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# Growth and yield of colored-fiber cotton grown under salt stress and nitrogen fertilization

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**Key words:**
*Gossypium hirsutum* L.
saline water
nitrogen
BRS Rubi

**ABSTRACT**
This research was conducted in order to evaluate the growth and production of colored-fiber cotton, cv. 'BRS Rubi', irrigated with water of different salinities and nitrogen (N) doses. The experiment was carried out in drainage lysimeters filled with soil material from an eutrophic Regolithic Neosol with sandy-loam texture under greenhouse conditions in Campina Grande, PB. The experiment was conducted in a randomized block design and the treatments consisted of five levels of irrigation water salinity with the following electrical conductivities - ECw (5.1, 6.1, 7.1, 8.1 and 9.1 dS $m^{-1}$), combined with five N doses - ND (65; 100; 135; 170; 205 mg of N $kg^{-1}$ of soil), distributed in a 5 x 5 factorial scheme with three replicates. The growth of the cotton cv. 'BRS Rubi' was negatively affected by irrigation with saline water, and the leaf area was the most sensitive variable; the highest production of seed cotton and number of bolls per plant were obtained using water of 5.1 dS $m^{-1}$ and N dose of 170 mg $kg^{-1}$.

**Palavras-chave:**
*Gossypium hirsutum* L.
águas salinas
nitrogênio
BRS Rubi

## Crescimento e produção do algodoeiro de fibra colorida cultivado sob estresse salino e adubação nitrogenada

**RESUMO**
Nesta pesquisa objetivou-se avaliar o crescimento e a produção do algodoeiro de fibra colorida cv. BRS Rubi em função da irrigação com águas de diferentes salinidades e doses de nitrogênio. O experimento foi conduzido em lisímetros de drenagem preenchido com material de solo proveniente de Neossolo Regolítico Eutrófico de textura franco-arenosa em condições de casa de vegetação, em Campina Grande, PB. O delineamento estatístico utilizado foi o de blocos ao acaso cujos tratamentos foram constituídos por cinco níveis de salinidade da água de irrigação com as seguintes condutividades elétricas – CEa (5,1; 6,1; 7,1; 8,1 e 9,1 dS $m^{-1}$) combinados com cinco doses de nitrogênio - DN (65; 100; 135; 170; 205 mg de N $kg^{-1}$ de solo), distribuídos em esquema fatorial 5 x 5, com três repetições. O crescimento do algodoeiro cv. BRS Rubi foi afetado de forma negativa pela irrigação com águas salinizadas sendo a área foliar a variável mais sensível; a maior produção de algodão em caroço e o maior número de capulhos por planta foram obtidos quando as plantas foram irrigadas com água de 5,1 dS $m^{-1}$ e dose de 170 mg de N $kg^{-1}$ de solo.

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## Introduction

Cotton (*Gossypium hirsutum* L.) is a tropical climate species cultivated in most regions of hot climate and one of the main crops exploited in Brazil, due to its great economic and social potential (Cardoso et al., 2010). It stands out for being the main natural fiber used in textile industries; in addition, it can be used in the form of cake or in the production of edible oil with high added value, working as protein supplement for animal and human consumption (Alves et al., 2008).

In the semi-arid region of Northeast Brazil, the waters available for irrigation most of the times have moderate concentrations of salts (Silva Filho et al., 2000). High concentrations of soluble salts present in these waters cause one of the abiotic stresses that most limit plant growth and development (Freire et al., 2014), because of the decrease in the osmotic potential of the soil solution, the toxicity by specific ions and nutritional imbalance (Neves et al., 2009), triggering various events that severely affect the physiological processes of the plants, inhibiting photosynthesis and the synthesis of proteins, which lead to restrictions in the growth and production of the crops (Dolatabadian et al., 2011; Hashem et al., 2015).

Thus, given the problem of water scarcity that affects the semi-arid region, it becomes necessary to generate technologies that allow to mitigate the degenerative effects caused by salt stress on plants, since it is essential to use saline waters in agriculture (Sousa et al., 2012). Among the strategies that can be employed, nitrogen (N) fertilization stands out because, according to Dudley et al. (2008), this macronutrient can increase the osmotic adjustment capacity of the plants and increase the tolerance of the crops to salt stress, because of its functions in plant metabolism, participating in the formation of organic compounds and constituents of the chlorophyll molecule, nucleic acids, amino acids and proteins, among others.

