Growth of sugar cane varieties under salinity

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ABSTRACT

Large salty areas in the Brazilian semi-arid region have limited farming in Northeastern Brazil. One example is the sugar cane cultivation, which reinforces the need of selecting varieties that are more tolerant to salinity. The objective of this study was to evaluate the effect of salinity on growth of ten varieties of sugar cane. The experiment was conducted in a greenhouse, set in the experimental field of Embrapa Semiárido, in Petrolina, Pernambuco State. The experimental design was randomized blocks arranged in a 6 X 10 factorial arrangement, comprised of six levels of salinity (0, 1.0, 2.0, 4.0, 6.0 and 8.0 dS m^{-1}) and ten sugar cane varieties (VAT 90212; RB 72454; RB 867515; Q 124; RB 961003; RB 957508; SP791011; RB 835089; RB 92579 and SP 943206). Salt levels of irrigation water were obtained by adding NaCl, $CaCl_2.2H_2O$ and $MgSO_4.7H_2O$ to achieve an equivalent ratio among Na:Ca:Mg of 7:2:1. Sixty days later, plant height, stem diameter (base), number of leaves, stalks and sprouts, leaf area and fresh and dry mass of the aerial part and roots were all measured. The varieties of sugar cane showed similar responses for growth reduction as soil salinity increases, being considered moderately sensitive to salinity.

Key words: biomass, height, leaf area, salt stress.

RESUMO

Crescimento de variedades de cana-de-açúcar submetidas à salinidade

As extensas áreas salinizadas no semiárido têm limitado a produção agrícola no Nordeste brasileiro, a exemplo da cana-de-açúcar, o que reforça a necessidade de selecionar variedades mais tolerantes à salinidade. O objetivo do presente trabalho foi avaliar o efeito da salinidade no crescimento de dez variedades de cana-de-açúcar. O experimento foi realizado em vasos, em casa de vegetação, instalada no campo experimental da Embrapa Semiárido, em Petrolina-PE. O delineamento experimental utilizado foi em blocos casualizados dispostos em arranjo fatorial de 6 X 10, considerando-se seis níveis de salinidade na água de irrigação (0; 1,0; 2,0; 4,0; 6,0 e 8,0 dS m^{-1}) e dez variedades de cana-de-açúcar (VAT 90212, RB 72454, RB 867515, Q 124, RB 961003, RB 957508, SP 791011, RB 835089, RB 92579 e SP 943206). Os níveis de salinidade da água de irrigação foram obtidos pela adição de NaCl, $CaCl_2.2H_2O$ e $MgSO_4.7H_2O$, de modo a se obter proporção equivalente entre Na:Ca:Mg de 7:2:1. Após sessenta dias foram feitas medidas de altura das plantas, diâmetro do colmo (base), número de folhas, colmos e brotações, área foliar e massas de matéria fresca e seca da parte aérea e raízes. As variedades de cana-de-açúcar apresentam respostas semelhantes quanto à redução do crescimento à medida que a salinidade do solo aumenta, sendo consideradas moderadamente sensíveis à salinidade.

Palavras-chave: estresse salino, altura, biomassa, área foliar.

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INTRODUCTION

Sugar cane production in northeastern Brazil was estimated at 61.2 million tonnes, representing 9.34% of the Brazilian average (CONAB, 2015). Most of that is produced in northeastern semi-arid region, more specifically in the Submiddle of São Francisco River Valley that has achieved high yields of that crop due to irrigation technologies used (Silva, 2009).

However, because of soil and climate conditions favorable to soil salinization, the semiarid region presents some limitations on the exploitation of certain areas for the production of sugar cane due to the negative effect of salts on the growth and development of this crop.

As a result, the need of selecting genetic material with greater production potential under salt conditions (García & Medina, 2003) is important to facilitate the use of these areas and to achieve greater economic returns.

