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Growth aspects and production of cotton under salt stress as a function of organic fertilizer

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The cotton plant is a species cultivated in many parts of the world, with enormous economic importance. The objective of this study was to evaluate the effect of salinity levels in earthworm humus quantities function on the growth and production of cotton. The experiment was conducted in a greenhouse at the Campus IV in the State University of Paraiba, municipality of Catolé do Rocha-PB, Brazil. A completely randomized design with four replications, in a factorial 4 x 4 was used. The first factor consisted of salinity levels in irrigation water (0.8, 3, 4.5 and 6 dS m^{-1}) and the second factor of earthworm humus amounted to: 0, 1, 2 and 3 kg/plant. At the end of the experiment, the growth characteristics: plant height, stem diameter, leaf number, unit leaf area and leaf area of the plant were evaluated. The production: number of flower buds, number of bolls per plant, seed weight per boll, number of seeds per boll, 100 seed weight, total production, fiber production and seed production were also estimated. The interaction between salinity levels and quantities of earthworm humus did not affect the growth and production of cotton. The increase in salinity levels adversely affected the cotton crop. Largest earthworm humus quantities gave an increase in cotton production.

Key words: *Gossipium hirsutum* r. *latifolium* H., Electrical conductivity of water, humus earthworm.

INTRODUCTION

The cotton crop (*Gossipium hirsutum* L. r. *Latifolium* H.) stands out as one of the most important Brazilian agribusiness activities, and the herbaceous cotton is cultivated in more than fifteen countries (Oliveira et al., 2012). Although, a tolerant crop, the cotton can suffer substantial reductions in their growth, yield and quality when exposed to salt stress condition (Oliveira et al., 2008).

For most crops grown in semi-arid northeast, irrigation is important due to irregularities in rainfall and irrigation management which is crucial to achieving high production and quality of the products; however, the amount of water, the quality of the water used, particularly in relation to the concentration of soluble salts are important in irrigation (Oliveira et al., 2011).

Salinity is one of the abiotic stresses which affects the growth and productivity of plants (Nascimento et al., 2011; Blanco, 2008), affecting the osmotic potential of the soil solution, causing water stress and toxic effects on plants, which result in metabolism and nutritional disorders (Garcia et al., 2007; Sousa et al., 2010).

The work carried out with cotton in saline soil by Oliveira et al. (2012a) observed a reduction in which all characteristics with increasing irrigation water salinity had great reductions in leaf area (average 65.8%) and dry weight of vegetative parts (64%). Santos et al. (2016) also found that salinity irrigation water affects the growth and production of cotton.

In order to mitigate the effects of salt stress, organic inputs were applied. However, in the literature, there is a lack of studies related to earthworm humus effects and its use in crop plants under saline environment. In addition, due to the rising cost of mineral fertilizers and the growing environmental pollution, the use of organic waste in agriculture is an attractive option from an economic point of view, because of the carbon cycling and nutrients (Silva et al., 2010).

Organic fertilizers such as manure and earthworm humus are the most used among the small and medium producers of vegetables; however, the supply to the soil should consider the type, texture, structure and content of organic matter (Santos et al., 2006).

In this sense, the objective is to evaluate the effect of salinity levels in earthworm humus quantities function on growth and production of cotton.

MATERIALS AND METHODS

The experiment was conducted in a greenhouse at the Center for Humanities and Agrarian State University of Paraíba (UEPB) in municipality of Catolé do Rocha-PB, Brazil (6° 20'38 "S, 37° 44'48" W) 275 m altitude. The climate of the city, according to Koppen classification, is the BSW type, that is, hot and dry steppe type, with average monthly temperatures exceeding 18°C throughout the year. A completely randomized design was adopted, with a factorial arrangement of 4 x 4, with four repetitions, corresponding to four levels of salinity of irrigation water (0.8, 3, 4.5 and 6 dS m^{-1}) according to the quantity of earthworm humus: (0, 1, 2 and 3 kg/plant).

Table 1. Physical and chemical attributes of earthworm humus used in the experiment. Catolé do Rocha-PB, UEPB 2014.

