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Sources and doses of nitrogen in the production of sunflower plants irrigated with saline water[1]

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Helianthus annuus L.
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ABSTRACT

The cultivation of sunflower allows its use as bio-fuel and alternative forage. It is a viable alternative in the semiarid regions. Current study evaluates the effect of saline water use, sources and doses of nitrogen fertilization on the production of sunflower in the experiment conducted in drainage lysimeters between May and August 2012, under protected conditions, at Pombal - PB Brazil. The experiment consisted of a randomized block design, with a 2 x 3 x 4 factorial arrangement and three replications. The treatments consisted of two levels of electrical conductivity of water - ECw (0.3 and 3.0 dS m^{-1}), three sources of nitrogen (urea, ammonium sulfate and calcium nitrate) and four levels of N (40, 80, 120 and 160% of recommended dose - 100 mg kg^{-1}, for trials in pots). Dry mass of chapter (DMC), mass of achenes (MAc), the number of viable seeds (MVS), total number of seeds (TNS) and internal (DCI) and external (DCE) diameter of chapter. Irrigation with water of ECw=3.0 dS m^{-1} negatively affected all variable evaluated. Doses of N 104 and 160% of recommended dose for trials in pots, resulted in the highest DMC, TNS, DCE and DCI. N sources and the interaction between factors did not affect significantly any of the variable evaluated.

Fontes e doses de nitrogênio na produção do girassol irrigado com águas salinas

Palavras-chave:
Helianthus annuus L.
condutividade elétrica da água
nutrição mineral

RESUMO

O cultivo do girassol possibilita seu uso na produção de biocombustíveis e como forragem, alternativas essas viáveis sobretudo em regiões semiáridas. Desse modo, objetivou-se com este estudo avaliar o efeito da salinidade da água de irrigação, fontes e doses de nitrogênio sobre a produção do girassol em experimento conduzido em lisímetros de drenagem, entre maio e agosto de 2012, sob condições de ambiente protegido em Pombal-PB, utilizando-se o delineamento de blocos ao acaso, em esquema fatorial 2 x 3 x 4 com três repetições. Os tratamentos consistiram de dois níveis de condutividade elétrica da água - CEa (0,3 e 3,0 dS m^{-1}), três fontes de nitrogênio (uréia, sulfato de amônio e nitrato de cálcio) e quatro doses de N (40; 80; 120 e 160% da dose recomendado - 100 mg kg^{-1}, para ensaios em vasos). Avaliaram-se a massa seca de capítulo (DMC), produção de aquênios (MAc), massa de sementes viáveis (MVS), número de sementes total (TNS) e diâmetro de capítulo externo (DCE) e interno (DCI). A irrigação com água de CEa de 3,0 dS m^{-1} afetou negativamente todas as variáveis avaliadas. Doses de N variando de 104 e 160% da recomendação, proporcionaram os maiores valores para DMC, TNS, DCE e DCI; as fontes de N assim como a interação entre os fatores não influenciaram significativamente nenhuma variável avaliada.

Introduction

The sunflower (*Helianthus annuus* L.) is an oleaginous plant and one of the most relevant vegetal species with high potential for the production of bio-fuel. It is also an important option for farmers in crop rotation systems. Its easy adaptability to different climatic conditions and quantity and quality of oil in seeds have inserted the sunflower within Brazilian production and biodiesel use (Câmara, 2006).

The entire agricultural area of Brazil is suitable for the cultivation of the sunflower due to satisfactory climatic conditions and agronomical characteristics of this crop, such as tolerance to water deficit, low pest and disease incidence, and yield not affected by latitudes, altitudes and photoperiod (EMBRAPA, 2013).

Compared to other regions of Brazil, the Brazilian northeast has the largest participation in the Family Agriculture Program of the Federal Government where the sunflower is cultivated in approximately 77,883 ha, featuring 76,492 ha with crop, producing 86,730 t of grain, with an average yield of 1,134 kg ha^{-1}(IBGE, 2012).

Although there are many water sources on the planet, they are frequently badly distributed. In some places, demand is so high that water availability decreased and underground water resources are quickly depleted (Oliveira et al., 2010). However, several alternatives may attenuate these drawbacks, such as the use of saline water, the control of losses in water supply systems, collection techniques of rainwater and the adoption of procedures to decrease water consumption (Nascimento & Heller, 2005).