In this context, this study aimed to evaluate the growth and production of the colored-fiber cotton, cv. 'BRS Rubi', as a function of irrigation with waters of different saline levels and N doses.

## Material and Methods

The experiment was carried out using drainage lysimeters under greenhouse conditions, between March and July 2016, at the Center of Technology and Natural Resources of the Federal University of Campina Grande (CTRN/UFCG), located in the municipality of Campina Grande-PB, Brazil (7° 15' 18" S; 35° 52' 28" W; 550 m).

The adopted experimental design was randomized blocks, in 5 x 5 factorial scheme, with three replicates, and the treatments consisted of five levels of irrigation water salinity with the following electrical conductivities - ECw (5.1, 6.1, 7.1, 8.1 and 9.1 dS $m^{-1}$) and five nitrogen doses - ND (65; 100; 135; 170; 205 mg of N $kg^{-1}$ of soil), considering the dose of 100 mg of N $kg^{-1}$ of soil as recommendation for pot experiments (Novais et al., 1991).

Plants were conducted in drainage lysimeters with capacity for 20 L (height of 35 cm, bottom diameter of 20 cm and upper opening of 31 cm). The methodology of installation of the experiment (filling the lysimeters, preparing the water used in irrigation and irrigation management) were similar to that described by Lima et al. (2014) and Lima et al. (2016). The soil material came from an eutrophic Regolithic Neosol with sandy loam texture, whose chemical and physico-hydraulic characteristics were determined according to the methodologies described by Claessen (1997): $Ca^{2+}$ = 3.49 $cmol_c$ $kg^{-1}$; $Mg^{2+}$ = 2.99 $cmol_c$ $kg^{-1}$; $Na^+$ = 0.17$cmol_c$ $kg^{-1}$; $K^+$ = 0.21$cmol_c$ $kg^{-1}$; $H^+$ = 5.81$cmol_c$ $kg^{-1}$; $Al^{3+}$ = 0 $cmol_c$ $kg^{-1}$; CEC = 12.67 $cmol_c$ $kg^{-1}$; organic matter (OM) = 18.30 g $kg^{-1}$; P = 18.2 mg $kg^{-1}$; pH in water (1:2.5) = 5.63; electrical conductivity of the saturation extract (dS $m^{-1}$) = 0.61; SAR (mmol $L^{-1}$)$^{½}$ = 1.46; sand, silt and clay = 572.3, 100.8 and 326.9 g $kg^{-1}$, respectively; moisture at 33.42 and 1519.5 kPa = 12.68 and 4.98 dag $kg^{-1}$ respectively.

The experiment used the cotton cultivar 'BRS Rubi', because it is a genetic material indicated for cultivation in the semi-arid region of Northeast Brazil. It is a cultivar with dark brown or reddish brown fiber, mean height of 1.10 m and cycle from 120 to 140 days. It has mean yield of 1,894 kg $ha^{-1}$, under rainfed conditions, and in the Northeast region, its yield can reach more than 3,500 kg $ha^{-1}$ (EMBRAPA, 2011).

Eight seeds of 'BRS Rubi' cotton were sown in each lysimeter at depth of 3.0 cm, equidistantly distributed. At 15 and 25 days after sowing (DAS), thinnings were performed to maintain only one plant per lysimeter.

Basal fertilization with phosphorus and potassium was performed based on the recommendations of Novais et al. (1991), by applying the equivalent to 300 mg of $P_2O_5$ and 150 mg of $K_2O$ $kg^{-1}$ of soil, using single superphosphate and potassium chloride as sources. Phosphorus was applied totally as basal. Urea was used as N source. Fertilizations with potassium and the different N doses were split, and the $K^+$ doses were applied at 12, 28 and 42 DAS, while N doses were applied at 15, 30, 45 and 60 DAS, as recommended by Carvalho et al. (2011).

The fertilizations with micronutrients were performed through the application of 3 L of 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%)] through foliar application, at 25, 40 and 55 DAS. Phytosanitary control was performed preventively, applying insecticides from the Neonicotinoid chemical group, fungicide from the Triazole chemical group and acaricide from the Abamectin chemical group.

