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Salinity in irrigation water with organic fertilizer application on growth of castor bean

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Plants grown under salt stress are adversely affected, however, it has been suggested the use of organic inputs in order to mitigate the deleterious effects of salinity. As a result, it aimed to evaluate the effect of different electrical conductivities of irrigation water due to the application of organic fertilizers in the cultivation of castor bean. The experiment was conducted in greenhouse located at State University of Paraiba, municipality of Catolé do Rocha-PB, Brazil. It adopted a completely randomized design (CRD), in a factorial scheme 5 x 3, with 8 repetitions. The first factor was the electrical conductivity of irrigation water (ECw) 0.5; 1.5; 2.5; 3.5 and 4.5 dS m^{-1} and the second factor refers to organic fertilizers: control treatment, biofertilizers beef and cow urine. There was interaction between the electrical conductivity x organic fertilizer factors. The unit increased from 0.5 dS m^{-1} of electrical conductivity of irrigation water reduced the growth, development and dry matter production of castor bean. The application of bovine growth provides greater biofertilizer castor. Furthermore, the organic raw material attenuates the effects of salt stress.

Key words: *Ricinus communis* L. salt stress, biofertilizer, cow urine.

INTRODUCTION

The castor bean (*Ricinus communis* L.) has great economic importance because of the diversity of products derived, like oil, used for the production of biodiesel, and the pie that can be applied as fertilizer and soil conditioner. Moreover, after getting the necessary benefits, castor bean pie can still be used as animal feed supplement (Mesquita et al., 2012).

The main castor bean crops are located in northeastern Brazil, especially in the semiarid region, however, in these areas there is a huge climate change and is characterized by high temperatures, low rainfall, uneven distribution of rainfall, as well as high rates of evapotranspiration, resulting in drought in most regions. Thus, irrigated farming is essential to meet the water needs of crops (Nobre et al., 2013), concurrently, irrigation water quality is a factor that directly influences

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the production and quality of crops.

Although castor is adaptable semi-arid conditions, it is important that the water supply is met so that the culture can develop properly; achieving satisfactory yields in the physical and economic point of view (Ribeiro et al., 2012). Thus, the research of monitoring the vegetative behavior, planting the beginning of flowering or fruiting, is an essential step for making decisions on how to manage irrigation and crop fertilization (Rios et al., 2011; Mesquita et al, 2012).

The irrigation management is one of the best agricultural strategies to ensure the quality of production, however, inadequately associated with high evapotranspiration combined with low rainfall has caused several problems, including salinization of soils, due to the accumulation of salts in the soil (Lima et al., 2014a).

As a strategy to mitigate the effects of salt stress have used organic inputs that demonstrate benefits (El-Dardiry, 2007, Miranda et al., 2011), mainly organic matter, promoting improvements in soil aeration, provides conditioning effect also improves soil permeability, enhancing water movement (El-Dardiry, 2007), moreover, release humic substances that act as mitigating the effects of salinity (Aydin et al., 2012).

The use of saline water in the cultivation of castor bean has been studied for several researchers (Santos et al., 2013; Lima et al, 2014a; Nobre et al., 2013; Lima et al., 2015), which generally observed that the culture is moderately sensitive to salts and irrigation water salinity provides negative effect on germination, growth and production of castor bean.

Despite these studies with the culture of castor bean, it is clear that more information is needed about the interaction of irrigation water salinity with the use of organic fertilizers in castor bean as a way to mitigate the negative effects of the use of saline water in the cultivation of this oleaginous. In this sense, the objective was to evaluate the effect of different electrical conductivity in the irrigation water associated with the application of organic fertilizers on growth and development of the castor bean crop.

MATERIALS AND METHODS

The experiment was conducted at the State University of Paraiba (UEPB), Catolé do Rocha, Paraíba, (6°20'38"S, 37°44'48"W) Brazil, from September 2014 to January 2015, in the greenhouse. The plants were grown in plastic pots filled substrate composed of soil classified as Fluvisol, sandy clay loam texture, with the following chemical and physical characteristics: pH (H_2O) = 5.02; P (Mehlich) = 0.70 mg dm^{-3}; K = 0.76 mg dm^{-3}; Ca^{+2} + Mg = 7.02 cmol$_c$dm^{-3}; H + exchangeable Al = 0.0 cmol$_c$dm^{-3} and organic matter = 8.05 kg dm^{-3}.

The experimental design was completely randomized, with a factorial scheme of 5 x 3, with 8 repetitions. The treatments consisted of irrigation water application in the electrical conductivities (ECw) 0.5; 1.5; 2.5; 3.5 and 4.5 dS m^{-1} combined with application of organic fertilizers (control treatment, biofertilizers beef and cow urine). The experimental units were composed of three plants, grown in plastic pots with 8 dm³ capacity.

Table 1. Chemical attributes of bovine biofertilizer and cow urine used in the experiment. Catolé do Rocha - PB, UEPB 2014.

Characteristics	Biofertilizer bovino	Cow urine
pH $CaCl_2$	4.68	4.50
CE (dS m^{-1})	4.70	0.40
Ca^{+2} (cmol$_c$ dm^{-3})	3.75	3.10^{-4} mg L^{-1}
Mg^{+2} (cmol$_c$ dm^{-3})	3.30	4.10^{-5} mg L^{-1}
Na^{+} (cmol$_c$ dm^{-3})	1.14	2.10^{-4} mg L^{-1}
K^{+} (cmol$_c$ dm^{-3})	0.71	1 mg L^{-1}
P (mg dm³)	14.45	4.8.10^{-4} mg L^{-1}
Al^{3+} (cmol$_c$ dm^{-3})	0.00	0.00 mg L^{-1}
H^{+} + Al^{3+} (cmol$_c$ dm^{-3})	1.00	-
SB	7.76	-
T	8.90	-
MO (g kg^{-1})	8.00	-

EC = Electric Conductivity extract 1: 2.5; SB = Ca^{+2} + Mg^{+2} + K^{+} + Na^{+} H^{+} + Al^{3+} CTC = SB + H^{+} + Al^{+3}; OM = organic matter.

