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**ORIGINAL RESEARCH ARTICLE**

# Growth and phytomass of sugar beet under supplemental irrigation with water of different saline concentrations

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## ABSTRACT

The use of saline water in agriculture is a viable alternative, considering the increased demand for fresh water. The objective of this study was to evaluate the growth and phytomass production of sugar beet under irrigation with water of different saline concentrations in a field experiment on the campus of the Federal University of Alagoas in Arapiraca. The treatments were five levels of electrical conductivity (1.0, 2.0, 3.0, 4.0 and 5.0 dS $m^{-1}$). The design was in randomized blocks, with four repetitions. The maximum yield of sugar beet at 27 days after the application of saline treatments was obtained with a salinity of 3.0 dS $m^{-1}$, for the variables plant height (PA), stem diameter (CD), root length (RC), aboveground dry phytomass (FSPA) and total dry phytomass (FST). At 42 days after the application of saline treatments, the variables aboveground fresh phytomass (FFPA), root fresh phytomass (FFR), total fresh phytomass (FFT), aboveground dry phytomass (FSPA) and total dry phytomass (FST) increased with increasing water salinity. Rain may have influenced the results obtained for the evaluations, performed at 42 days after the application of the saline treatments.

***Keywords:*** *Beta vulgaris* L.; Electrical Conductivity; Water Quality

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## 1. Introduction

Irrigation is an effective instrument for increasing productivity and expanding agricultural frontiers, but its inadequate use can cause soil salinization, especially in arid and semi-arid regions, reducing crop yields, or even resulting in land abandonment. Salinization and sodification is a problem with economic, social and ecological consequences[1].

According to Silva *et al.*[2], human-induced salinity is the one that brings the greatest economic losses, because it occurs in areas in which high investments have been made, such as irrigation systems and fertilizations. Induced salinity is generally associated with inadequate management of irrigation and fertigation, and can be caused by both the poor quality of irrigation water and the excessive application of fertilizers to the soil.

It is necessary to seek alternative technologies for the use of these saline waters, with their greater utilization in plant production, reducing environmental impacts[3]. One alternative proposed is the use of salinity tolerant crops for intensive plant production.

Used in several semi-arid regions of the world, sugar beet (*Beta* *vulgaris* L.) is an option for production in saline soil conditions[4], since, besides standing out for its nutritional composition, especially in sugars and for the way the tuberous root is consumed, it presents itself as one of the vegetables tolerant to high levels of salts[5].

According to Ayers and Westcot[6], sugar beet presents threshold salinity values (EC) of 7.0 dS $m^{-1}$, becoming more tolerant to excess salts in advanced stages of growth. For this reason, the use of this crop may serve as an alternative income for rural producers with water salinity problems.

Despite its economic importance, there are few papers that study the effect of salinity on the crop, particularly studies of the growth and early development of sugar beets under salt stress and its potential for cultivation in salinized field conditions due to incorrect irrigation management.

For this reason, the objective of this study was to evaluate the growth and phytomass production of sugar beet, under irrigation with water of different saline concentrations.

## 2. Material and methods

The experiment was developed under field conditions, in an area belonging to the Federal University of Alagoas (UFAL), Arapiraca Campus, at coordinates 9°45'58"S and 35°38'58"W, at an altitude of 264 m. This region is represented by the transition between Zona da Mata and Sertão Alagoas, whose climate is, according to Koppen's classification, tropical with summer dry season.