Chemical properties	Values
pH H_2O (1: 2.5)	7.38
Electrical conductivity (dS m^{-1})	2.11
Calcium ($cmol_c$ dm^{-3})	3.54
Magnesium ($cmol_c$ dm^{-3})	1.93
Sodium ($cmol_c$ dm^{-3})	0.18
Potassium ($cmol_c$ dm^{-3})	0.14
S ($cmol_c$ dm^{-3})	5.79
Hydrogen ($cmol_c$ dm^{-3})	0.00
Aluminum ($cmol_c$ dm^{-3})	0.00
Phosphorus ($cmol_c$ dm^{-3})	5.51

The water used for irrigation had electrical conductivity of 0.8 dS m^{-1}. Water analysis was performed and showed the following chemical characteristics: pH = 7.53; Ca = 2.30 $cmol_c$ dm^{3}; Mg = 1.56 $cmol_c$ dm^{-3}; Na = 4.00 $cmol_c$ dm^{-3}; K = 0.02 $cmol_c$ dm^{-3}; Chloride = 3.90 $cmol_c$ dm^{-3}; Carbonate = 0.57 $cmol_c$ dm^{-3}; Bicarbonate = 3.85 $cmol_c$ dm^{-3}; RAS (Soil Adsorption Ratio) = 2.88 $(mmol_c\ l^{-1})^{1/2}$.

The plants were cultivated in polyethylene pots with a capacity of 8.5 dm. It was used to fill the soil polyethylene pots and earthworm humus in the ratio of 2:1, and the soil was classified as Fluvisol of clayey sandy loam texture. The soil was analyzed and it showed the following characteristics: Ca = 4.63 $cmol_c$ dm^{-3}; Mg = 2.39 $cmol_c$ dm^{-3}; Na = 0.30 $cmol_c$ dm^{-3}; K = 0.76 $cmol_c$ dm^{-3}; Sum of bases - SB = 8.08 $cmol_c$ dm^{-3}; H = 0.00 $cmol_c$ dm^{-3}; Al = 0.00 $cmol_c$ dm^{-3}; cation exchange capacity (CTC) = 8.08 and = 1.88% organic matter. The earthworm humus used in filling had the characteristics shown in Table 1.

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

$$Q\ (mg/L^{-1}) \times 640 = ECw \quad (1)$$

In that ECw (dS m^{-1}) is the desired value of the electrical conductivity of water. Water chosen as control - S_1 (0.8 dS m^{-1}) stems from a well located in the Amazons UEPB. The experimental units were composed of two plants, grown in plastic pots with a capacity of 8.5 dm^3. The seeds were sown in plastic pots with a capacity of 8.5 kg. The soil was sieved and mixed with earthworm compost in the ratio 2:1. At 14 days after sowing, there was thinning of plants keeping only the most vigorous.

At the end of the experiment, the growth characteristics and production plant height, stem diameter, number of leaves, unit leaf area, leaf area of the plant, number of flower buds, number of bolls per plant, seed weight per boll, number of seeds per boll, 100 seed

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weight, total production, fiber production and seed production were evaluated. The plant height was determined by a graduated tape measure in centimeters positioned at the stem base near the soil to the youngest leaf of the seedling. The stem diameter was measured using a digital caliper, the measurements was taken at the stem base approximately 2 cm above the ground. The number of sheets was conducted by counting the leaves longer than 2 cm.

The leaf area was obtained through linear measurements on leaves, starting from the equation proposed by Wendt (1967) log y = 0.006 + 1.863 log x, where y is leaf area (cm²) exo length of the midrib of the leaf (cm). The leaf area of the plant was measured by the sum of the leaf area of the rolling cottons.

At 120 days after sowing, the crop was harvested and made manually once. After harvesting, the bolls were packed in paper bags with identification and later taken to the Plant Physiology Laboratory, Department of Agriculture. Weighing the bolls of each plant was done manually through delinting for separation of the fiber cores.

Statistical analyses were performed with the aid of Computational Program SISVAR 5.1. The data were analyzed and interpreted from analysis of variance (F test) and by comparison of means by Tukey test, according to Ferreira (2011).

