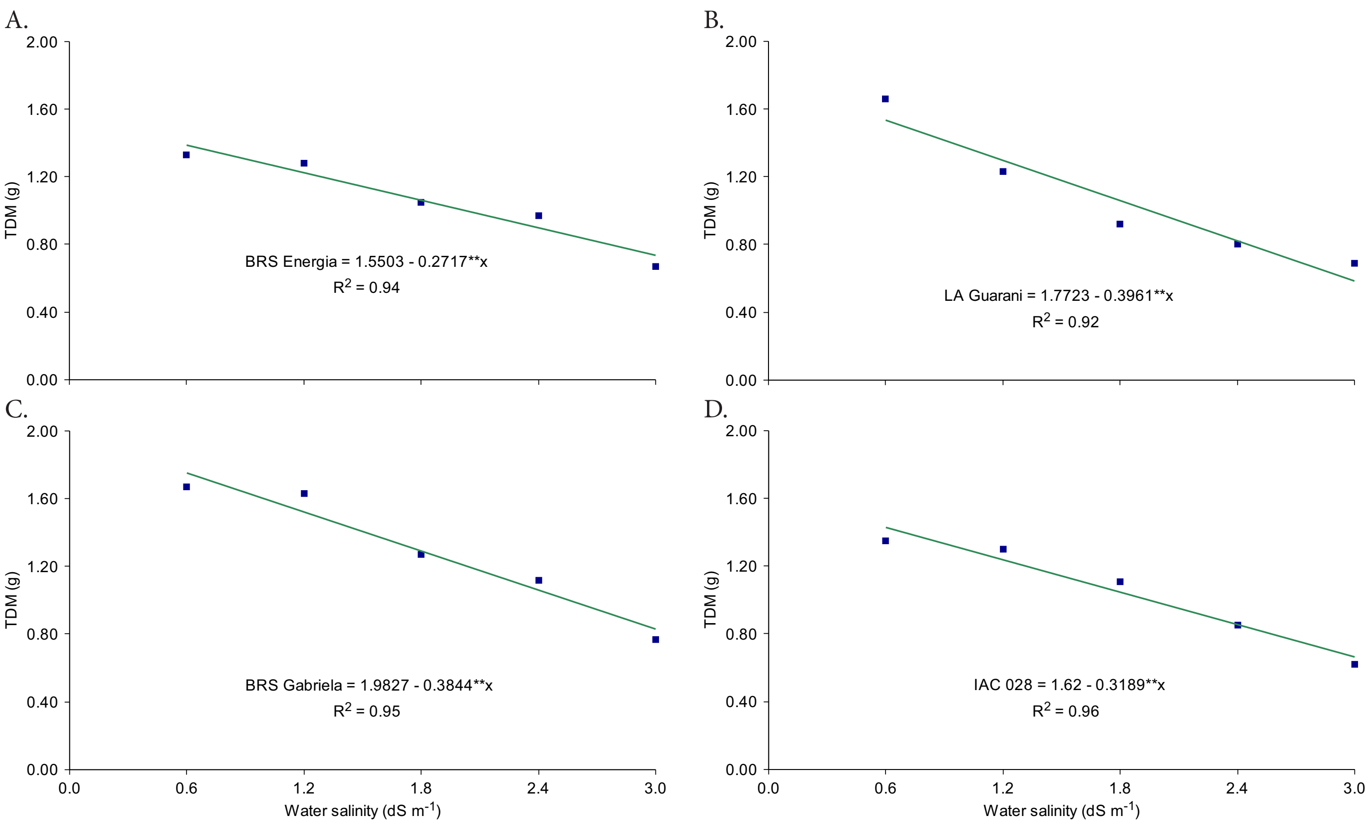


Figure 6. Total dry matter (TDM) of the castor bean cultivars BRS Energia (A), LA Guarani (B), BRS Gabriela (C) and IAC 028 (D) subjected to different levels of irrigation water salinity at 30 days after sowing