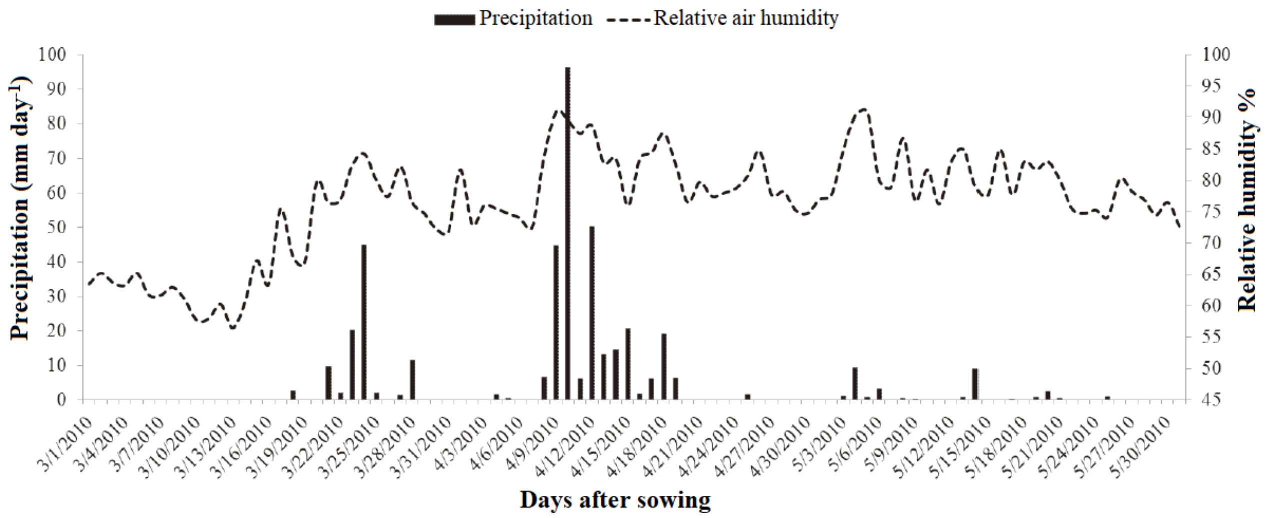


**Figure 1.** Rainfall and relative humidity during the experiment period.

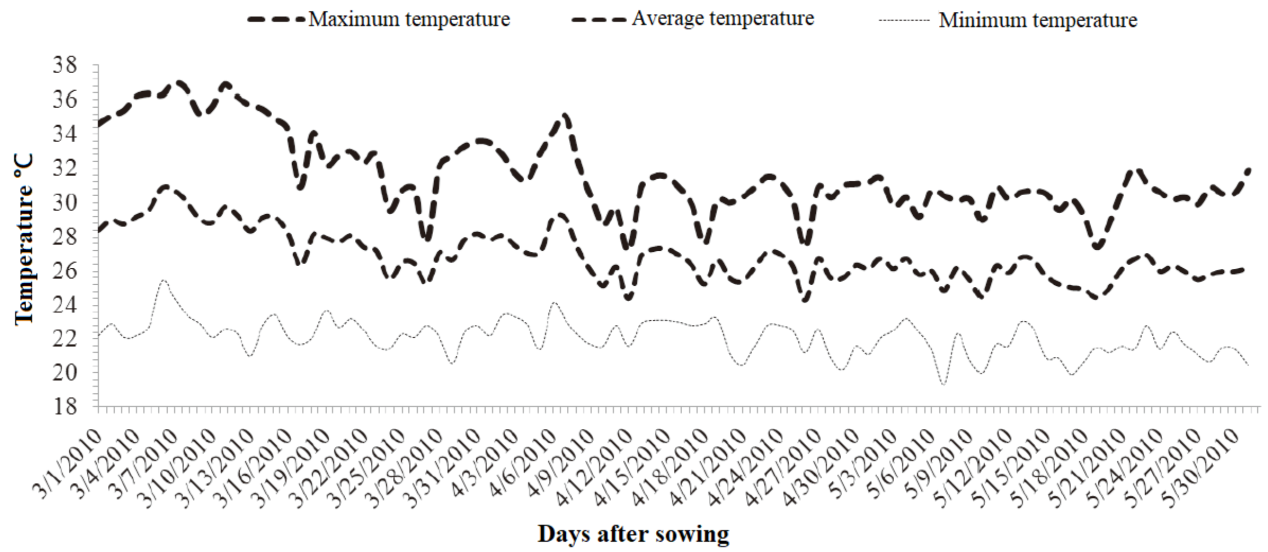


**Figure 2.** Maximum, average and minimum air temperatures during the experimentation period.

The daily data of rainfall and relative humidity of air from the city of Arapiraca, AL, for the period from March to May 2010, the season corresponding to the conduct of the experiment, were obtained from the National Institute of Meteorology (INMET) and are shown in **Figure 1**. The maximum, mean and minimum air temperatures for the period of the experiment, obtained from the National Institute of Meteorology (INMET), are shown in **Figure 2**.

The soil used in the research was classified as a dystrophic Red Argissolo and its chemical characteristics, at a depth of 0–20 cm, are presented in **Table 1**.