Wahid & Ghazanfar (2006) state that the existing varieties present some differences among them regarded to salt tolerance. Santana *et al*. (2007) state that sugar cane yield can be reduced by 50% in soils with electrical conductivity of 10.4 dS m^{-1}. According to Plaut *et al*. (2000), using salt water over 8 dS m^{-1} promotes severe effects on the growth of sugar cane varieties, with a significant reduction in leaf area and perspiration, and the increase in senescence and greater accumulation of Na^+ and Cl^-.

The different responses obtained from varieties of sugar cane regarding tolerance to salinity are related to the mechanisms developed by them to minimize the osmotic effect of salts in the soil, which limits the water absorption besides the less vulnerability to toxic concentrations of ions such as Na^+ and Cl^- (Munns & Tester, 2008).

The salt effects on the sugar cane are displayed with some restrictions in the assimilation of CO_2 (Vasantha *et al*., 2010), decrease in chlorophyll content (Silva *et al*., 2010), reduction in turgor pressure, limited elongation and cell division (Taiz & Zeiger, 2013), accumulation of compounds known as reactive oxygen species (Willadino *et al*., 2011) among other factors that directly reflect the depletion of plant growth.

Thus, morphological variables can help to evaluate the degree of salt tolerance of plants, as they express their adaptive traits to survive under stressful conditions. The objective of this study was to evaluate the effect of salinity on growth of ten sugar cane varieties.

MATERIAL AND METHODS

The experiment was conducted in a greenhouse set at EMBRAPA - Semi-Arid in the city of Petrolina, State of Pernambuco (latitude: 9º09'S, longitude: 40º22'W, 365.5 m above sea level). The climate in the region is the BSWh type according to Köppen, semi-arid tropical as described by Reddy & Amorim Neto (1983).

This experiment used a random block design in a 6 X 10 factorial arrangement, where six salt levels were represented by electrical conductivity (EC) of the irrigation water: 0, 1.0, 2.0, 4.0, 6.0 and 8.0 dS m^{-1}, and ten sugar cane varieties: VAT 90212 (V1), RB 72454 (V2), RB 867515 (V3), Q 124 (V4), RB 961003 (V5), RB 957508 (V6), SP791011 (V7), RB 835089 (V8), RB 92579 (V9) and SP 943206 (V10); totaling sixty treatments and three replicates.

To conduct the experiment, 8-dm^3 polyethylene pots were used, filled with a Quartzipsamment whose chemical and textural characteristics are shown in Table 1. The soil was air-dried, crushed, sieved in a 5-mm mesh sieve and homogenized.

According to the results of soil analysis, its fertility was corrected by applying dolomitic limestone (620 mg dm^{-3}) 45 days prior to planting and subsequent nutrient supply considering the following values: 118 mg dm^{-3} P (single application), 70 and 100 mg dm^{-3} of N and K, respectively, applied in two splits: 14.8, 3.7, 4.0, 34.8 and 7.6 mg dm^{-3} Cu, B, Mn, Zn and Fe, respectively, split in three applications.

In each pot, two sugar cane sprouts were planted. Those sprouts were from the Active Germplasm Bank of Embrapa and Agroindústria do Vale do São Francisco (Agrovale). Then, the soil was moistened up to field capacity, using salt-free water.

The salt water used in irrigation were prepared from the salts NaCl, $CaCl_2.2H_2O$ and $MgSO_4.7H_2O$, in order to obtain equivalent ratio of 7:2:1 between Na:Ca:Mg (Aquino *et al*., 2007). The water was renewed weekly and stored in a fresh, shady place in order to avoid alterations of the EC values for possible evaporation and temperature variations. The salt water was applied every two days in order to raise soil moisture to field capacity, with 15% leaching fraction.

After sixty days of salt stress, the following measurements were taken: plant height, stem diameter (base), number of leaves, stalks and sprouts and then removal of plants was started. The total leaf area was determined by means of Li-3100 C countertop scanner. The plants were separated into aerial part and roots, weighed to determine their respective values of fresh matter. After that, they were placed in oven at 65 ºC for 72 hours and weighed again, and mass of dry matter of the aerial part and roots were set.