Water scarcity is a worldwide concern, although the issue is more serious in arid and semiarid regions which include the Brazilian northeastern regions. Irrigation has been adopted as the best practice to warrant agricultural production. However, inadequate irrigation management, high evaporation-transpiration and insufficient rainfall to leach salts from the soil contribute towards the accumulation of salts and the salinization of irrigated areas (Sairam & Tyagi, 2004).

One of the effects of soluble salts in water is the inhibition of germination and the lack of uniformity in growth, decline in productive capacity and quality of products (Arruda et al., 2002) due to decrease in water potential and to the effect of salt accumulation, mainly Cl^- and Na^+ (Munns & Tester, 2008).

In spite of greater risks, the need for alternative sources of water for agricultural activities is more than evident (Rhoades et al., 2000). Actually agriculture is the sector which retrieves most water, or rather, 69% of the total surface water (Paz et al., 2000).

Linked to the relevance of irrigation, mineral nutrition is an important environmental factor, underscoring nitrogen as the macronutrient required in great quantity by agriculture (Chaves et al., 2011). In fact, it is related to functions in plants metabolism and participates as a constituent part of chlorophyll molecules, nucleic acids, amino acids and proteins, triggering the plant growth and reducing the effects of salinity (Barhoumi et al., 2010).

Current research evaluates the effects of irrigation with water of different salinity levels, nitrogen sources and doses on the yield and components of production of the sunflower cv. Embrapa 122/V-2000.

Materials and Methods

Research was performed in a greenhouse between May and August 2012, in lysimeters, at the Centro de Ciências e Tecnologia Agroalimentar (CCTA) of the Universidade Federal de Campina Grande (UFCG), Pombal -PB, Brazil.

The experiment was conducted in completely randomized blocks arranged in a factorial scheme 2 x 3 x 4, with three replications. Treatments consisted of two levels of electrical conductivity of irrigation water - ECw (S1 - 0.3 and S2 - 3.0 dS m^{-1}), three nitrogen sources (urea, ammonium sulfate and calcium nitrate), and four nitrogen rates (N1- 40; N2 - 80; N3 - 120; N4 - 160% of recommended dose (100 mg kg^{-1}) for assays in pots, following recommendations of Novais et al., 1991).

Water of EC = 3.0 dS m^{-1} was prepared from tap water from the local supply (0.3 dS m^{-1}) with the addition of an amount (Q) of sodium chloride, determined by the equation Q (mg L^{-1}) = EC x 640, following Rhoades et al. (2000), where ECw (dS m^{-1}) represents the desired salinity in the water. ECw at 3.0 dS $m^{-1}$was selected because it is frequently found for water in the semiarid regions of the northeastern Brazil and due to the fact that this limit caused a 50% reduction in yield of sunflower in previous assays.

Sunflower cv. Embrapa 122/V-2000 was selected since its genetic material standout for early maturation, productivity, quality and oil content in the achenes. Seeds of the sunflower were provided by Embrapa Algodão.

Eighteen liter-drainage lysimeters were filled with 0.5 kg of pebbles and 1 kg of gravel, which covered the bottom, plus 13 kg of non-saline and non-sodic material of soil (sandy loam texture), without clods, collected in Pombal-PB, Brazil. Physical and chemical characteristics of the soil (Table 1) were determined in the Soil and Plant Nutrition Laboratory of CCTA/UFCG, following methodologies recommended by Claessen (1997). Further, 4 kg of soil mixed with 3% (total weight of the filled pot) cattle manure (6.3 g kg^{-1} N; 1.28 g kg^{-1} P; 0.53 g kg^{-1} K) were added to complete the volume of the lysimeter. Holes at the bottom of the lysimeters allowed follow-up of volume of drained water and calculation of water consumed by the plants. Lysimeters were placed in double rows with 0.9 m spacing between the double rows; 0.6 m between single rows and 0.2 m between pots within the row. After its accommodation in the lysimeters, soil was irrigated to attain field capacity with respective water according to treatment.