RESULTS AND DISCUSSION

Statistical analysis revealed statistical significance of salinity levels on leaf number and unit leaf area of BRS Rubi cotton plant, not affecting significantly the plant height, stem diameter and leaf area of the plant. In turn, the quantity of humus do not significantly affect those variables, plant height, stem diameter and plant leaf area, with mean values without significant differences. However, there are significant effects for the variables, number of leaves and leaf unit area. For the unit leaf area variable, the interaction (CEa x H) was statistically significant, indicating that the salinity levels did not behave similarly with the quantities of humus and vice versa.

The number of sheets in relation to levels of salinity in the irrigation water which was adjusted to a quadratic behavior model with a correlation coefficient of 0.99 is shown in Figure 1A. For the increased levels of salt in the irrigation water, there was a reduction in the number of leaves to the level of optimal salinity of 4.5 dS m^{-1} which provided the maximum number of sheets 26. Thereafter, there was a decrease until it reached the level of 6.0 dS m^{-1}, which has possibly occurred because of the main consequence of increasing the total concentration of soluble salts in the irrigation water.

The reduction in the growth of plants when they are subjected to salinity is caused due to water deficit caused by the excess soluble salts in the root zone, causing a decline in the turgidity therefore resulting in decreased cell growth and reduction in plant growth (Bai et al., 2008; Khalid and Silva, 2010). This occurs due to the closure of the stomata and consequently lowers CO_2 assimilation limiting the photosynthetic processes (Debez et al., 2008; Taarit et al., 2010). Moreover, it may still be caused by energy expenditure which is necessary in the synthesis of organic solutes and the compartmentalization process and regulation of ion transport (Mendonça et al., 2007).

Similar results were obtained by Oliveira et al. (2012a) who observed that the number of sheets has been reduced by increasing the salinity, with a reduction of approximately 4.23 per plant unit in response to increased irrigation water conductivity.

Regarding the effects of earthworm humus amounts applied on the colored cotton plants BRS Rubi (Figure 1B), it is observed that the optimal amount of humus of earthworm was 1.9 kg/plant for the maximum number of 26 sheets. Afterward, there was a decrease in the number of sheets to the extent that it increased the amount of earthworm humus, possibly this decrease was due to nutrient leaching which is responsible for the absence of residual effect of nitrogen in the soil. However, the data adjusted a quadratic polynomial model, with a coefficient determination of 0.99.

Regression equations were fitted to the experimental data of the unit leaf area of cotton BRS Rubi, resulting from the split of the salinity levels interaction in irrigation water set against the amount of earthworm humus that had a quadratic response to the amounts of humus (2 and 3 kg) with determination coefficients of 0.83 and 0.92, respectively (Figure 2).

The reduction in leaf area, issuing new leaves and death and leaf drop occurs due to the effects of salt stress, since these are strategies as a means to reduce water loss (Mahmoud and Mohamed, 2008). In addition, the issuance of new leaves and/or leaf senescence also occurs because these bodies present sensitivity to salinity and reduce the presence of high concentrations of salts. Deleterious effect of salinity on the leaf area was also observed by Medeiros et al. (2011), Vieira et al. (2016) and Lycoskoufis et al. (2012) in tomato. Santos et al. (2016) also observed that the increase in salinity levels affected leaf area, where values decreased by respectively, 7.92 and 9.55% per unit increase in the electrical conductivity of irrigation water.

Statistical analysis revealed significant salinity levels on a number of flower buds, seed number per boll, 100 seed weight, total production, seed production and fiber production. To this end, the quantities of earthworm humus effect were observed only for the number of flower buds. The interaction between salinity levels and quantities of earthworm humus was not statistically significant, indicating that the salinity levels behaved in a similar way with the quantities of humus and vice versa.