The water used for irrigation was acquired from a local supply well located in UEPB and showed electrical conductivity of 0.5 dS m^{-1}. The plants were irrigated daily with each type of water, from the fifteenth day after sowing was carried out by manually irrigation sprinkler, providing a sufficient blade to raise the soil moisture level of field capacity.

The bovine biofertilizer was prepared according to the methodology of Silva et al. (2012) obtained by anaerobic fermentation in hermetically sealed container. For release of methane at one end of a thin hose upper base of each digester was coupled and the other end was immersed in a container of water. For the preparation of bio-fertilizer, we used 70 kg of manure from dairy cows and 120 liters of water.

Treatments with biofertilizer and cow urine were applied 15 days after sowing (DAS), at 8 days intervals, totaling 6 applications in the dosage of 10% of the substrate. Before application, bovine biofertilizer and cow urine were diluted in water (5%), bovine biofertilizer was subsequently subjected to the filtering process by the screen to reduce the risk of clogging of the sieve watering holes. The biofertilizer and cow urine was analyzed, and had the following chemical characteristics as shown in Table 1.

The different ECw levels were obtained by addition of sodium chloride (NaCl) water from the local supply system according to the study of Rhoades et al. (2000), and the quantity of salts (Q) was determined by the equation:

Q (mg / L$^{-1)}$ = ECw x 640. Wherein, ECw (0.5 dS m^{-1}) is the desired value of electric conductivity from water.

Sowing was carried out directly in the pots, placing five seeds of the castor bean cv. The growth of castor beans was evaluated at 30, 60, 90 and 120 days after sowing (DAS) by measuring height of the plant, number of leaves, stem diameter and leaf area. At the end of the experiment at 120 DAS, the dry matter of root, stem and shoot were also evaluated.

In plant height measurement, graduated tape measured in cm was used, measuring the distance between the neck and the apex of the plant (younger sheet insert fully formed). The number of leaves was obtained by counting. The stem diameter measurements were taken with a digital caliper to 2 cm above the plant lap. The leaf area was obtained according to the study of Severino et al. (2005). From the monthly average values of plant height, stem diameter and leaf area were calculated according to

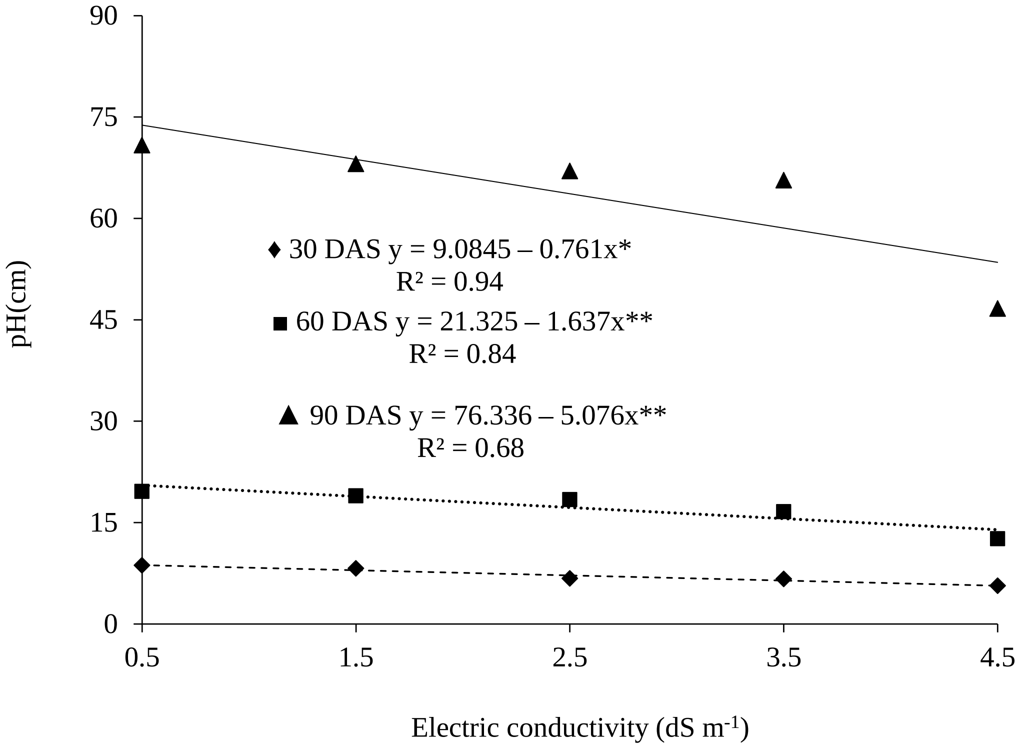

Figure 1. Castor bean plant height (PH) at 30, 60 and 90 DAS under different electrical conductivities of irrigation water ((♦) Control; (■) Biofertilizer; and (▲) Cow Urine).

their respective absolute growth rate (AGR) and relative growth rates (RGR) according to the study of Benincasa (2003).

Dry mass of root, stem and shoot determined after fresh weight remain approximately 48 h in air circulating oven forced into a 60°C until obtaining a constant weight were weighed in a balance 0.0001 g precision. The total dry matter production data were used to calculate the percentages partitioned between vegetative organs and the rate of salinity tolerance, comparing the data from saline treatments with the control (ECw = 0.5 dS m^{-1}) according to Aquino et al. (2007).

Data were evaluated by analysis of variance by F test at 0.05 and 0.01 probability, and in cases of significance, there was linear and quadratic polynomial regression analysis using the statistical software SISVAR 5.0 (Ferreira, 2011).