**Table 1:** Chemical analysis of the soil used in the experiment

| pH | P | M.O | K | Ca | Mg | Al | H+Al | T | V | Fe | Cu | Zn | Mn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ($H_2O$) | (mg $dm^{-3}$) | (g $dm^{-3}$) | ($cmol_c$ $dm^{-3}$) | | | | | | (%) | (mg $dm^{-3}$) | | | |
| 5.7 | 13 | 15 | 0.2 | 1.4 | 1.4 | 0.2 | 4.0 | 7.0 | 42.9 | 44.5 | 0.86 | 2.4 | 32 |

The statistical design was a randomized complete block design with four repetitions. The treatments were a combination of five salinity levels of irrigation water (S1: 1; S2: 2; S3: 3; S4: 4 and S5: 5 dS $m^{-1}$), with four repetitions. The treatments were arranged in 40 pots, each plot consisting of two 2 L pots, spaced at 0.5 m between pots and 0.9 m between pot rows. The waters with different saline concentrations were obtained from additions of sodium chloride (NaCl) to the water supply, calculated according to equation 1, proposed by Richards[7].

$$C = 640 * CEa \quad (1)$$

where: C = NaCl concentration (mg $L^{-1}$); CEa = Electrical conductivity of the solution (dS $m^{-1}$).

The beet cultivar used was the “Early Wonder”. The seedlings were grown in 128-cell expanded polyethylene trays filled with a substrate composed of rice husk and worm humus in a 1:1 ratio. One seedling per pot was transplanted when it presented four to five definitive leaves, which occurred around 25 days after sowing.

Before planting, irrigation was performed to bring the soil to field capacity, and the soil in the pots was collected, following the gravimetric (standard) greenhouse method, where a moisture at field capacity of U = 26.32% was obtained. Irrigation was performed daily always in the late afternoon and water was applied only to the soil.

The volume of water consumed was calculated in the morning of the following day by the difference between the volume of water applied and drained. The crop evapotranspiration (consumption), determined daily, was estimated. Thus, the volume of water to be applied was calculated based on the previous day’s consumption.

According to equation 2 of Rhoades[8], and leaching fraction 0.15, the treatments for this source of variation were obtained. Consequently, an identical calculation was performed for leaching fraction 0.20, thus characterizing ten treatments with the saline concentrations. According to the water requirement, this value varied with each stage of the crop cycle.

$$VI = \frac{VA - VD}{1 - FL} \quad (2)$$

where: VI: Vblume of water to be applied in irrigation (mL); VA: Volume of water applied in the previous irrigation or period (mL); VD: Volume of water drained in the previous irrigation or period (mL); FL: Leaching fraction (0.15 and 0.20).

Irrigation was performed manually, with a graduated cylinder to measure the amounts to be applied and drained daily.

The evaluations were performed at 27 and 42 days after application of the salt treatments. The plants of each experimental unit were harvested separately and packed in paper bags previously identified, transported to the Soil Physics Laboratory of UFAL, where the variables were analyzed: 1) plant height (PA), measured from the neck of the plant to the base of the last emitted leaf, with a ruler graduated in cm; 2) number of leaves per plant (NF), by direct counting; 3) stem diameter, measured with a graduated pachymeter; 4) leaf area ($cm^2$), using an electronic leaf area integrator, model LI-3100; 5) root length (RC), measured with a graduated ruler; 6) fresh phytomass for the aboveground part, root and total; 7) dry phytomass for the aboveground part, root and total.

To obtain these variables, the plants were removed from the pots, preserving their structures, avoiding damage to both the root and aboveground parts. To determine the fresh and dry root and aboveground phytomass, the plants were removed from the pots and washed, the roots and aboveground were weighed separately.

They were then packed in paper bags and placed in an oven with forced air circulation at 65 °C for 48 hours for subsequent weighing on an analytical balance of 0.01 g precision. The total fresh and dry phytomass was obtained by adding the respective fresh and dry masses.

The results were submitted to variance analysis using the F test, and the means were compared using the Tukey test at 5% with the statistical software SISVAR[9]; for the salinity levels factor, a regression test was performed (by orthogonal polynomials), with significance levels of 0.01 or 0.05 probability.

## 3. Results and discussion

There was an effect of salinity ($p < 0.01$) on the variables AP, AF, FFPA FSPA, and FST, respectively. There was a significant quadratic effect ($p < 0.01$) on AP, DC, AF, CR, FSPA, and FST, as a function of irrigation water salinity.

According to the regression equation for plant height, **Figure 3A**, the maximum height was obtained at 3.11 dS $m^{-1}$, which corresponds to 12.8 cm at 27 days after application of the salt treatments.