For the number of flower buds of colored cotton plants BRS Rubi (Figure 3A), it is observed that as the salinity levels in the irrigation water increased, there was an increase in the number of flower buds. For each unit

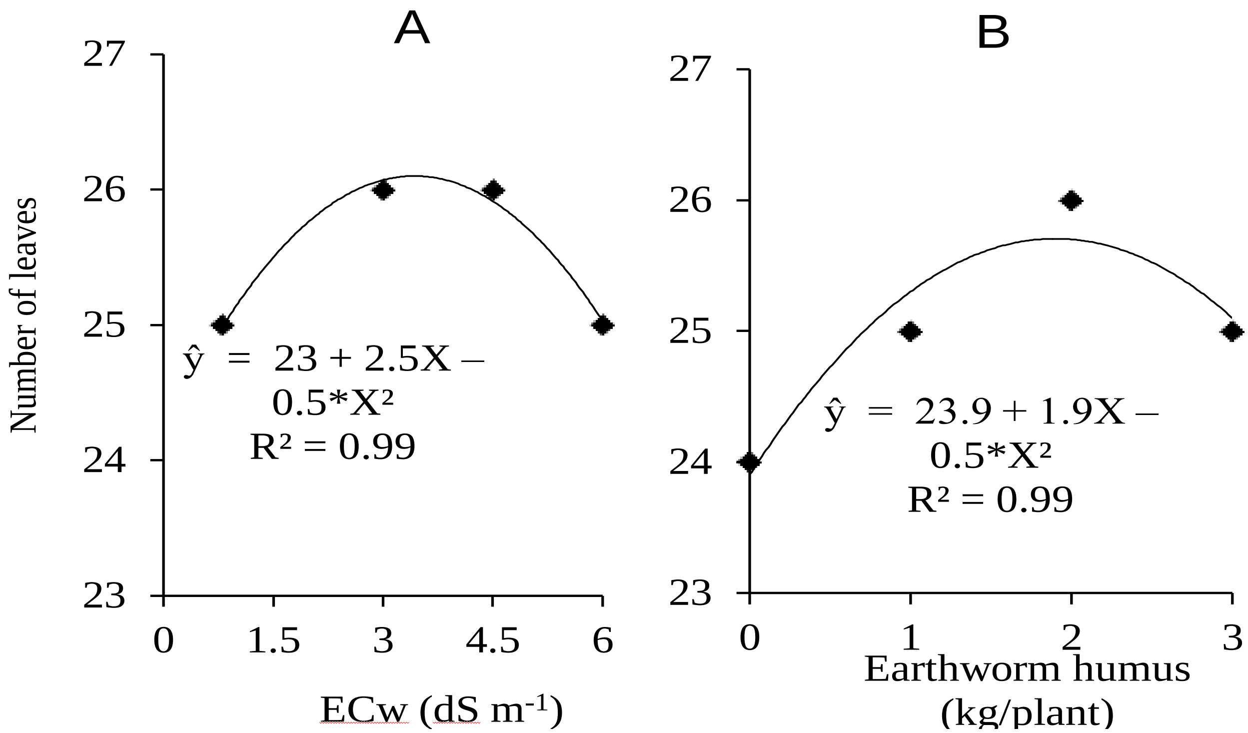

Figure 1. Effect of salinity levels (A) and quantities of earthworm humus (B) on the number of leaves on cotton BRS Ruby.