RESULTS AND DISCUSSION

There was interaction between the electrical conductivity of irrigation water (CIW) and organic fertilizers for the number of leaf growth variables (NL), stem diameter (SD) and leaf area (LA) in all growth stages evaluated, plant height was statistically influenced by the interaction only 120 days after sowing (DAS), with isolated effect of ECw in other periods.

Analyzing the growth variables, it is observed that the increase in ECw provided a reduction in the castor bean plant height in all evaluation periods, however, in the 90 DAS, the plants showed superiority compared to those at 30 and 60 DAS, even under heavy conditions salt (Figure 1). The increase of ECw caused a decrease in plant height at 30, 60 and 90 DAS 0.76; 1.63 and 5.07 cm per unit increased in ECw, being verified smaller plant height values for irrigated with water of 4.5 dS m^{-1}, 5.65; 12.6 and 46.66 cm.

Nobre et al. (2013) also observed that ECw negatively influenced plant height of castor bean BRS Energy to 67 DAS, which found that there were decreases in the order of 6.22% (16.72 cm) in AP per unit increased in ECw. Sá et al. (2016) found a decrease of 3.73 cm in plant height per unit increased in ECw.

With regard to plant height at 120 DAS, there is interaction between CIW and organic fertilizers, which according to the regression equations (Figure 2), there was a decreasing linear response of plant height at increasing ECw occurring decreases in the order of 9.7; 4.12 and 9.8 cm per unit increased in ECw for plants treated without application of fertilizer, biofertilizer beef and cow urine, respectively. It is also observed that the highest values were obtained in salinity (0.5 dS m^{-1}) with a height of 77.75; 88 and 78 cm. The cow urine behaved similarly to the control, however, bovine biofertilizer promoted the highest values.

Lima et al. (2015) related that salinity levels interfered negatively on the castor bean height to 100 DAS when it was under salt stress and nitrogen fertilizer, verifying a

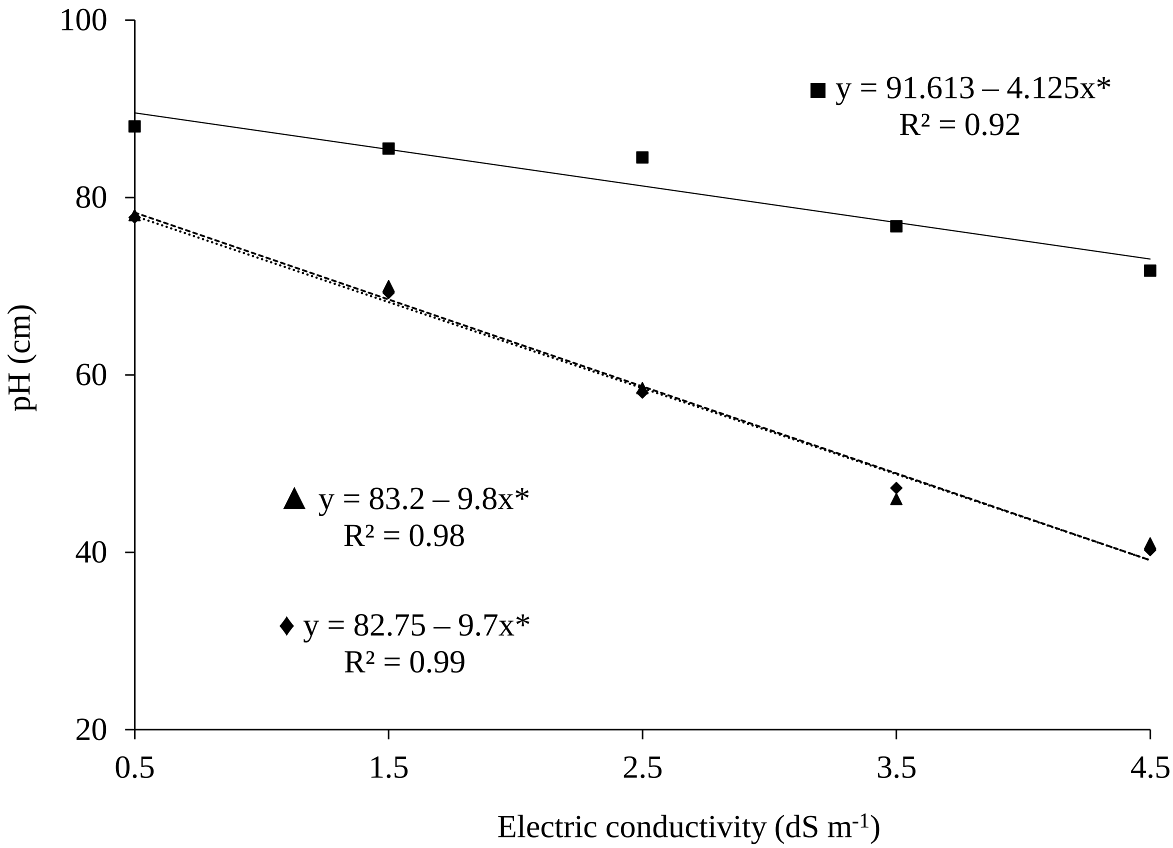

Figure 2. Castor bean plant height (PH) at 120 DAS under different electrical conductivities of irrigation water due to the application of organic fertilizers ((♦) Control; (■) Biofertilizer; and (▲) Cow Urine).

reduction of 9.64 cm for each unit increase in ECw. Nobre et al. (2013) also observed that ECw negatively influenced plant height of castor bean BRS Energy 'to 120 DAS, with decreases in the order of 17.86 cm AP per unit increased in ECw.

As for the height of the plant, the interaction between ECw x organic fertilizer factors had a significant effect on the number of sheets in the evaluated dates and, as shown in Figure 3, there was a linear reduction in plants with decreases of 2.3; 1.4 and 3.3 leaves at 30 DAS (Figure 3A) of 2.65; 2.5 and 3.0 leaves at 60 DAS (Figure 3B) per unit increase in CEA plants treated without the application of fertilizer, biofertilizer and beef cow urine, respectively.