Nitrogen fertilization was partitioned into four applications: ¼ was applied at the start and ¾ were divided into three parts and were applied by fertigation at 15, 30 and 45 days after sowing (DAS). In the case of urea, 0.27 (N1), 0.53 (N2), 0.80 (N3) and 1.07 g (N4) were applied per pot; equivalent amounts of ammonium sulfate 0.57 (N1), 1.14 (N2), 1.71 (N3) and 2.29 g (N4) and calcium nitrate 1.03 (N1), 2.05 (N2), 3.08 (N3) and 4.10 g (N4) were applied per pot. Potassium and phosphate fertilization followed the chemical analysis of the soil according to the nutritional requirements of the crop in pot culture experiments. Potassium sulfate (K_2SO_4) was used in treatments with urea and calcium nitrate, whereas potassium chloride (KCl) was used in treatments with ammonium sulfate for nutritional balance between the several sources and elements. Fertilizers

Table 1. Physical and chemical characteristics of soil used in the experiment

Density	Total porosity	Water content (%)		Available water	Exchangeable cations ($cmol_c$ kg^{-1})				pH_{sp}	EC_{se}
(kg dm^{3})	(%)	0.33 atm	15.0 atm	(%)	Ca^{+2}	Mg^{+2}	Na^+	K^+	-	(dS m^{-1})
1.34	48.26	18.01	9.45	8.56	3.95	3.70	0.37	0.43	5.01	0.09

$Ca^{2+}$and Mg^{2+} extracted with KCl 1 mol L^{-1} pH 7.0; Na^+ and K^+ extracted with NH_4OAc 1 mol L^{-1} pH 7.0; pH_{sp} - pH of saturated paste ; EC_{se} - electrical conductivity of saturation extract.

were applied at 5-cm depth, at a distance of 10 cm from the plant´s stem.

Seven seeds were sown in each pot on May 23, 2012, at a depth of 2 cm and distributed at equal distance. Seedlings emerged 3 days after sowing (DAS) and continued until 13 DAS. Thinning was done at 15 DAS and three vigorous plants per pot were kept; other thinnings occurred on the 25 and 30 DAS in which a plant per pot was removed at each occasion.

After sowing irrigation was performed daily with respective water according to treatments, and volume of water to be added was calculated by water balance (volume applied - volume drained), plus an addition of 10% to compensate leaching.

The dry mass of the chapter (DMC), achene production (MAc), mass of viable seeds (MVS), total number of seeds (TNS), external diameter section (DCE) and internal (DCI) of the chapter were determined. The seeds of each chapter were manually threshed and subsequently separated into filled and unfilled achenes (only with the pericarp of the seed).

Data were evaluated by analysis of variance by test F at 0.05 and 0.01 probability level; when significant, polynomial regression analysis was performed for N doses; irrigation water salinity and N sources were evaluated by Tukey´s test at 0.05 probability. All analysis were performed by SISVAR-ESAL.

Results and Discussion

Summary of F test (Table 2) show a significant effect of the salinity of irrigation water on all variables under analysis, namely, the dry mass of chapter (DMC), achene production (MAc), mass of viable seeds (MVS), total number of seeds (TNS) and diameter of internal (DCI) and external (DCE) of the chapter. There was a significant effect of N dose on DMC, TNS, DCE and DCI. N sources and interaction between factors did not show significant effect on the variables under analysis (Table 2). Lima et al. (2011) analysed the effect of irrigation water salinity and nitrogen doses on the initial growth of the castor bean plant and did not detect any interaction between the factors.

The electrical conductivity of irrigation water affected significantly (p<0.01) the dry mass of chapter (Table 2). When plants were cultivated with the highest saline level (3.0 dS m^{-1}) a 60.20% decrease in DMC occurred compared to those irrigated with ECw of 0.3 dS m^{-1} (Figure 1A). According to Gulzar et al. (2003), as a rule, stress caused by excess of ion decreased CO_2 assimilation, stomatal conductance, transpiration and photosynthesis of the plants and consequently, damaged the components of crop production, as observed in current research.

With regard to N doses, it was observed by regression equation (Figure 1B) that the model to which data fitted best, in terms of dry mass of chapter of sunflower, was the quadratic where a positive response of N supply was noted and dose of 160% yielded maximum DMC (8.74 g). According to Bruginski & Pissaia (2002), studies on the application of different rates of N (0 to 125 kg ha^{-1}) on sunflower plants showed no significant effect on the production of dry matter of stem, petiole, leaves and chapter. High content of organic matter in the soil was mentioned as one of the factors that contributed towards this result. Nobre et al. (2011) studied sunflower under different N doses (50 to 125% of recommended dose) and did not find any significant effect on the dry mass of the shoot though a 6.9%