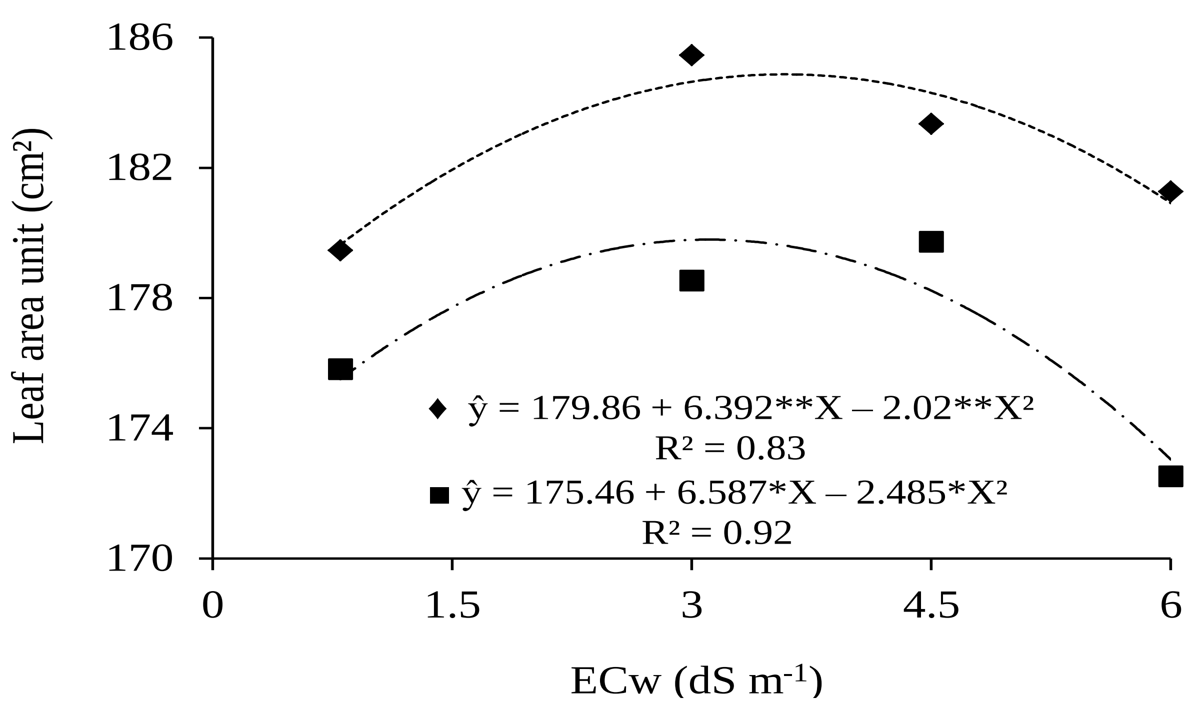

Figure 2. Leaf area units of cotton plants BRS Rubi irrigated with saline water, soil ♦ 2 kg/plant and ■ 3 kg/plant of earthworm humus.

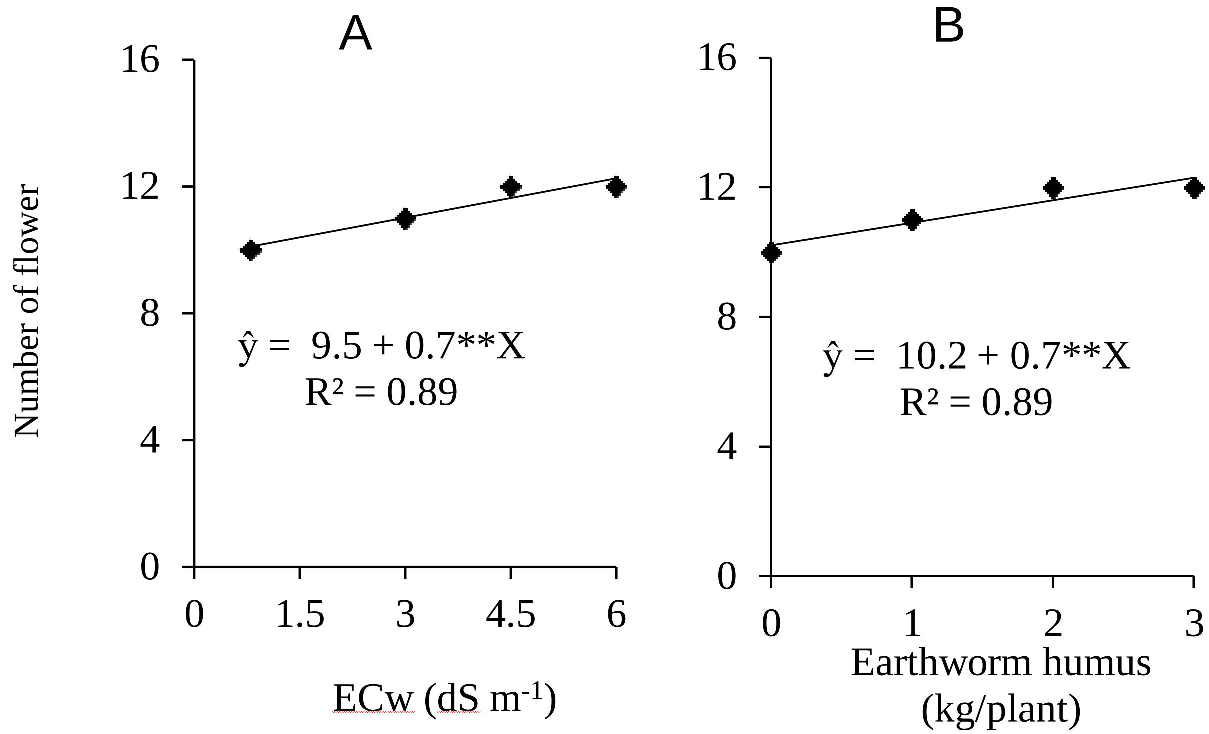

Figure 3. Effect of salinity levels (A) and quantities of earthworm humus (B) on the number of flower buds cotton BRS Rubi.