The data were submitted to analysis of variance using the Sisvar 5.0 programme. For situations where there was a significant interaction between varieties and salinity levels, variable unfolding was carried out within each factor, otherwise, the independent effect of the factors was considered for the variables studied.

For comparison among salt levels, regression models of first and second degrees were evaluated when they were significant up to 5% probability. For comparison between the varieties, the Scott Knott test was performed at 5% probability.

RESULTS AND DISCUSSION

From the analysis of variance, it was found that the interaction between varieties and electrical conductivity (EC_w) was not significant for the studied variables (Table 2). However, significant differences between varieties were found, regardless of the salt level for plant height (PH), number of stalks (NST), leaves (NL) and sprouts (NSP), leaf area (LA), fresh and dry mass of the aerial part (FMAP and DMAP) and root fresh mass (RFM)

When the EC_w variation factor was evaluated, it was found that the attributes plant height, number of stalks, leaf area, fresh mass or the aerial part, dry mass of the aerial part, root dry mass and diameter showed significant responses for the different levels of salinity, regardless the analyzed variety (Table 2).

With regard to the variable height of the plants, it was found that the variety RB 835089 showed the best performance (117.2 cm) followed by varieties RB 72454, RB 957508, SP943206, RB 92579 and SP 791011, which showed average heights of 91.0, 81.1, 80.0, 78.7 and 77.9 cm, respectively. Varieties with greater height may present greater production potential as a positive correlation between growth of stalks and productivity has already been observed (Silva, 2009).

As for the variable number of stalks, it was found that the variety RB 835089 showed the highest value (8.4) followed by the varieties RB 957508, SP 943206, RB72454, RB 867515 and SP 791011, which presented values of 6.6, 6.2, 5.8, 5.8 and 5.8 respectively (Table 3).

It was also found that the variety RB835089 showed the highest value for number of leaves followed by varieties Q124 and RB 961003. The varieties 867515, Q 124, RB 961003, SP 791011, RB 92579 and SP 943206 showed similar behavior for number of sprouts (Table 3). Although Silva (2007) stated that plants with higher number of sprouts tend to have lower values of stem diameter, no significant differences were found between the varieties studied for this variable. In addition, its average value was 1.9 cm.

The variable number of leaves was partly correlated with the leaf area - LA (Table 4) since it showed higher values for RB 835089 and RB961003, although the variety VAT 90212 stood out, as well.

Table 1: Chemical and physical characteristics of the soil used for growing sugar cane varieties under different salt levels

O.M.	pH H_2O	EC_{se}	Ca^{+2}	Mg^{+2}	Na^+	K^+	Al^{+3}	T
g kg^{-1}	(1:2,5)	dS m^{-1}			cmol$_c$ dm^{-3}			
10.2	4.8	0.6	1.4	0.4	0.04	0.28	0.05	3.6
P	**V**	**Cu**	**Fe**	**Mn**	**Zn**	**Sand**	**Silt**	**Clay**
mg dm^{-3}	%		mg dm^{-3}				%	
4.2	59	0.2	9.1	12.0	1.1	73.0	19.0	8.0

EC_{se}= electrical conductivity of saturation extract; OM= organic matter; P= available phosphorus extracted by Mehlich^{-1}; Ca^{2+}= exchangeable calcium; Mg^{2+}= exchangeable magnesium; Na^+= exchangeable sodium; K^+= exchangeable potassium; Al^{+3}: exchangeable acidity; T= cation Exchange capacity at pH 7.0; V=base saturation; Fe=available iron; Mn= available manganese; Cu= available cupper; Zn= available zinc. Micronutrients extracted with Mehlich^{-1}

Table 2: Analysis of variance for growth variables in varieties of sugar cane under different salt levels