The effects of the treatments on the growth and production of cotton, cv. 'BRS Rubi', were measured through stem diameter (SD), plant height (PH), leaf area (LA), leaf dry phytomass (LDP) and stem dry phytomass (SDP) in evaluation made at 120 DAS, while seed cotton weight (SCW) and number of bolls per plant (NBP) were estimated at the end of the cycle (130 DAS). Plant height was measured considering the distance from the base to the insertion of the apical meristem. Stem diameter was measured at height of 5 cm from the base of the plant and the total leaf area (y) was obtained by measuring the midrib length of all leaves (x) of the plants, considering the methodology described by Grimes & Carter (1969), according to Eq. 1:

$$y = \sum \left(0.4322x^{2.3002}\right) \quad (1)$$

For the determination of dry phytomass, the plants were collected and separated into different parts (stem and leaves), which were placed in paper bags and dried in a forced-air oven at temperature of 65 °C, until constant weight. Then, the material was weighed to obtain leaf dry phytomass (LDP) and stem dry phytomass (SDP). The bolls were manually harvested when 90% of them were open, then counted to obtain the number of bolls per plant. SCW was obtained using a scale with precision of 0.01 g.

The obtained data were evaluated using analysis of variance by F test at 0.05 and 0.01 probability levels and, in cases of significance, linear and quadratic polynomial regression analysis was performed, using the statistical program Sisvar (Ferreira, 2011).

## Results and Discussion

According to the summary of analysis of variance (Table 1), there was a significant effect ($p < 0.01$) of the different saline levels (SL) on all studied variables. On the other hand, the nitrogen doses (ND) did not have significant effects ($p > 0.05$) on any of the variables. However, the interaction SL x ND significantly influenced ($p < 0.05$) seed cotton weight and number of bolls per plant.

The irrigation with water of increasing saline levels caused significant reduction in the SD and PH of 'BRS Rubi' cotton and, according to the regression models (Figures 1A and 1B), there were linear decreases in SD and PH, equal to 5.36 and 7.15% per unit increase in ECw, respectively. Based on the regression equations, SD and PH decreased by 1.78 mm and 19.06 cm, respectively, in plants irrigated with water of 9.1 dS $m^{-1}$ in comparison to those subjected to ECw of 5.1 dS $m^{-1}$. The reduction in the growth of 'BRS Rubi' cotton, observed through the decrease in SD and PH, can be attributed to the reduction in the osmotic potential of the soil solution, to the restriction to water flow and to the ionic effect caused by the accumulation of ions in the plant tissues, which directly affects the meristematic activity and cell expansion, consequently causing a decrease in plant growth (Munns & Tester, 2008). As in the present study, Santos et al. (2016), in a research on the cotton cv. 'BRS Topázio' cultivated in protected environment, also observed reduction in stem diameter and plant height with the increment in irrigation water salinity.

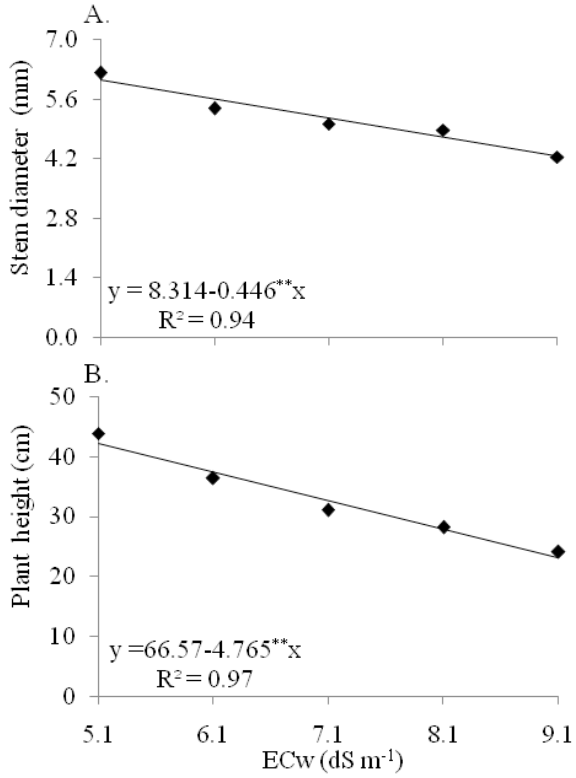


Figure 1. Stem diameter (A) and plant height (B) of cotton, cv. 'BRS Rubi', as a function of the irrigation water salinity (ECw)

As observed for SD and PH (Figures 1A and 1B), the increase in irrigation water salinity also negatively affected the leaf area of 'BRS Rubi' cotton. According to the regression equation (Figure 2A), the LA data fitted to a quadratic model and the maximum value (1757.80 $cm^2$) was obtained for irrigation with ECw of 5.1 dS $m^{-1}$. From this level on, there was a sharp decrease in LA and the lowest value (461.99 $cm^2$) occurred when plants were subjected to irrigation with ECw of 9.1 dS $m^{-1}$.