Table 2. Summary of F test for the dry mass of the chapter (DMC), achene yield (MAc), mass of viable seeds (MVS), total number of seeds (TNS) and internal (DCI) and external diameter of chapter (DCE) of the sunflower cv. Embrapa 122/V-2000, due to salinity of irrigation water, sources and N doses

Variation source	F Test					
	DMC	MAc	MVS[1]	TNS[1]	DCE	DCI
Saline level (S)	**	**	**	**	**	**
N source (NS)	ns	ns	ns	ns	ns	ns
N doses (ND)	**	ns	ns	*	*	*
Linear reg.	ns	-	-	ns	ns	ns
Quadratic reg.	**	-	-	*	*	*
Interaction S x NS	ns	ns	ns	ns	ns	ns
Interation S x ND	ns	ns	ns	ns	ns	ns
Interaction NS x ND	ns	ns	ns	ns	ns	ns
Interaction (SxNSxND)	ns	ns	ns	ns	ns	ns
Block	ns	ns	ns	ns	ns	ns
CV (%)	24.49	32.06	19.52	23.90	13,71	11,41

ns, **, * respectively not significant, significant at $p < 0.01$ and $p < 0.05$; [1]statistical analysis after data transformation in √x

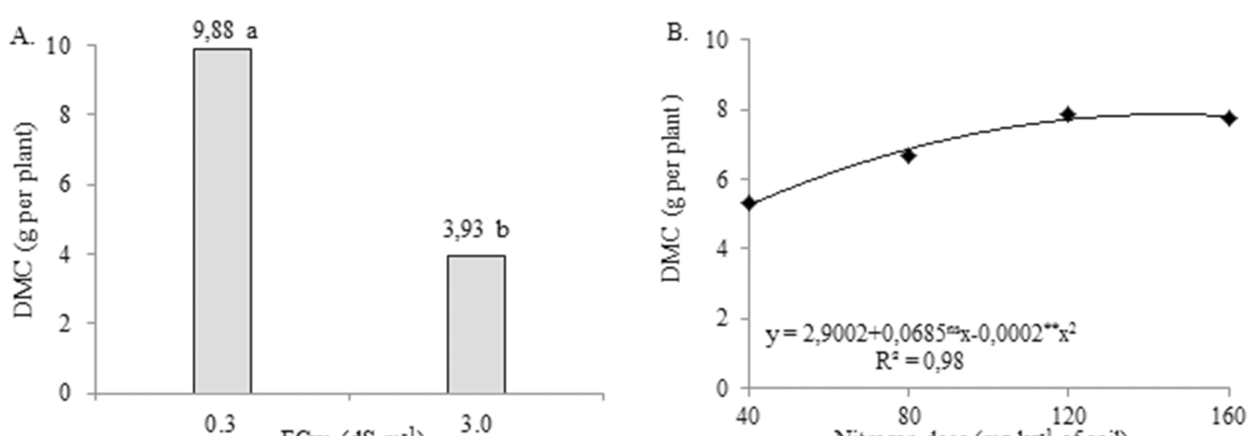

Figure 1. Dry mass of chapter (DMC) of sunflower plants as a function of salinity of irrigation water - ECw (A) and N doses (B)

linear increase for a rise of 25% applied N was reported with regard to the mass of 100 seeds.

Salinity of irrigation water affected significantly ($p<0.01$) and negatively the production of achenes (Figure 2A), with a 81,51% decrease in plants irrigated with water of 3.0 dS m^{-1} compared to control. Travassos et al. (2011) performed a greenhouse experiment with sunflower cv. Embrapa 122/V-2000, irrigated with varying water salinity (0.5 to 5.0 dS m^{-1}) and reported that production of achenes decreased 10.6% per unit increase in ECw. Analysing sunflower cv. Embrapa 122/V-2000 under salinity ranging from 0.5 to 4.9 dS m^{-1}, Nobre et al. (2011) found a reduction of 14.5% in MAc per unit increase in ECw. The authors did not observe any significant response for the N doses (25 to 125% of the recommended dose) on the variable MAc. Biscaro et al. (2008) studied the split application of nitrogen (0-80 kg ha^{-1}) on sunflower crop under field conditions, obtained an increase in growth and production up to a certain amount of N applied, and reaching maximum efficiency of production at the dose of 55 kg ha^{-1} N.