Factor of variation	Mean Square				
	PH	**θ**	**NL**	**NST**	**NSP**
Varieties	4.146**	0.17^{ns}	7.92**	26.1**	15.5**
EC_w	7.106**	0.24*	1.35^{ns}	24.5**	0.80^{ns}
Varieties X EC_w	240.8^{ns}	0.08^{ns}	1.09^{ns}	1.35^{ns}	2.02^{ns}
Residue	246.7	0.10	0.9	1.46	1.86
	LA	**FMAP**	**DMAP**	**RFM**	**RDM**
Varieties	339.313**	45.630**	3.017**	75.635**	4.035^{ns}
EC_w	539.086**	75.043**	2.828**	151.018**	29.414**
Varieties X EC_w	96.498^{ns}	4.078^{ns}	634.3^{ns}	17.233^{ns}	3.192^{ns}
Residue	70.613	4.148	779.5	12.759	3.313

PH – plant height; θ – stalk diameter; NF- Number of leaves; NST-number of stalks; NSP- Number of sprouts; LA- leaf area; FMAP- fresh mass of the aerial part; DMAP- dry matter of the aerial part; RFM- root fresh mass; RDM- root dry mass; *,** and ^{ns} are significant at 5%, 1% and non-significant, respectively.

Plants with larger leaf area (LA) may have greater production potential due to their higher capacity of intercepting solar radiation and biomass accumulation (Sinclair *et al*., 2004). This fact was observed in RB 835089, which presented higher production of fresh (FMAP) and dry (DMAP) mass of the aerial part, however, it was not observed an increase in the translocation of photoassimilates to the roots, to contribute to their root development (Table 4).

For root dry matter mass, no significant differences between the varieties (Table 4) were found, which may be due to the high value of the coefficient of variation (64.4%), showing that this is not a suitable variable for evaluating the potential of varieties regarded to their salt tolerance since their variances are influenced by other factors besides salt stress.

When the influence of the levels of salt stress on the plants of sugar cane was evaluated, it was found that regardless of the studied variety, plant height, stem diameter and number of stems reduced significantly as values of EC_w increased (Figure 1).

For the conditions of this study, reductions of 37.2 and 30.8% were observed in plant height and number of stalks, respectively, when comparing the results obtained with plants exposed to the highest salt level with those irrigated with not-saline water. However, the variable stem diameter was less sensitive to the effects of salinity, when presenting reduction of only 8% for these same conditions.

When working with sugar cane, Santana *et al.* (2007) obtained similar results, showing that salinity affected crop growth in na inversely proportional manner to the salt concentration in the irrigation water. Other authors (Gurgel *et al*., 2003; Willadino *et al*., 2011; Almeida *et al*., 2012), working with genotypes and varieties of different crops also report the deleterious effects of the salts on the physiological variables and growth.

Salt levels did not affect the number of sprouts, demonstrating that this is a variable more related to genetic differences among varieties than a particular response to the environmental conditions.

García & Medina (2010) when evaluating two genotypes of sugar cane under salt conditions found that

Table 3: Plant height (PH), stalk diameter (θ), number of leaves (NF), number of stalks (NST) and number of sprouts (NSP) for different varieties of sugar cane

Varieties	PH (cm)	θ (cm)	NL	NST	NSP
VAT 90212	74.1 c	1.9 a	6.2 c	5.1 c	1.1 b
RB 72454	91.0 b	1.9 a	6.2 c	5.8 b	0.9 b
RB 867515	70.3 c	2.0 a	5.4 c	5.8 b	2.9 a
Q 124	67.8 c	1.7 a	6.8 b	5.1 c	2.7 a
RB 961003	62.6 c	2.0 a	6.4 b	3.8 d	2.5 a
RB 957508	81.1 b	1.8 a	5.6 c	6.6 b	1.3 b
SP 791011	77.9 b	1.9 a	5.7 c	5.8 b	3.4 a
RB 835089	117.2 a	1.8 a	7.5 a	8.4 a	1.1 b
RB 92579	78.7 b	1.9 a	5.4 c	4.9 c	3.0 a
SP 943206	80.0 b	2.1 a	5.8 c	6.2 b	2.3 a
C.V. (%)	19.6	16.3	15.5	21.0	64.7

*Means followed by the same letter in the column do not differ from each other by the test of Scott Knott at 5% of probability.