Regarding the number of leaves at 90 and 120 DAS, it appears that as it increased ECw 0.5 to 4.5 dS m^{-1} it promoted a reduction in the number of leaves of castor bean, where the maximum values were obtained with the application of bovine biofertilizer, registering 28 sheets at 90 DAS (Figure 3C) and 41.5 leaves to 120 DAS (Figure 3D). In the same ECw obtained the lowest values of 10 sheets at 90 DAS and 24 sheets to 120 DAS in plants without organic fertilizer application.

Nobre et al. (2013) observed that the number of castor bean leaves suffered decreases to 67 DAS and 120 DAS, of 26.57 and 19.52 sheets per unit increase of ECw, when comparing the plants irrigated with water of 4.4 dS m^{-1} with 0.4 dS m^{-1}. Sá et al. (2016) evaluated castor bean cultivars under salinity in irrigation water found that BRS Gabriela and IAC 028 decreased linearly with increasing salinity level, with respective reductions of 0.44 and 0.55 leaves of the $plant^{-1}$. Lima et al. (2015) found that the salts in irrigation water interfered negatively on the number of castor bean leaves to 100 DAS, registering a decrease of 34.54% compared to plants receiving water of 0.3 dS m^{-1} when compared with those irrigated with water of 3.9 dS m^{-1}. Costa et al. (2013) found no significant effect of different treatments with saline water on the growth of castor bean cultivar BRS Energy 100 days after sowing. This reduction in the number of leaves may have occurred because of damage to the photosynthetic apparatus, thereby restricting the synthesis of carbohydrates (Silva et al., 2014).

It is observed in Figure 4 that increased ECw promoted reduction in stem diameter (SD) of castor 0.79; 0.53 and 1.37 mm at 30 DAS (Figure 4A), 1.14; 0.42 and 1.66 mm at 60 DAS (Figure 4B) 1.09; 0.52 and 1.76 mm at 90 DAS (Figure 4C) and 0.70; 0.53 and 1.61 mm to 120 DAS

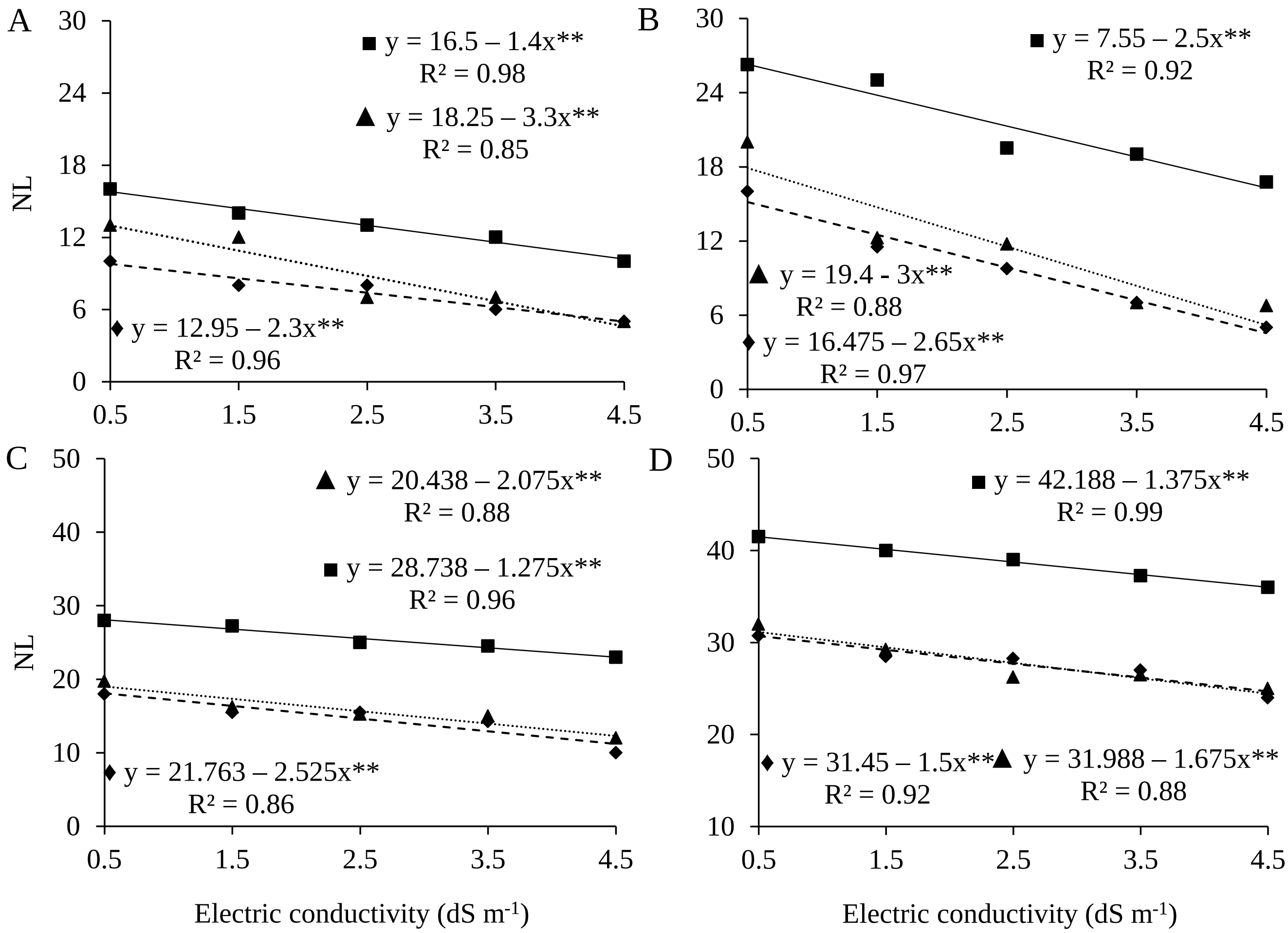

Figure 3. Number of leaves (NL) of castor bean at 30 (A), 60 (B), 90 (C) and 120 (d) to under the effect of different electrical conductivities of irrigation water according to the application of organic fertilizers ((♦) Control; (■) Biofertilizer and (▲) Cow Urine).