The inhibition in the LA of 'BRS Rubi' cotton (Figure 2A), due to the increase in ECw, must have been caused mostly by the toxic effects of the salts absorbed by the plants at levels that alter the cell ionic equilibrium or by the reduction of the total water potential resulting from the increase of the saline concentration (Silva et al., 2011). On the other hand, the reduction in leaf area (Figure 2A) represents an important mechanism of adaptation of the plants to the salt stress, because it reduces water losses through the stomatal flow and

Table 1. Summary of the analysis of variance for stem diameter (SD), plant height (PH), leaf area (LA), leaf dry phytomass (LDP), stem dry phytomass (SDP), seed cotton weight (SCW) and number of bolls per plant (NBP) of cotton, cv. 'BRS Rubi', irrigated with waters of different saline levels and nitrogen doses

| Source of variation | DF | Mean square | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | SD | PH | LA | LDP | SDP | SCW | NBP |
| Saline levels (SL) | 4 | $7.97^{**}$ | $892.05^{**}$ | $4218672.50^{**}$ | $114.29^{**}$ | $17.61^{**}$ | $123.33^{**}$ | $29.33^{**}$ |
| Linear regression | 1 | $29.39^{**}$ | $3351.20^{**}$ | $15485209.40^{**}$ | $411.43^{**}$ | $63.13^{**}$ | $440.08^{**}$ | $103.28^{**}$ |
| Quadratic regression | 1 | $0.38^{ns}$ | $87.37^{ns}$ | $711694.58^{*}$ | $27.38^{**}$ | $4.61^{*}$ | $35.11^{**}$ | $9.06^{**}$ |
| N doses (ND) | 4 | $0.16^{ns}$ | $9.28^{ns}$ | $59979.66^{ns}$ | $1.45^{ns}$ | $0.64^{ns}$ | $1.11^{ns}$ | $0.72^{ns}$ |
| Interaction (SL*ND) | 16 | $0.31^{ns}$ | $16.55^{ns}$ | $103545.14^{ns}$ | $1.47^{ns}$ | $0.40^{ns}$ | $8.12^{*}$ | $1.10^{*}$ |
| Blocks | 2 | $0.48^{ns}$ | $33.89^{ns}$ | $83082.62^{ns}$ | $0.54^{ns}$ | $0.89^{ns}$ | $0.96^{ns}$ | $0.41^{ns}$ |
| Residual | 48 | 0.22 | 22.97 | 84376.94 | 1.00 | 0.42 | 2.43 | 0.51 |
| CV (%) | | 9.27 | 14.69 | 19.54 | 20.84 | 18.42 | 16.05 | 18.75 |

$^{ns}$; **; *Not significant, significant at $p < 0.01$ and $p < 0.05$, respectively

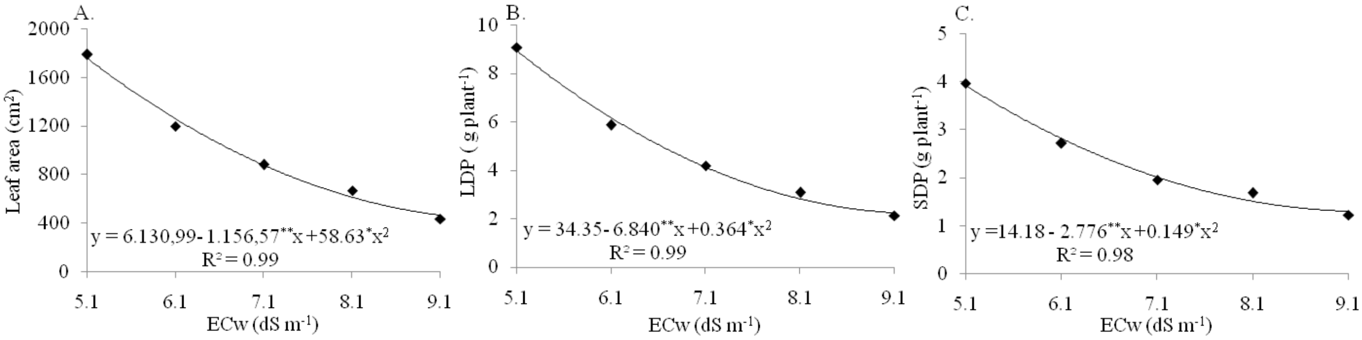


Figure 2. Leaf area (A), leaf dry phytomass - LDP (B) and stem dry phytomass - SDP (C) of cotton, cv. 'BRS Rubi', as a function of the irrigation water salinity (ECw)

contributes to the maintenance of a high water potential in the plant (Nascimento et al., 2011).