Table 4: Leaf area (LA), fresh mass of the aerial part (FMAP) and roots (RFM) and dry mass of the aerial part (DMAP) and roots (RDM) for different varieties of sugar cane

Varieties	LA (cm^2)	FMAP (g)	DMAP (g)	RFM (g)	RDM (g)
VAT 90212	1165.8 a	209.4 b	52.3 b	383.6 b	83.3 a
RB 72454	951.0 b	229.8 b	61.1 b	396.5 b	53.7 a
RB 867515	814.6 b	172.6 c	63.7 b	303.0 c	36.9 a
Q 124	857.9 b	152.1 c	44.9 b	465.2 a	64.5 a
RB 961003	1159.9 a	192.0 b	53.9 b	416.6 b	78.4 a
RB 957508	909.9 b	199.6 b	50.9 b	443.2 b	52.4 a
SP 791011	924.1 b	215.4 b	66.1 b	421.5 b	69.9 a
RB 835089	1166.5 a	340.1 a	91.5 a	373.5 b	61.0 a
RB 92579	877.7 b	201.2 b	54.5 b	343.6 c	42.4 a
SP 943206	896.7 b	195.3 b	54.2 b	539.2 a	72.2 a
C.V. (%)	27.3	30.6	47.1	27.8	64.4

*Means followed by the same letter no differ from each other by the test of Scott Knott at 5% of probability.

genotype PR 692176 showed higher value for the number of sprouts when compared with the genotype V78-1, thus strengthening the hypothesis that genotypes or varieties may have different responses for the same level of salt.

The effect of the soil salt levels on variables leaf number and leaf area are shown in Figure 2. It is observed that the number of leaves remained almost constant with increasing salt levels, while the leaf area (LA) was negatively affected, demonstrating greater influence of salts on the leaf expansion, therefore contributing to alterations in values of leaf area (LA). In this case, leaf área increased up to level of salinity corresponding to 5.2 dS m^{-1}, when its maximum value (1.139 cm^2) is achieved; from that point, it declines up to the value of 1.045 cm^2, corresponding to salinity of 8 dS $m^{-1.}$

This characteristic may be related to osmotic adjustment mechanisms developed by plants, in which the effect of the absorption and transport of ions to the aerial part and accumulation of compatible solutes promotes the maintenance of the leaf water status up to certain salt levels not considered toxic to plants (Munns & Tester, 2008).

The sensitivity of leaf area in relation to salt effects on varieties of sugar cane grown in growth chambers in North Carolina (USA) were also reported by García & Medina (2010).

The variables fresh mass of the aerial part, dry mass of the aerial part, root fresh mass and root dry mass were significantly influenced by the salt levels in the soil, regardless of the studied range (Figure 3). For these variables, there were linear reductions with soil salinity