(Figure 4D) per unit increased in ECw for plants treated without application of fertilizer, biofertilizer beef and cow urine, respectively.

Sá et al. (2016) found that the diameter of the stem of the castor bean cultivars was reduced by 0.455 mm with the increase in water salinity, with a total reduction of 18.1% in plants grown from the highest (3.0 dS m^{-1}) and lower (0.6 dS m^{-1}). Nobre et al. (2013) also found in 67 DAS, there were declines of 4.68; 5.17; 8.53; 6.64; 8.89 mm in SD plants irrigated with ECw 4.4 dS m^{-1} in relation to those under 0.4 dS m^{-1}.

We observed that the increase in ECw also committed castor bean leaf area (Figure 5), being registered reductions of 51.95; 26.39 and 38.56 cm² at 30 DAS (Figure 5A) 20.35; 10.33 and 28.56 cm² at 60 DAS (Figure 5B), 35.91; 14.33 and 61.56 cm² at 90 DAS (Figure 5C) and 35.51; 32.33 and 71.56 cm² at 120 DAS (Figure 5D) per unit increased ECw for plants treated without application of fertilizer, biofertilizer beef and cow urine, respectively. Corroborating, Lima et al. (2014b) to establish that the ECw had a negative effect on leaf area of castor bean, occurring decreases at 30 and 60 DAS 0.176 and 0.504 m^2 in the AF of plants irrigated with water of 3.9 dS m^{-1} in relation to the submitted 0.3 dS m^{-1}, respectively. Santos et al. (2013) also observed that the leaf area of castor bean had 53 and 42% reductions at 35 and 65 DAE for each unit increase in ECw. According to Sá et al. (2016), sheet increasing occurs due to a tolerance mechanism, which attempts to increase leaf area and produce a greater number of photosynthetically active leaves, stimulating the growth of plants.

Lima et al. (2014a) evaluating the growth of the castor 80 DAS noted that CEA promoted decline 963.3 cm^2 leaf area for each unit increase of ECw corresponding to a reduction of 3467 cm^2 in plants that received water CEA 3, 9 dS m^{-1} compared to those irrigated with ECw 0.3 dS m^{-1}. Lima et al. (2015) and Lima et al. (2014b) found that leaf area of castor bean to 100 and 120 DAS was negatively affected, with 0,068 reductions; 0.079; 0.079 and 0.061 m^2 of plants under irrigation with ECw 3.9 dS m^{-1} compared to plants irrigated with water ECw 0.3 dS $m^{-1.}$