The factor salinity of irrigation water significantly affected ($p<0.01$) the mass of viable seeds (Table 2) and, according to Figure 2B, there was reduction of 78,73% (137,7 g) of MVS in plants irrigated with water of 3.0 dS m^{-1} compared to control (0.3 dS m^{-1}). According to Rhoades and Loveday (1990) increase in ECw increases the tension necessary for the plant to absorb water from the soil, as soil water potential becomes more negative and, consequently, it becomes more difficult for plant to use water, despite its presence in the soil it is not totally available to plants, contributing to reduction in the growth and biomass accumulation by the plant species under such stress. Salinity promotes water deficit and in this context, Castro et al. (2006) showed in their analysis on sunflower crop that water deficit when occurred mainly at the start of flowering and grain filling caused a decrease in total dry mass of achenes and oil content.

As reported for DMC, MAc and MVS, an increase in ECw had a significant effect ($p<0.01$) on the total number of seeds (Table 2) and there was a 71.28% (376 seeds) reduction in plants irrigated with ECw of 3.0 dS m^{-1} when compared to those irrigated with 0.3 dS m^{-1} (Figure 3A). According to Rhoades et al. (2000), soil salinity caused by irrigation with saline water or by combination of factors water, soil and crop management may result in the decrease of the number of fruits, weight of fruits and seeds, with a consequent decrease in the dry matter production of plant.

Nitrogen fertilization influenced significantly ($p<0.05$) the total number of seeds of the sunflower and according to

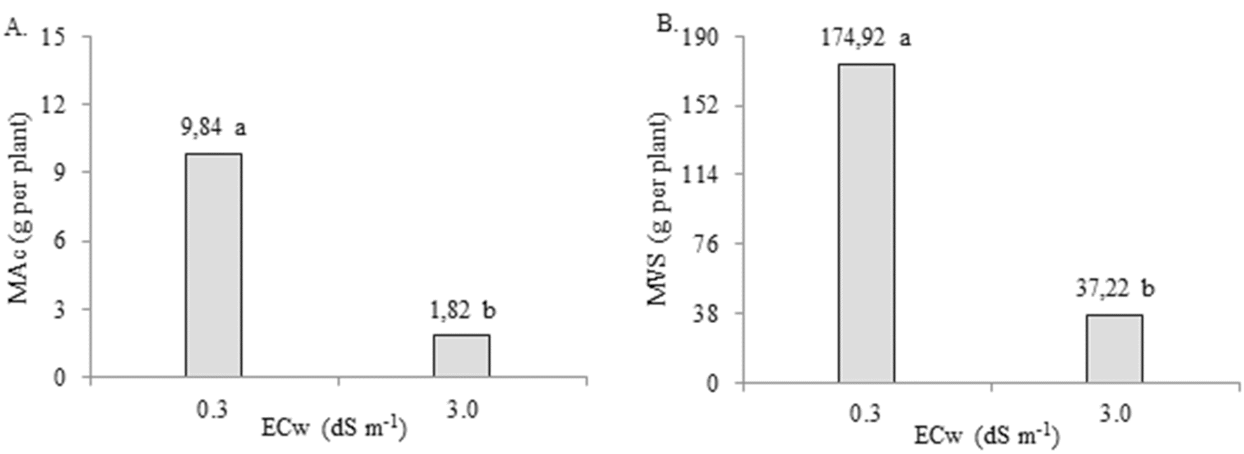

Figure 2. Achene yield - MAc (A) and mass of viable seeds - MVS (B) of sunflower as a function of salinity of irrigation water - ECw