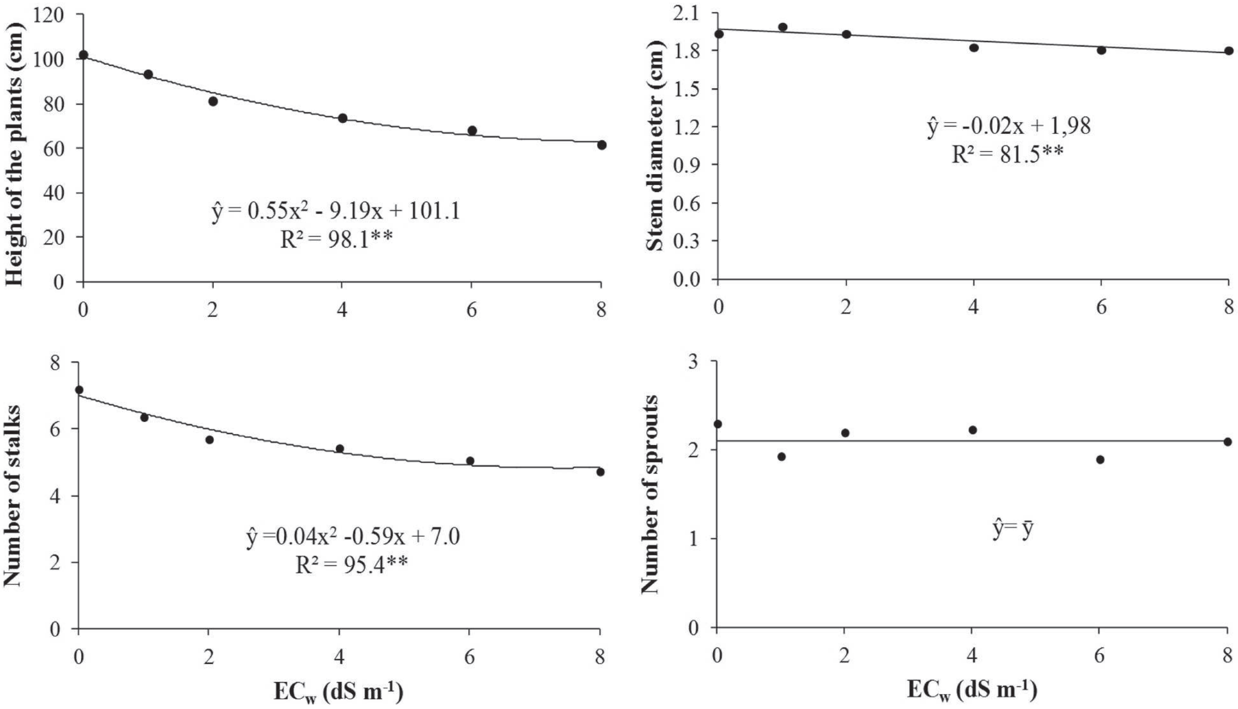

Figure 1: Height of the plants, stem diameter, number of stalks and number of sprouts in sugar cane plants under different levels of salinity. ** Significant regressions at 1% of probability.

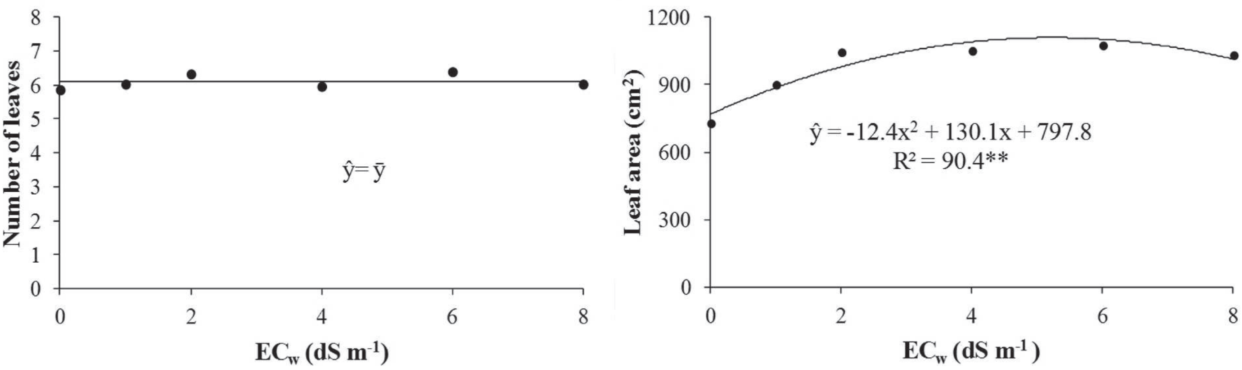

Figure 2: Number of leaves, leaf area in sugar cane plants under different levels of salt. ** Significant regression at 1% of probability.