The mathematical model that best fitted the stem diameter was quadratic (**Figure 3B**). The maximum stem diameter, at 37 days after the application of treatments, occurred at 3.0 dS $m^{-1}$, corresponding to 0.33 mm.

In studies such as Silva's[16], the reduction in the values of stem diameter and water consumption of plants is attributed to the osmotic potential of the soil solution, due to the excess salts present, hindering the absorption of water by the plant, making it require greater energy effort for the absorption of water and nutrients, thus reducing its growth.

The results of leaf area as a function of the salt treatments applied are shown in **Figure 4A**. The maximum production was obtained with a salinity of 2.85 dS $m^{-1}$, which corresponds to 21.4 $cm^2$. From this point on, there was a decrease of 24%, when comparing S1 with S5.

Oliveira *et al.*[10] reported that the highest value of leaf area of radish irrigated with saline water was obtained with the application of the lowest level of salinity (2 dS $m^{-1}$), obtaining 497.20 $cm^2$, while, at the highest level of salinity (10 dS $m^{-1}$), resulted in the lowest value of leaf area, obtaining 220 $cm^2$, corresponding to a reduction of 55.75%, reaffirming the data obtained in this study, even with higher concentrations of salts in the water.

According to Tester and Davenport[11], salinity reduces the osmotic potential, reflecting in the reduction of water uptake by the plants and compromising the physiological processes; thus, the plants may present morpho-physiological modifications, in order to increase their tolerance to salinity, with emphasis on the reduction of leaf area, as a result of the reduction of cell volume. With a reduction in the leaf area and an increase in the total concentration of solutes in the leaf, an osmotic adjustment of the cells occurs, ensuring that the plants can absorb water.

According to the regression model for root length (**Figure 4B**) the maximum value, at 27 days after application of the saline treatments, was reached at 2.82 dS $m^{-1}$, which corresponds to 13.0 cm. According to Mohammad *et al.*[12], the increase in salinity is accompanied by a reduction in root length, thus confirming the results obtained in this work.

The mathematical model that best fitted the dry phytomass of the aerial part, at 27 days after the application of treatments, was quadratic (**Figure 5A**) being obtained the maximum at 3.0 dS $m^{-1}$ and the difference of 20% between the highest (S5) and lowest (S1) salinity level. Chen and Jiang[13] state that the effect of salts causes a reduction in the part area of certain species because they do not present an osmotic adjustment as an adaptability mechanism to excess salts in the soil solution.

For the total dry phytomass variable (**Figure 5B**), at 27 days after application of the salt treatments, the maximum yield was obtained with 3.5 dS $m^{-1}$ and corresponds to 0.25 g.

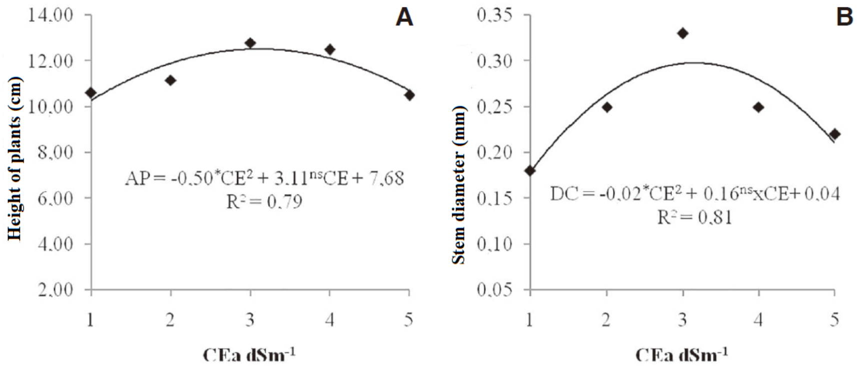


**Figure 3.** Plant height (**A**) and stem diameter (**B**), 27 days after the application of treatments as a function of irrigation water salinity.

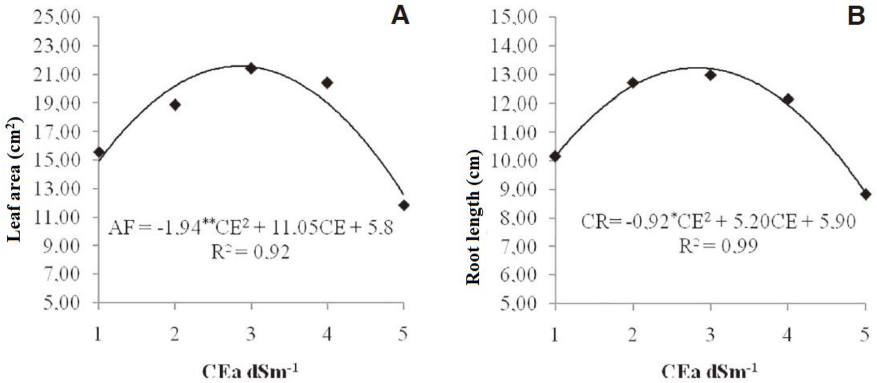


**Figure 4.** Leaf area (**A**) and root length (**B**), at 27 days after the application of treatments as a function of irrigation water salinity.