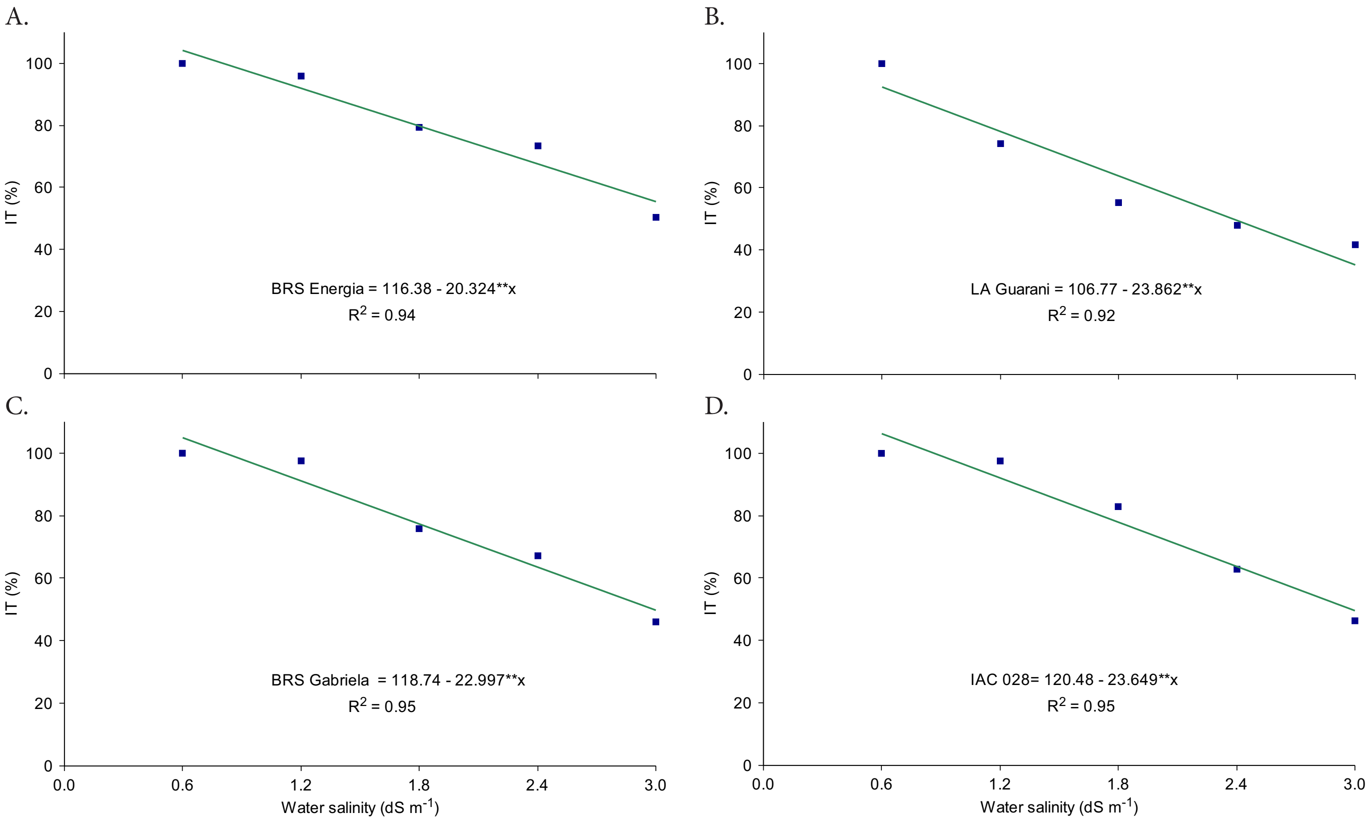


Figure 7. Index of salt tolerance (IT) of the castor bean cultivars BRS Energia (A), LA Guarani (B), BRS Gabriela (C) and IAC 028 (D) subjected to different levels of irrigation water salinity at 30 days after sowing

of salt tolerance of the cultivars, which were equal to 67.60 and 55.41% for BRS Energia, 49.50 and 35.18% for LA Guarani, 63.55 and 49.75% for BRS Gabriela and 63.72 and 49.53% for IAC 028, respectively (Figure 7A, B, C and D). Therefore, the salt tolerance of the cultivars follows the following order: BRS Energia > BRS Gabriela = IAC 028 > LA Guarani. Thus, the cultivar LA Guarani is considered as inadequate for cultivation in regions affected by water salinity problems.

Conclusions

1. The increase in the levels of irrigation water salinity reduced the growth and dry matter accumulation of all the evaluated cultivars.

2. The salt tolerance of the studied castor bean cultivars follows the following order: BRS Energia > BRS Gabriela = IAC 028 > LA Guarani.

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