increase in salinity levels, there was an increase of 0.7 in the number of flower buds of BRS Rubi cotton plants.

Regarding the effect of the quantity of earthworm humus on the number of flower buds (Figure 3B), it is observed that there was a linear increase in the number of flower buds on the quantity of humus of earthworm. For each unit increase in the amount of humus, it showed an increase of 0.7 kg/plant in the number of flower buds on cotton plants.

For the number of seeds per colored cotton boll BRS Rubi (Figure 4A), as there is increase in the salinity levels in the irrigation water, there was a decrease in the number of seeds grown cotton plants in greenhouse. For each unit increase in salinity levels, there was a decrease of -0.6 (units) in the number of seeds per boll.

By studying the number of seeds per boll (Figure 4B), it was observed that there was a linear increase in the number of seeds per organic cotton bolls on the quantity of humus California red earthworm. For each unit increase of the applied amount of humus, there was an increase of 0.4 (units) in the number of seeds per bolls on cotton plants.

Choi et al. (2005) studied the growth and production of cotton cultivars under different levels of salinity, and found that the yield in seed of the two cotton cultivars were significantly influenced by the interaction of salinity of irrigation water and genotypes.

The weight of 100 seeds and the total production were adversely affected by salinity levels, and the regression equation adjusted linearly, with decreases in weight of 100 seeds of 60.45% (Figure 5A) and the total production of 58.38% (Figure 5B) per unit increase of salinity levels. It also observed that the maximum seed weight (19.28 g) and the maximum total output (26.94 g) were obtained when the plants were irrigated with water of low salinity (0.8 dS m^{-1}).

Oliveira et al. (2012) also observed that the weight of 100 seeds was affected negatively and linearly by salinity of irrigation water, with a reduction of 0.54 g 100 seeds as increased salinity levels, and overall reduction in higher salinity (6.5 dS m^{-1}), 28.46% when compared with the results obtained with salinity of 0.5 dS m^{-1}. The same authors found out using the weight of 100 seeds, total production was affected by an increase in electrical conductivity of irrigation water, harmful effect was observed from 3.5 dS m^{-1}, with a reduction of 52.23%.

Moreover, salt stress causes negative effects on the plant, such as changes in growth and development of the roots, thus interfering with ion water absorption, hindering the development of crops, since a well-developed root