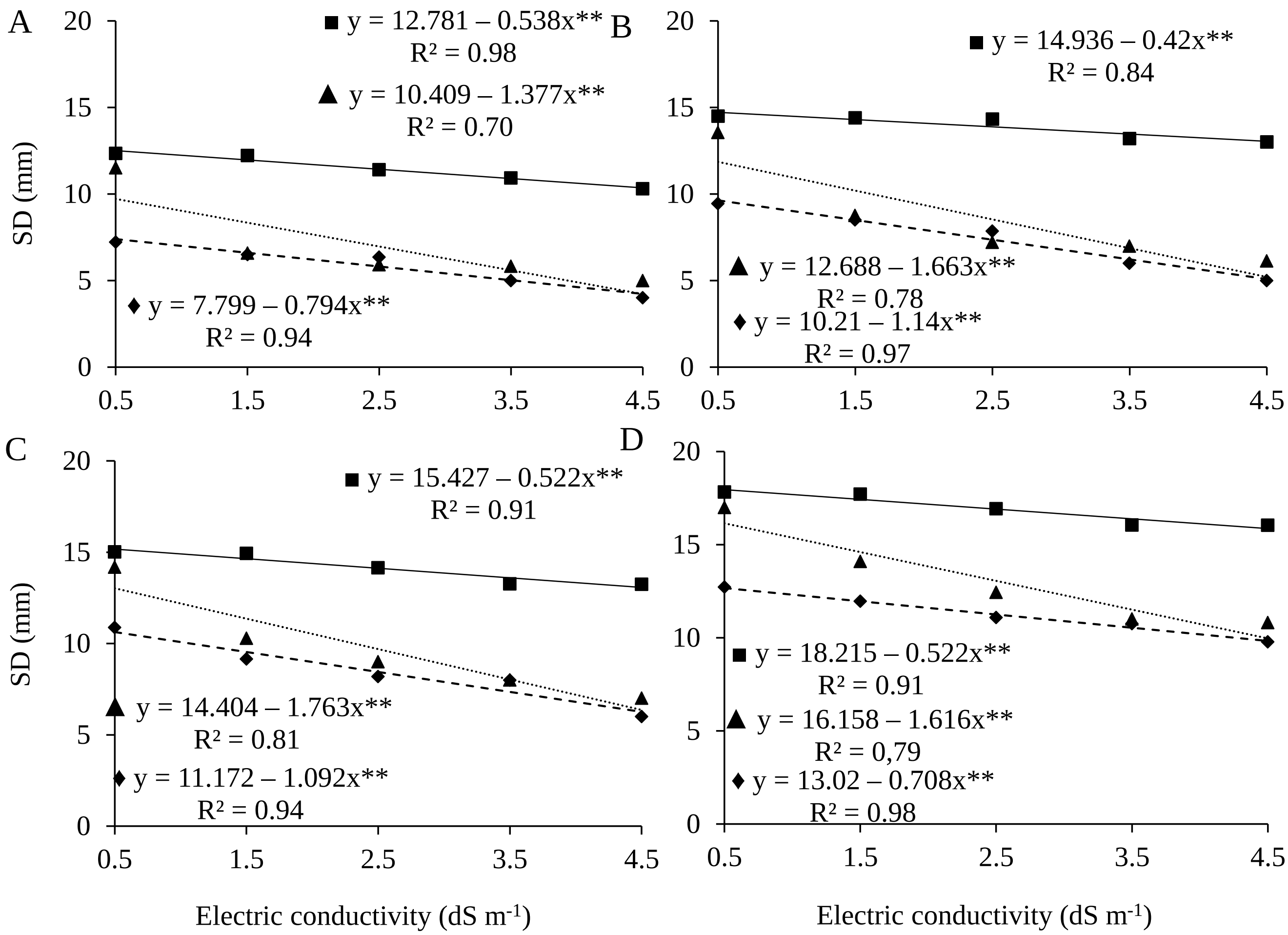

Figure 4. Stem diameter (SD) and 30 (A), 60 (B), 90 (C) and 120 (d) to different electrical conductivities in the irrigation water according to the application of organic fertilizers ((♦) Control; (■) Biofertilizer and (▲) Cow Urine).

There was a significant effect for the interaction between ECw x organic fertilizer to the dry mass of roots, stems, shoots and index of tolerance, and the factor ECw variables analyzed. There was a significant effect for the application of organic fertilizer to the dry mass of roots, stems, shoots and tolerance index. It is observed that the absolute growth rate in plant height (AGRph) had the lowest value, obtaining 0.3 cm day^{-1} to 90-120 DAS when the plants were irrigated with saline water of 4.5 dS m^{-1} while the highest rate of 2.26 cm^{-1} was observed at day 30-60 irrigated water with 0.5 dS m^{-1} (Figure 6A). The relative growth rate in height (RGRph) plants was reduced with increased ECw observing maximum values of 0.08 da^{-1} cm^{-1} cm in plants irrigated with water of 0.5 dS m^{-1} in period of 30 to 60 DAS and lower rate in plants irrigated with water of 4.5 dS m^{-1} cm^{-1} 0.01 cm^{-1} day (Figure 6B).

The ECw negatively influenced the absolute growth rate in stem diameter (AGRsd) (Figure 6C), indicating decreased AGRsd 50% per unit increase of ECw in the period of 30 to 60 DAS and 19.90% in the period of 90 to120 DAS. The highest absolute growth rate was achieved in plants irrigated with water of 0.5 dS m $^{-1}$ to 0.92 mm $^{-1}$ mm day $^{-1}$ to 30 to 60 DAS and minor irrigation of 4.5 dS m $^{-1}$ getting a rate of 0.1425 mm mm $^{-1}$ day $^{-1}$ to 90 to 120 DAS. It is observed in Figure 6D that the relative growth rate (RGRsd) was influenced by the levels of ECw RGRsd linear decrease of the order of25% per unit increase in the ECw level period and 30 to 60% at 90 to 120 of 30.

It can be seen in Figure 7B that the castor bean plants when subjected to ECw 4.5 dS m^{-1} showed relative growth rate in lower leaf area compared to plants irrigated with low salinity (0.5 dS m^{-1}) in the periods of 30 to 60 and 90 to 120 DAS, in the first study period (30-60 DAS) there is a decrease of 28.57% and in the second period (90-120 DAS) 16.66% when the plants were irrigated with low salinity (0.12 dS m^{-1}) than those irrigated with water of 4.5 dS m^{-1}.

Lima et al. (2014c) found the AGRph of castor bean in the range of 22 to 30 DAS, with increasing ECw, reaching a 2.47 cm day^{-1} in plants irrigated with water of 0.3 dS