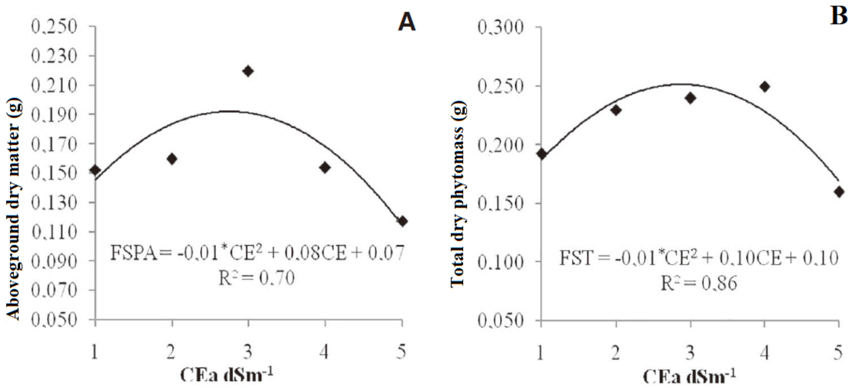


**Figure 5.** Aboveground dry phytomass (**A**) and total dry phytomass (**B**), 27 days after the application of treatments, as a function of irrigation water salinity.

Gondim *et al.*[14], studying the electrical conductivity in the production and nutrition of lettuce in NFT hydroponic cultivation system, also found that the total dry phytomass showed a quadratic response to the increase of the solution EC, reaching a maximum of 100.4 g with 2.68 mS $cm^{-1}$. From this EC, there was a 7.1% reduction in MST at an EC of 4 mS $cm^{-1}$.

There was an effect of salinity ($p < 0.01$) on FFPA, FFR, FFT, FSPA, FSR and FST. There was significant linear effect ($p < 0.01$) on FFPA, FFR, FFT, FSPA, FSR and FST as a function of irrigation water salinity, respectively. Similar results were observed by Silva *et al.*[19], studying water relations in sugar beet cultivars at different soil salinity levels.

Hassanli *et al.*[15], in studies on the influence of irrigation methods and water quality on sugar beet production, observed a significant effect of water salinity on growth. The reduction in values is attributed to the increased osmotic potential of the soil solution, due to the excess salts present, hindering the absorption of water by the plant, making it require greater energy effort for the absorption of water and nutrients, thus reducing its growth[16].

As the salinity of the irrigation water increased, there was an increase in the fresh phytomass of the aerial part and root at 42 days after application of the saline treatments (**Figure 6A** and **B**). The highest yield for both variables was observed with 5 dS $m^{-1}$, corresponding to 3.13 and 0.59 g, respectively, which probably can be explained by the high rainfall during the experimental period, causing leaching of salts present in the root zone of the plants.

These results are in disagreement with those found in several studies, such as those of Putti *et al.*[17], Paulus *et al.*[18], Silva *et al.*[19], Silva *et al.*[20] and Silva *et al.*[21], studying the effect of salts on various crops. According to Greenway and Munns[22], cultivation with 200 mM NaCl for a given period of time may cause the death of sensitive species such as beans, cause reductions of up to 60% in the biomass of species such as cotton, or reduce the dry matter weight of beets by 20%.

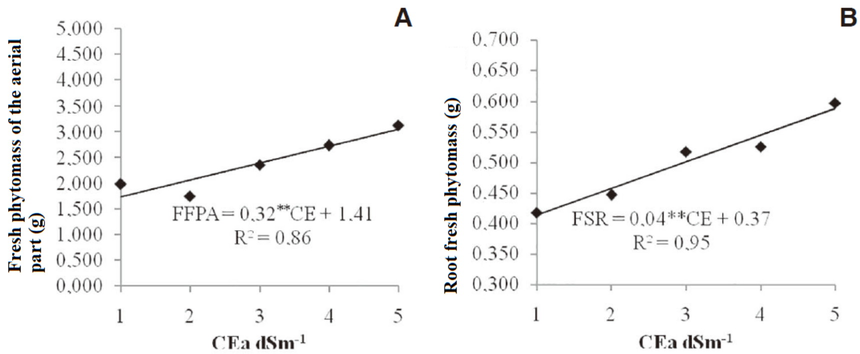


**Figure 6.** Aboveground fresh phytomass (**A**) and root fresh phytomass (**B**), at 42 days after treatment application, as a function of irrigation water salinity.