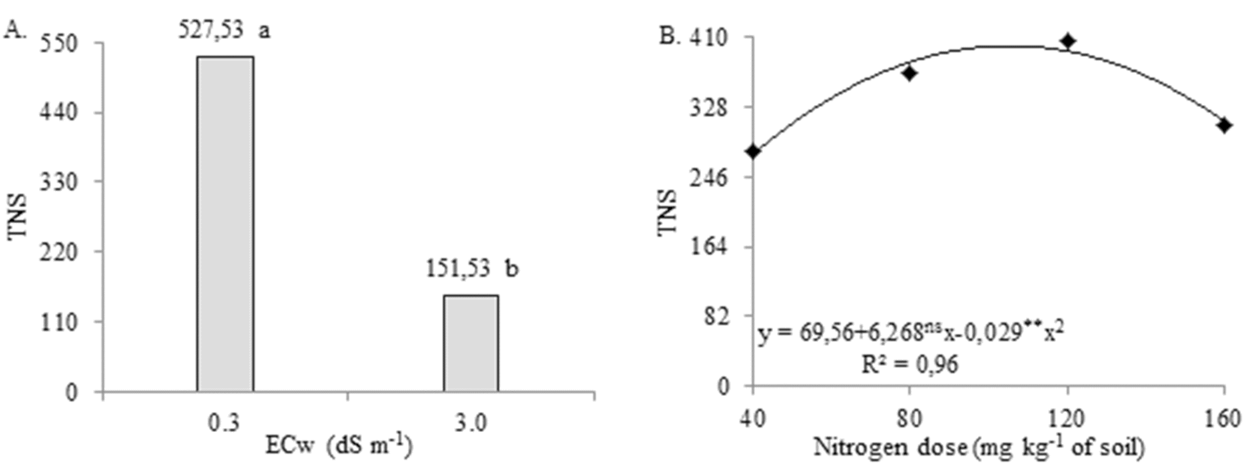

Figure 3. Total number of seeds - TNS per chapter of sunflower as a function of salinity of irrigation water - ECw (A) and nitrogen doses (B)

quadratic regression equation (Figure 3B), the largest TNS (408.2 seeds) was obtained when 108% of the recommended dose was applied. Taiz & Zeiger (2009) reported that crop development has a high relationship with nitrogen supply, a fact confirmed in the current research; plants with adequate doses of N showed higher production. Under field conditions, Carvalho & Pissaia (2002) obtained 499 achenes per chapter with 50 kg N ha^{-1} applied as top dressing under no tillage, using the sunflower hybrid M 734, though the authors reported that number of achenes was low, perhaps due to irregularity in water application during the flowering phase.

Increase in salinity of irrigation water affected significantly ($p < 0.01$) and negatively the external and internal diameter of the chapter (Table 2). As shown in Figure 4A, it reduced the DCE by 30.35% (6.1 cm) and the DCI by 33.33% (2.4 cm) in plants irrigated with water of 3.0 dS m^{-1} in relation to those under ECw 0.3 dS m^{-1}. The accumulation of salts in the soil decreased the osmotic potential and consequently the availability of water for plants (Silva et al., 2009) affecting the formation of yield components of sunflower. Furthermore, plants under salt stress tend to have ion toxicity, nutritional imbalance or both, depending on the accumulation of determined ions in excess in plant tissues. The plants under water and/or salt stress tend to close their stomata to reduce water loss through transpiration, resulting in lower photosynthetic rate, and contributing to reduced growth and production (Flowers, 2004). In contrast to the results obtained in this study, Maciel et al (2012) evaluating the use of brackish water on yield and quality of the inflorescence of ornamental sunflower plants, observed no significant influence of the salinity levels of the nutrient solution on the external and internal diameter of the chapter, with mean values of 16.4 and 6.6 cm, respectively.

Regarding the doses of N a significant effect ($p < 0.05$) was noted on DCE and DCI of sunflower (Table 2) and, according to the regression equations (Figure 5), a quadratic effect was verified, and the maximum values of DCE (17.36 cm) (Figure 5A) and DCI (6.27 cm) (Figure 5B) were obtained respectively with N rates of 106 and 104% of recommended dose, while the lowest values for these variables were obtained at doses of 40 and 160% of N. According to Fageria and Baligar (2006) the N is the most limiting nutrient for many crops in the world, and its efficient use is of great economic importance for the production in agricultural systems. Moreover, the natural dynamics of the N in soil-plant system creates a unique challenge for its correct management because high levels of N may lead to nutritional imbalance and, consequently, affects crop growth and yield (Oliveira et al., 2009). Biscaro et al. (2008) evaluating the response of sunflower subjected to different doses of nitrogen (topdressing) under field conditions, also observed