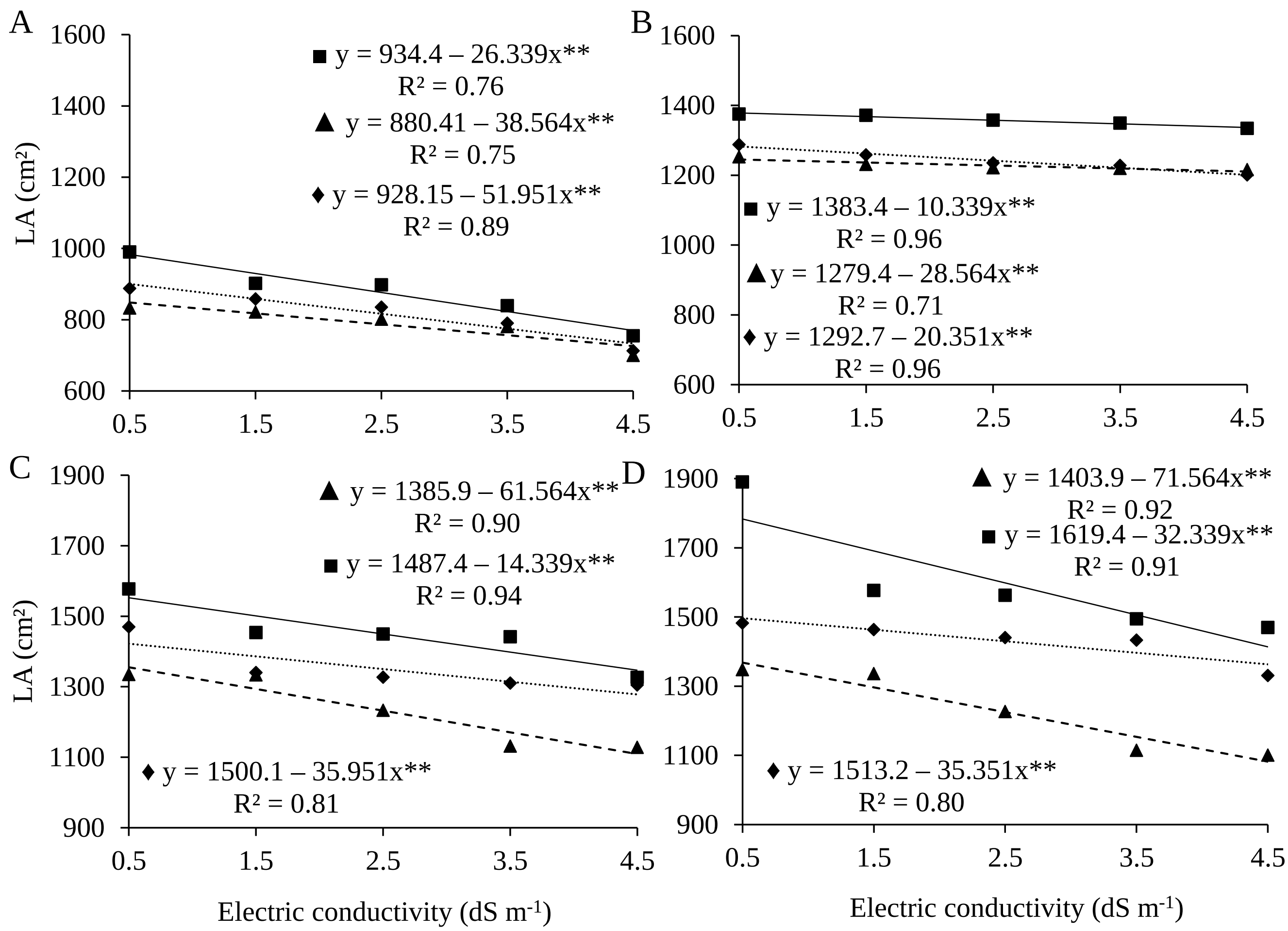

Figure 5. Leaf area (LA) of the castor 30 (A), 60 (B), 90 (C) and 120 (d) to different electrical conductivities in the irrigation water according to the application of organic fertilizers ((♦) Control; (■) Biofertilizer and (▲) Cow Urine).

m^{-1}, however, measured only 0.50 cm day^{-1} for plants under irrigation with ECw water of 3.9 dS m^{-1}. Nobre et al. (2014) observed that the salinity in irrigation water adversely affected the AGRph, down 0.14 cm day^{-1} in plants irrigated with ECw 4.4 dS m^{-1} in relation to the subject to 0.4 dS m^{-1}. The same authors found that the relative growth rate in plant height at 30-40 DAS period was lower in plants irrigated with low salindidade water (0.3 dS m^{-1}) afforded 0.024 cm cm^{-1} day^{-1}, and higher in plants irrigated with ECw water of 3.9 dS m^{-1} the maximum values in RGRpg of 0.0659 cm cm^{-1} day^{-1}.

Different results were obtained by Nobre et al. (2014) who observed that RGRph had a linear increase in the order of 1.63% per unit increase in the ECw, that is, increment of 6.52% on RGRph plants irrigated with water 4,4dS m^{-1} compared the control (0.4 dS m^{-1}). Santos et al. (2013) concluded that the AGRsd was reduced with increasing irrigation water salinity, which obtained the highest rate at 80 DAE with 4.8 dS m^{-1} getting 2.95 mm day^{-1} and 0.006 mm day^{-1} when the plants were irrigated with water of low salinity (0.12 dS m^{-1}). For RGRsd, the same authors observed a decrease during the evaluation period, regardless of the salt content of irrigation water, which obtained the highest relative growth rate in stem diameter of 0.03 mm mm^{-1} d^{-1} in irrigated plants with low salinity water (0.12 dS m^{-1}) and water of higher salinity, the growth rate of stem diameter was 0.02 mm mm^{-1} day^{-1} and the AGRlf of castor beans was reduced with the increase in ECw, where they obtained the highest AGRlf of 194 cm^{-1} to 2 days 35 and 20 DAE under irrigation with water of 0.12 dS m^{-1} and -51 4 cm^{-1} to 2 days 80 and 65 DAE under irrigation with high salinity (4.8 dS m^{-1}).

The dry mass of roots, stems, shoots and tolerance index were negatively affected by ECw, with decreases in root dry mass of 1.20; 0.72 and 1.37g (Figure 7A), the stem dry weight decrease of 2.51; 1.33 and 424 g (Figure 7B), shoots of 6.07; 8.38 and 10.54 g (Figure 7C) and the index of tolerance 14.22; 9.22 and 13.82% (Figure 7D) per unit increased ECw, plants were treated without application of organic fertilizer, biofertilizer beef and cow urine, respectively.