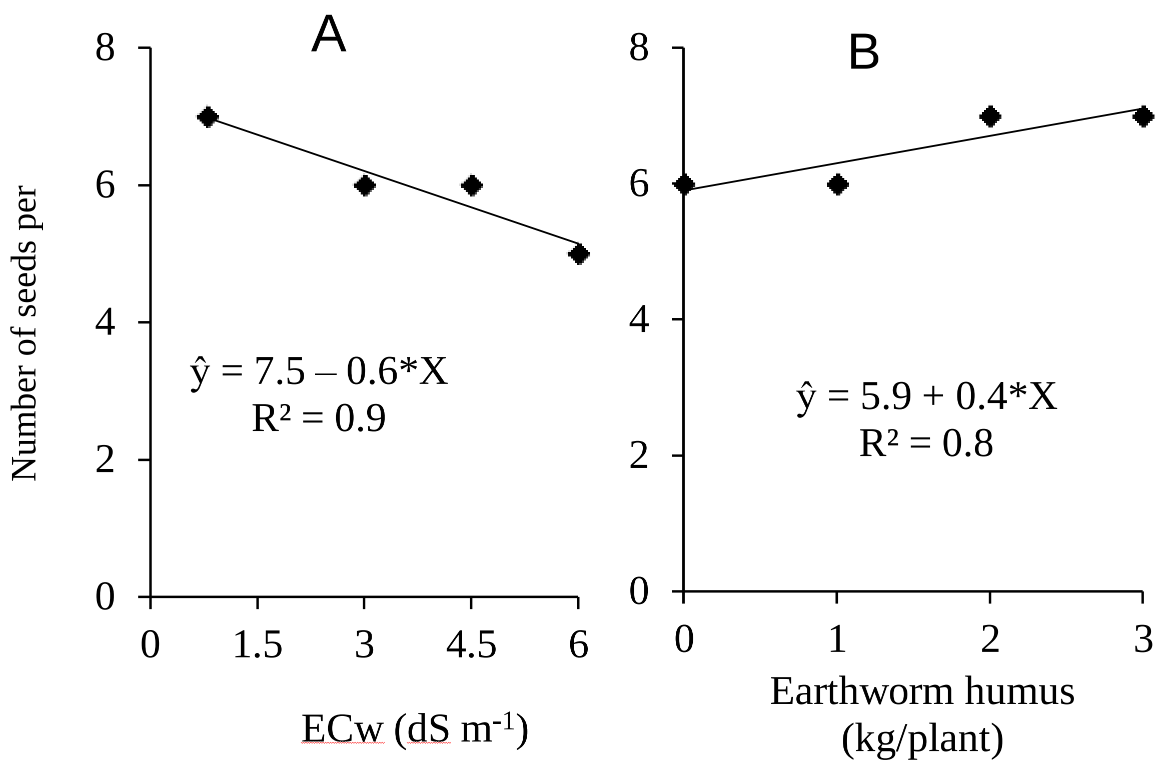

Figure 4. Effect of salinity levels (A) and quantities of earthworm humus (B) on the number of seeds per cotton boll BRS Ruby.

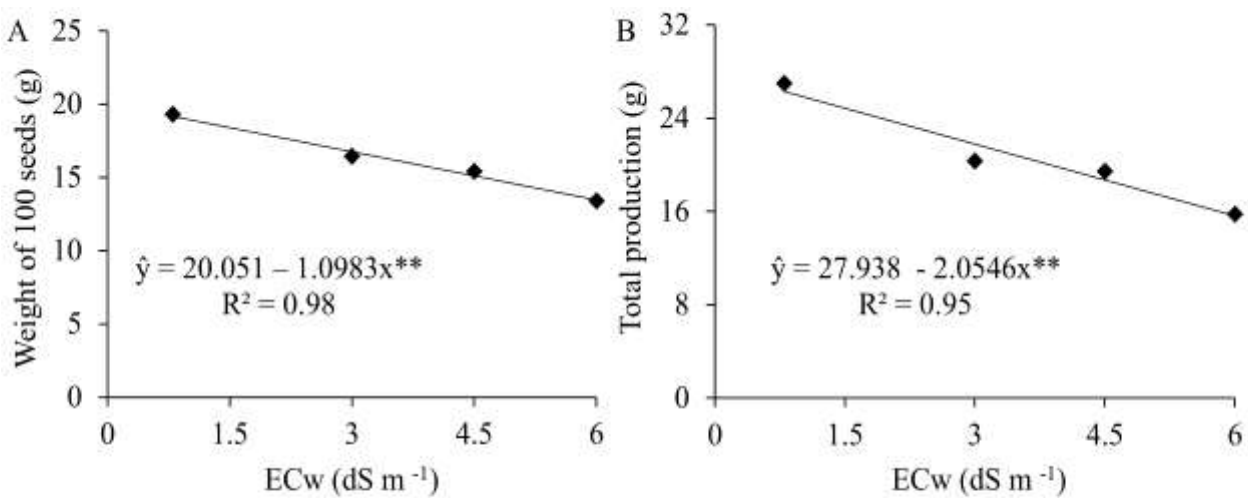

Figure 5. Effect of salinity levels on the weight of 100 seeds (A) and total output (B) of cotton, BRS Rubi.

system provides increased absorption area, promotes better conditions to meet the requirements of the plant for water and nutrients, especially in the early days, in seedling stage, when adverse conditions may compromise their survival (Soares et al., 2011). The use of saline waters for irrigation of plants cause various changes in physiological and biochemical functions, many of which result in disturbances in water relations and on changes in the absorption and utilization of essential nutrients to plants, and as a result retard growth