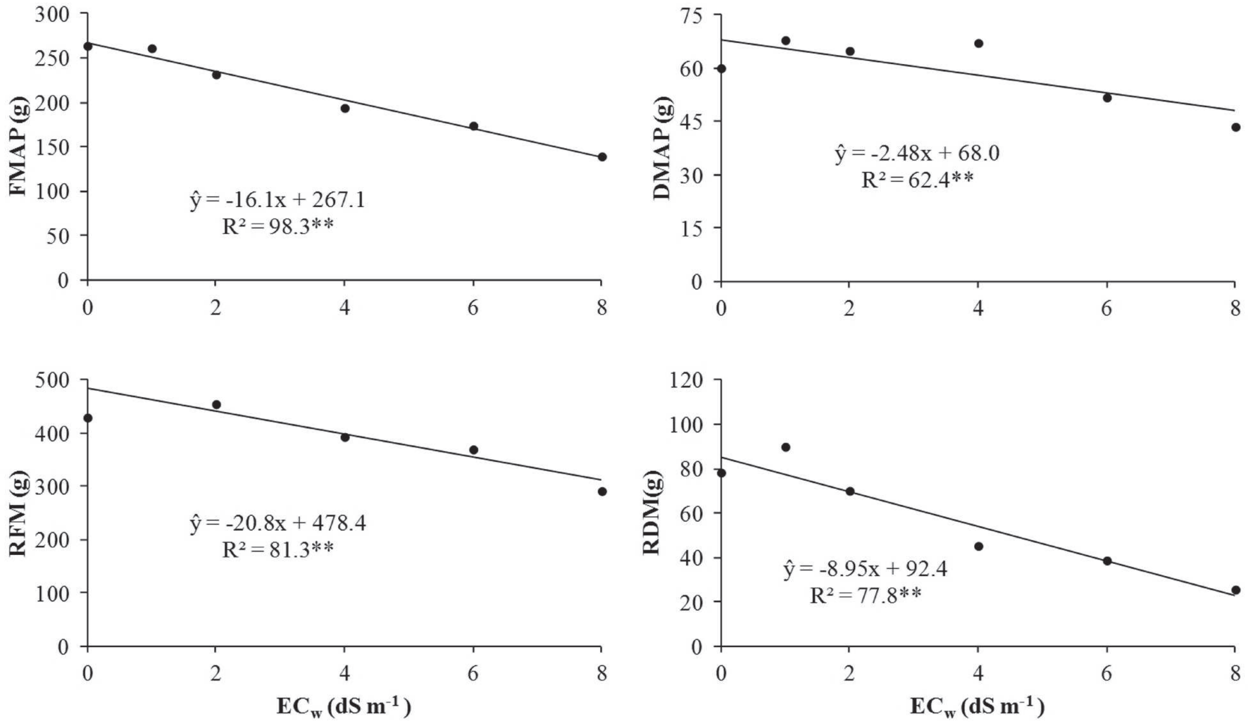

Figure 3: Fresh mass of the aerial part (FMAP) and roots (RFM) and dry mass of the aerial part (DMAP) and roots (RDM) in sugar cane plants under different levels of salt. ** significant regression at 1% of probability.

levels, reaching relative reductions of 48, 29, 35 and 77%, respectively, for the treatment at 8 dS m^{-1} when compared to the control (0.1 dS m^{-1}), showing higher sensitivity of root dry mass to the variation of soil salinity and lower sensitivity for the dry mass of the aerial part.

It was found that for every increase of 1 dS m^{-1} in the irrigation water, fresh mass of the aerial part, dry mass of the aerial part, root fresh mass and root dry mass decreased by 6.0, 3.6, 4.4 and 9.6% respectively. Of these results, dry mass of the aerial part is the variable that is the closest to the values pointed by Fageria *et al*. (2010), who suggest a reduction of 5.9% in the yield of this crop for each EC_{se} unit. Thus, based on the criterion used by Maas (1986), the evaluated sugar cane varieties can be considered moderately sensitive to salinity.

Santana *et al*. (2007), working with sugar cane (SP80-1842) under salt stress in greenhouse using soils with different textures (sandy, clayey and medium texture) and irrigation water salinity ranging from 0.1 to 8 dS m^{-1}, also observed that dry mass of the aerial part and the root dry mass were significantly affected by the salt effect on different types of soil.

CONCLUSIONS

The evaluated sugar cane varieties have similar responses in reducing the growth as the salinity increases, being considered moderately sensitive to salinity.

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