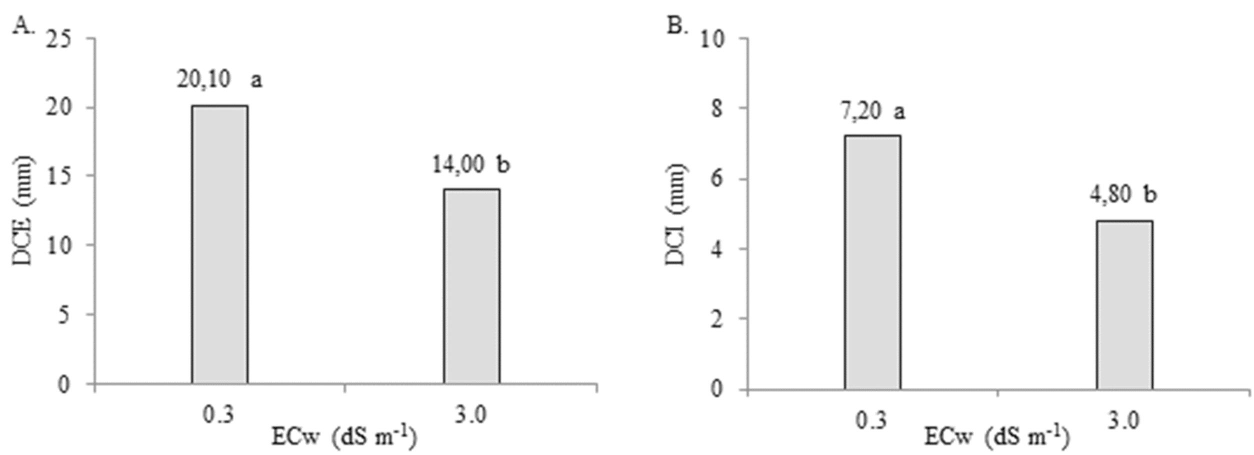

Figure 4. External - DCE (A) and internal - DCI (B) diameter of chapter of sunflower as affected by salinity of irrigation water - ECw

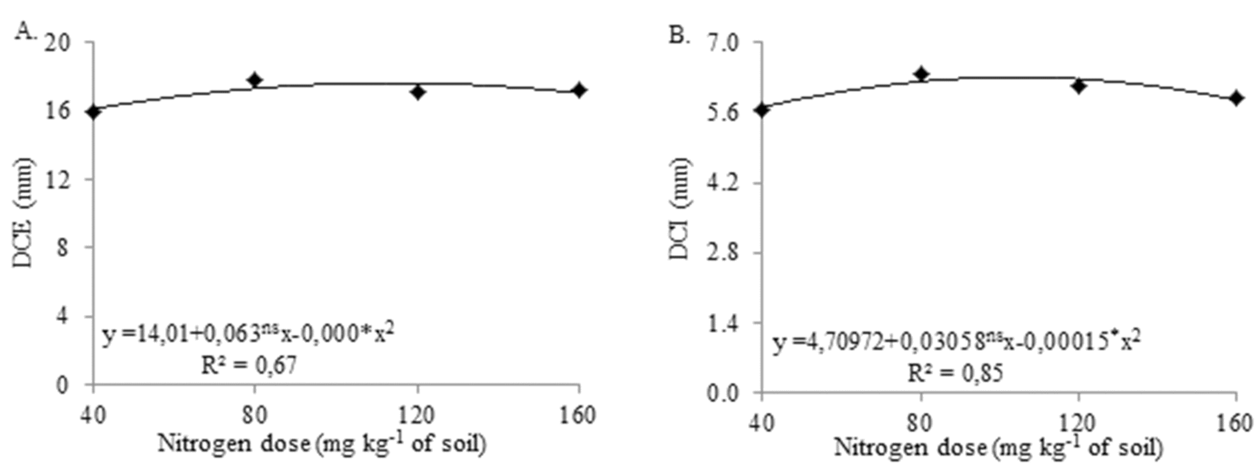

Figure 5. External - DCE (A) and internal - DCI (B) diameter of chapter of sunflower as affected by nitrogen dose

a quadratic effect on the chapter diameter due to the increase of nitrogen, obtaining estimated maximum diameter of 11.9 cm at 44.9 kg N ha^{-1}, indicating decrease in the diameter of the chapter with increasing doses of nitrogen.

Conclusions

1. Salt stress caused by salinity of irrigation water of 3.0 dS m^{-1} decreased the dry mass of the chapter and viable seeds, the number of achenes and internal and external diameter of the chapter of sunflower cv. Embrapa 122/V-2000; the most sensitive variables being the mass of viable seeds and total number of seeds per chapter.

2. Increasing nitrogen fertilizer levels promoted increase in diameter of outer and inner section, the number of seeds per chapter, the dry mass of the chapter and of shoots with the highest yields obtained with N doses ranging from 104 to 106 ng kg^{-1}.

3. Interaction between water salinity, different doses and/or sources of nitrogen did not affect any variable under analysis.

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