Corroborating, Lima et al. (2014b) observed that the

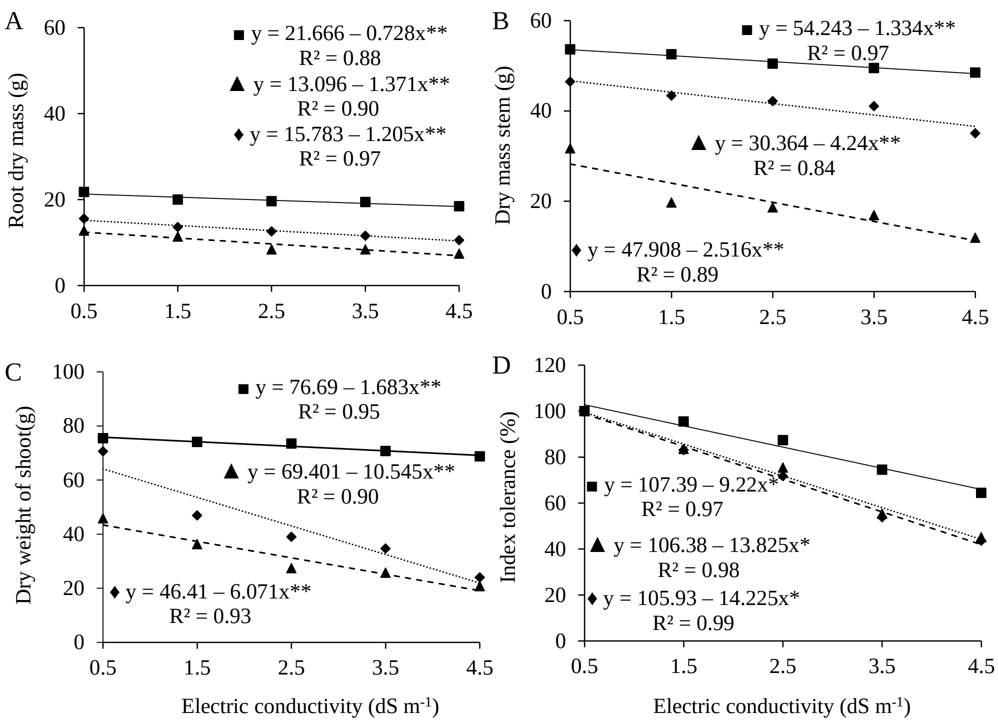

Figure 6. Absolute growth rate (AGR) and relative (RGR) of plant height (A and B), stem diameter (B and C) and leaf area (D and F) of castor bean under different electrical conductivities of water irrigation in the period from 30 to 60 and 90 to 120 days after sowing (DAS).

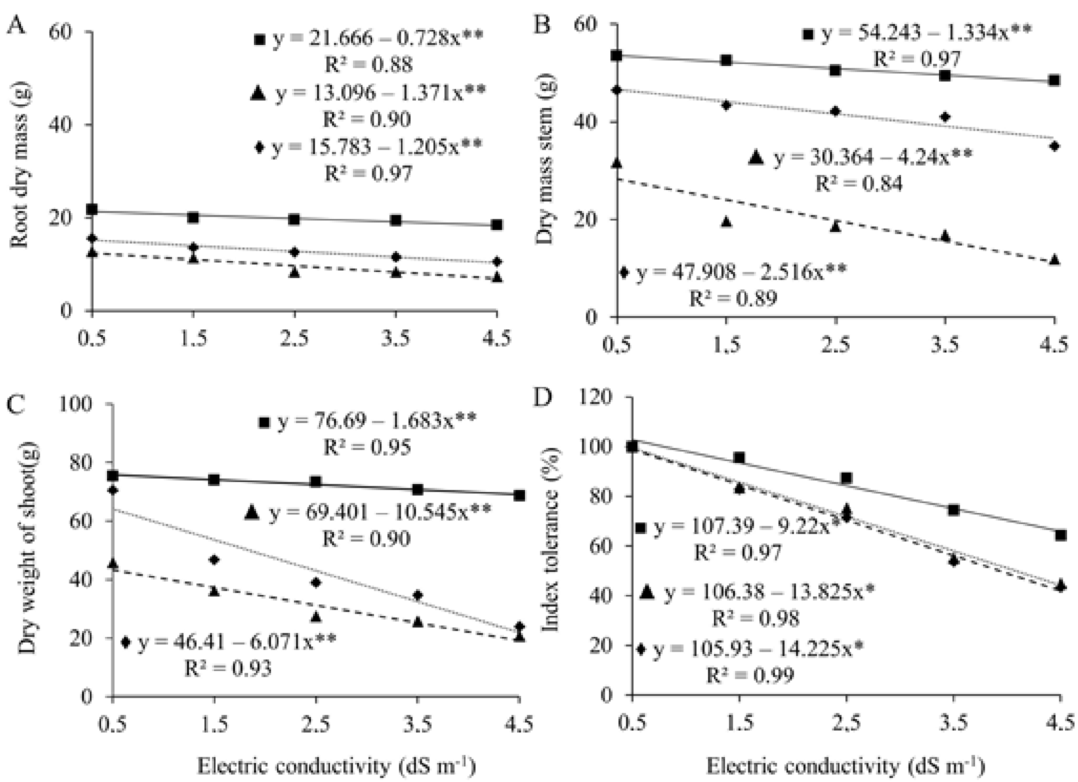

Figure 7. Dry root mass (A), dry matter of the stem (B), dry weight of shoot (C) and tolerance index (D) of castor bean under different electrical conductivities of irrigation water due to the application of fertilizers organic ((♦) Control; (■) Biofertilizer and (▲) Cow Urine).

dry mass of root and stem were affected by ECw, getting the maximum accumulation (48.25 g) of dry root mass in plants receiving water of 0.3 dS m^{-1} and the mass stem dried found that there was a decrease 13.33; 18.84; 16.36 and 13.36% per unit increase in ECw in plants irrigated with water of 3.9 dS m^{-1} compared to those that were irrigated with 0.3 dS m^{-1} water.

Nobre et al. (2013) also observed that ECw negative affect the root dry mass, with reductions of 8.32 g, 11.82 g, 16.45 g, 12.92 g and 25.86 g dry mass of root, and reductions of 45.44 g plant $^{-1}$ in the dry mass of shoots per unit increased ECw in plants irrigated with ECw 4.4 dS m $^{-1}$ relative under the ECw 0.4 dS m $^{-1}$. Sá et al. (2016) found that the increase in salinity levels caused linear reductions in salt tolerance index of all the varieties of castor bean, with 63.82% reductions to cultivate LA Guarani, 79.80, 75.51 and 77.91% for BRS Energy cultivars, BRS Gabriela and IAC 028, respectively.

Conclusions

The increase in electrical conductivity of irrigation water reduced the growth, development and dry matter production of castor bean. The application of bovine growth provides greater biofertilizer castor when under salt stress conditions. The cow urine does not attenuate the effects of salt stress on the culture of castor bean.

Conflict of Interests

The authors have not declared any conflict of interests.

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