The LDP of 'BRS Rubi' cotton was significantly influenced by the increment in ECw levels. Based on the regression equation (Figure 2B), cotton plants subjected to irrigation using water with lower saline level (5.1 dS $m^{-1}$) obtained greater LDP accumulation (8.93 g), and this value was 6.68 g higher than that of plants cultivated under conditions of higher ECw (9.1 dS $m^{-1}$). Hence, the accentuated reduction in the LDP of plants subjected to irrigation with water of 9.1 dS $m^{-1}$ is a reflex of the decrease observed in leaf expansion (Figure 2A). Thus, a lower increment of leaf phytomass results in decrease of the photosynthetic capacity of the plant, leading to lower accumulation of photoassimilates (Suassuna et al., 2012). Lima et al. (2014), evaluating the growth of the castor bean cv. 'BRS Energia' under saline conditions (ECw: 0.3 to 3.9 dS $m^{-1}$), also found expressive decrease in the accumulation of leaf dry phytomass, and this reduction was higher than 14.32 g $plant^{-1}$, comparing the highest and lowest ECw levels.

As observed for LDP, the cotton SDP also significantly decreased with the increment in irrigation water salinity and the data fitted best to a quadratic model. Based on the values estimated by the regression equation (Figure 2C), the SDP accumulation decreased as the ECw levels increased, reaching maximum value of 3.89 g in plants irrigated with water of 5.1 dS $m^{-1}$, while the minimum of 1.25 g (decrease of 67.75%) was obtained in plants subjected to irrigation with water of 9.1 dS $m^{-1}$.

The decrease in SDP accumulation under salt stress conditions has been attributed to the low availability of water resulting from the reduction of the osmotic potential, due to the increased saline concentration. Thus, the salinity imposes a higher expenditure of energy on the plants for water absorption and maintenance of metabolic activity, besides the synthesis of organic solutes for the osmoregulation and/or protection of macromolecules. Consequently, there is a reduction in plant growth, which results in lower accumulation of dry phytomass (Leonardo et al., 2007).

The SCW was significantly affected by the interaction between factors (SL x ND). According to the regression equation (Figure 3A), the effect of the different ECw levels on the SCW was quadratic for cotton plants irrigated with water of 5.1, 8.1 and 9.1 dS $m^{-1}$, and the highest productions of seed cotton (11.76, 2.78 and 2.08 g $plant^{-1}$) in these treatments were obtained when plants received doses of 170, 100 and 135 mg of N $kg^{-1}$