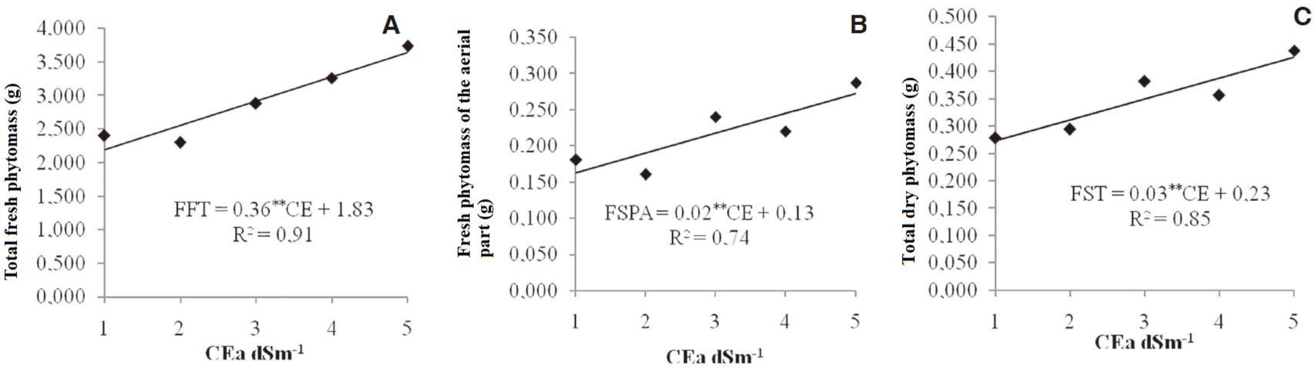


**Figure 7.** Total fresh phytomass (**A**), aboveground fresh phytomass (**B**) and total dry phytomass (**C**), at 42 days after the application of treatments, depending on the salinity of the irrigation water.

According to the regression studies, the mathematical model that best fitted the data of total fresh phytomass, aboveground dry phytomass, and total dry phytomass was linear at 42 days after the application of the salt treatments (**Figures 7A**, **B**, and **C**).

It was found that, as the salinity of irrigation water increased, there was an increase in the phytomass of beet plants, with the highest value observed at a salinity of 5 dS $m^{-1}$, corresponding to 3.73, 0.28 and 0.48 g, respectively, for the total fresh, dry and total dry phytomass. However, this increase in mass may be related to the fact that the leaves at higher levels are thicker and less flexible, which may be associated with the fact that the beet culture is considered tolerant to the effects of salts, and for a salinity of 4.7 dS $m^{-1}$, there is no reduction in the yield of the culture. Thus, as the treatments studied are within the salinity tolerated by the culture, there were no losses in yield[6]. However, attention should be paid to the rainfall during the period, which may have leached salts from the soil, compromising the results of the research.

However, it is worth noting, tolerance depends on the plant's ability to control salt transport at five specific points: 1) selectivity in the absorption process by root cells; 2) loading of the xylem preferentially with $K^+$, rather than with $Na^+$; 3) removal of salt from the xylem in the upper part of the roots, stem, petiole or leaf sheaths; 4) retranslocation of $Na^+$ and $Cl^-$ in the phloem, ensuring the absence of translocation to tissues of the growing aerial part, and excretion of salts by glands or vesicular pores[23].

## 4. Conclusions

The maximum values in sugar beet, at 27 days after the application of saline treatments, was obtained with a salinity of 3.0 dS $m^{-1}$, for the variables plant height, stem diameter, root length, aboveground dry phytomass and total dry phytomass.

At 42 days after the application of the salt treatments, the variables aerial fresh phytomass, root fresh phytomass, total fresh phytomass, aerial dry phytomass, and total dry phytomass increased with increasing water salinity.

The rainfall may have influenced the result obtained in the evaluation performed at 42 days after the application of the salt treatments.

## Conflict of interest

The authors declared that they have no conflict of interest.

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