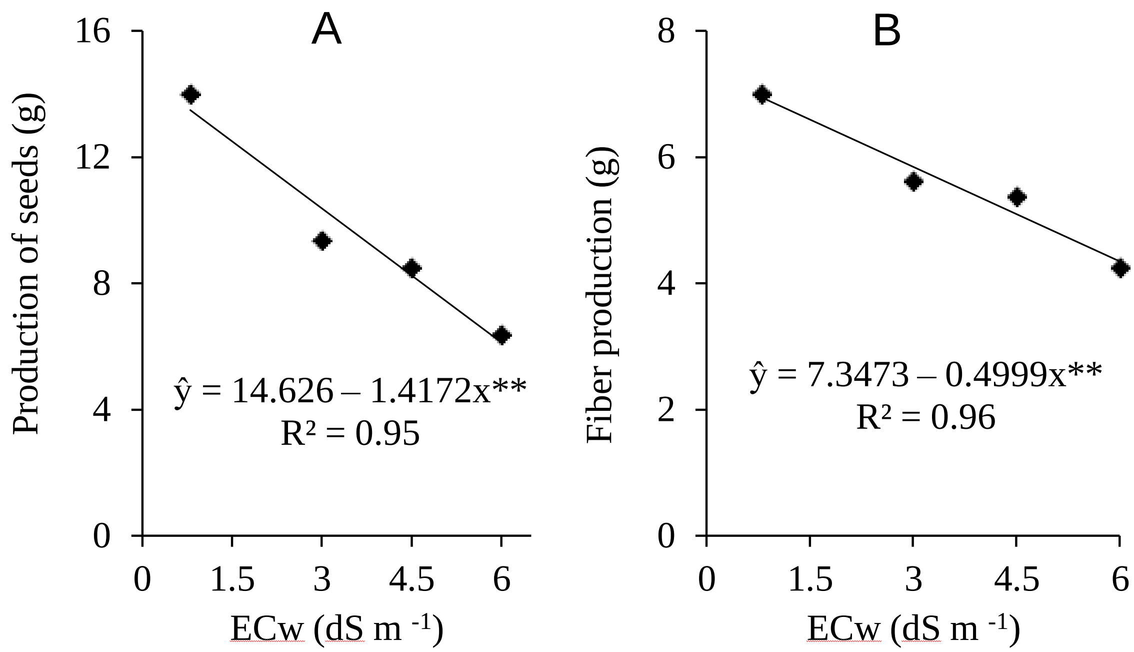

Figure 6. Effect of salinity levels on the production of seeds (A) and fiber production (B) cotton, BRS Ruby.

and reduce production (Amorim et al., 2010). It is observed in Figure 6A that the seed production was reduced as the increase in salinity levels. The lower seed yield (6.37 g) was obtained when the plants were irrigated with saline water, 6 dS m^{-1} while higher production was observed at lower salinity (0.8 dS m^{-1}),14 g representing a 45.5% loss in grain. For fiber production (Figure 6B), there was a linear reduction as the salinity level increased. Maximum values were observed as 7 g when the plants were irrigated with water of low salinity (0.8 dS m^{-1}) and minimum values of 4.25 g irrigation with water of 6 dS m^{-1}, representing a 60.71% reduction in fiber production.

Oliveira et al. (2012b) also reported that the production of seed and fiber production were reduced according to the increase in salinity levels, with a significant reduction from the ECw 3.5 dS m^{-1}, obtaining values of 8.28 and 12.94 g $plant^{-1}$, respectively. The reduction in the yield of cotton plant can be attributed to the increased conductivity of irrigation water, and in consequence less water absorption by the plants, thus leading to drought stress. Therefore, due to the low capacity of water absorption, the cotton may have a reduction in the production, according to results obtained by Sobrinho et al. (2007).

Conclusion

The interaction between salinity levels and the quantities of earthworm humus do not affect the growth and production of cotton, while the increase in salinity levels negatively affected cotton crop. Largest earthworm humus quantities provided an increase in cotton production.

Conflict of Interests

The authors have not declared any conflict of interests.

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