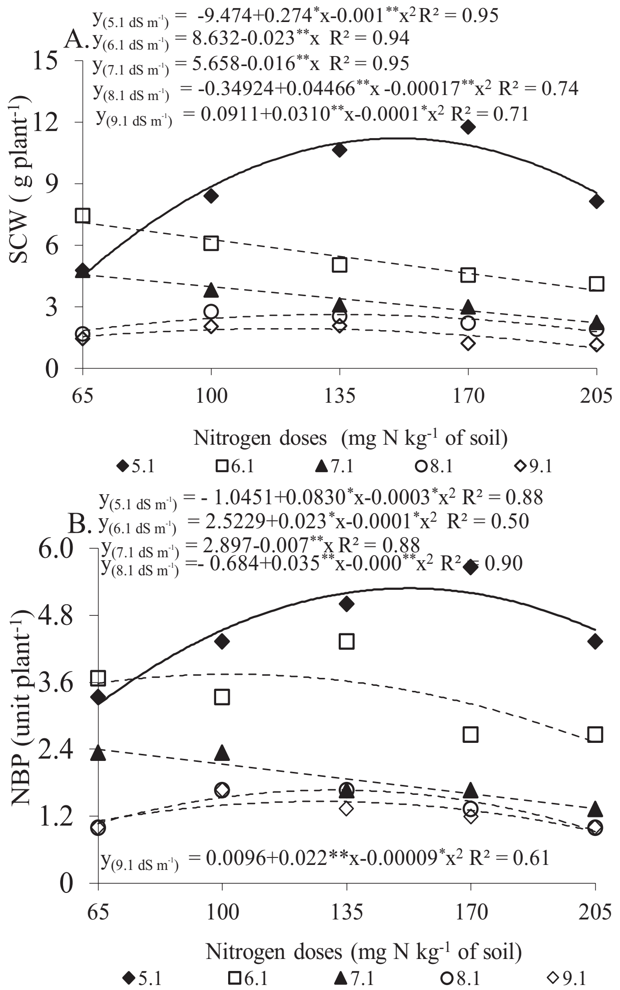


Figure 3. Seed cotton weight - SCW (A) and number of bolls per plant – NBP (B) of cotton, cv. 'BRS Rubi', as a function of the interaction between irrigation water salinity and nitrogen doses

of soil, respectively. For plants subjected to the ECw levels of 6.1 and 7.1 dS $m^{-1}$, there was a decreasing linear effect on SCW, with reductions of about 9.32 and 9.79%, respectively, for every increase of 35% in N doses, i.e., decreases of 3.33 and 2.52 g in the SCW of plants fertilized with 205 mg of N $kg^{-1}$ of soil, compared with those under 65 mg of N $kg^{-1}$ of soil. Based on the SCW data (Figure 3A), it becomes evident that the deleterious effect resulting from the management of saline water was more intense as the N doses increased, probably because of the greater accumulation of salts caused by the application of saline water combined with the excess of fertilizer.

According to the regression equations (Figure 3A), plants irrigated with water of 5.1 dS $m^{-1}$ and under the dose of 170 mg of N $kg^{-1}$ of soil produced higher SCW. Bosco et al. (2009) explain that plants cultivated under salt stress tend to absorb less N, while the absorbed and accumulated levels of $Cl^-$ are increased, due to the antagonistic effect existing between the nitrate and chloride ions, which can cause nutritional imbalance in the soil and, consequently, a reduction of growth, leading to decrease in crop production (Abd El- Shamad & Shaddad, 2000). Ferreira Neto et al. (2007) also add that, under salt stress conditions, the concentration of sodium chloride in the soil solution is high, which leads to a reduction in the absorption of nutrients, especially $NO_3^-$, $K^+$ and $Ca^{2+}$.

The interaction between factors also had significant effects on the NBP of 'BRS Rubi' cotton (Table 1). According to the regression equations (Figure 3B), the quadratic model showed the best fit for the NBP of cotton plants subjected to water salinity of 5.1, 6.1, 8.1 and 9.1 dS $m^{-1}$, although the ECw treatment of 6.1 dS $m^{-1}$ exhibited low coefficient of determination ($R^2$ = 0.50). The highest NBP values (5.67, 4.33, 1.67 and 1.67 $plant^{-1}$) were obtained when plants were subjected to N doses of 170, 135, 135 and 100 mg of N $kg^{-1}$ of soil, respectively. On the other hand, the lowest NBP values (3.33, 2.67, 1.00 and 1.00) were observed at the N doses of 65, 205, 205 and 205 mg of N $kg^{-1}$ of soil, respectively.

For cotton plants irrigated with ECw of 7.1 dS $m^{-1}$, there was a decreasing linear effect (Figure 3B), with reduction of 8.45% in NBP for every increase of 35% in the N dose, i.e., there was a decrease equivalent to 33.82% in the NBP of plants fertilized with 205 mg of N $kg^{-1}$ of soil, in relation to those that received 65 mg of N $kg^{-1}$ of soil. As observed for SCW (Figure 3A), irrigation using water of high ECw (9.1 dS $m^{-1}$) associated with the highest N dose (205 mg of N $kg^{-1}$ of soil) caused the greatest damage on NBP, probably because N contributed to the aggravation of the salinity of the soil solution.

## Conclusions

1. The growth of cotton, cv. 'BRS Rubi', is negatively affected by the irrigation with saline waters of 5.1 dS $m^{-1}$ on, and leaf area is the most sensitive variable.

2. The highest production of seed cotton and highest number of bolls per plant are obtained with irrigation using water of 5.1 dS $m^{-1}$ and dose of 170 mg of N $kg^{-1}$ of soil.

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