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# Seedling of development and tolerance of eggplant cultivars under saline stress

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**This study aimed to evaluate the initial growth and tolerance of eggplant cultivars under saline water irrigation. The experiment was carried out in protected environment (greenhouse) at the Federal University of Campina Grande - UFCG, located in the municipality of Pombal-PB, Brazil. The experiment was set in a completely randomized design, in a 2 × 5 factorial scheme, corresponding to two eggplant cultivars ($C_1$ - 'Comprida Roxa' and $C_2$ - 'Preta Comprida/Enbu') and five levels of irrigation water salinity (0.6, 1.2, 1.8, 2.4 and 3.0 dS $m^{-1}$), with four replication and five plants per replication. Plants were grown for 30 days on trays with 30 cells, with capacity for 0.1 $dm^3$ of substrate, monitored in relation to emergence, growth and phytomass accumulation, and evaluated with respect to the salinity tolerance index. Emergence, growth and dry matter accumulation of eggplant cultivars were negatively affected by the increase in irrigation water salinity. The cultivar 'Comprida Roxa' showed higher tolerance to irrigation water salinity in comparison to 'Preta Comprida/Enbu'.**

**Key words:** *Solanum melongena* L., irrigation, saline water, plant emergence.

## INTRODUCTION

Eggplant (*Solanum melongena* L.) is an herbaceous plant from the Solanaceae family, with annual cycle, and its centers of origin are the tropical regions of the East. In Brazil, areas cultivated with eggplant have expanded and surpassed 1500 ha, due to its medicinal properties, such as the potential to reduce cholesterol levels, and for being an important source of minerals and vitamins (Gonçalves et al., 2006).

This crop is cultivated in all regions of the country, especially in the Northeast, where it plays a fundamental role in the generation of jobs and income in family farming. However, this region faces problems with the quantitative and qualitative scarcity of water resources and thus has demanded the use of alternatives for the irrigation of crops, such as the use of water with concentrations of dissolved salts. In spite of that, studies on eggplant are scarce under salinity conditions (Bosco et al., 2009; Lima et al., 2015) and, with respect to the

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**Table 1.** Chemical characteristics of the components of the substrates used in eggplant cultivation.

| Substrate | EC | pH | P | $K^+$ | $Ca^{+2}$ | $Mg^{+2}$ | $Na^+$ | $Al^{3+}$ | $H^+$+$Al^{3+}$ | CEC | OM |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | dS $m^{-1}$ (1 : 2.5) | $H_2$0 | mg $dm^{-3}$ | | | | $cmol_c dm^{-3}$ | | | | G $kg^{-3}$ |
| A | 0.09 | 8.07 | 3.00 | 0.32 | 6.40 | 3.20 | 0.18 | 0.00 | 0.00 | 10.49 | 16.0 |
| B | 1.65 | 5.75 | 86.00 | 1.67 | 11.60 | 28.50 | 17.84 | 0.00 | 11.88 | 71.49 | 570.0 |

EC = electrical conductivity; CEC = cation exchange capacity; OM = organic matter; A = Soil; B = commercial substrate.

**Table 2.** Chemical analysis of the freshwater used in the preparation of the solutions.

| EC (dS $m^{-1}$) | pH | $K^+$ | $Ca^{+2}$ | $Mg^{+2}$ | $Na^+$ | $SO_4^{-2}$ | $CO_3^{-2}$ | $HCO_3^-$ | $Cl^-$ | RAS (mmol $L^{-1})^{0.5}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | ($mmol_c.L^{-1}$) | | | | | |
| 0.3 | 7.0 | 0.3 | 0.2 | 0.6 | 1.4 | 0.2 | 0.0 | 0.8 | 1.3 | 2.21 |

EC = electrical conductivity; SAR = Sodium adsorption ratio.

tolerance of eggplant cultivars to saline stress, such studies are absent in literature.

In general, the limit of tolerance to saline stress depends on the concentration of the salt in solution, time of exposure and the developmental stage of the plants (Munns and Tester, 2008). The eggplant crop is classified as moderately sensitive to salinity and shows threshold salinity of 1.5 dS $m^{-1}$ (Ünlünkara et al., 2010).

Nonetheless, the results given by many authors in the literature show divergence with respect to the limit of tolerance to salinity in the case of this crop: Bosco et al. (2009) reported significant reduction in growth and production of shoots and roots for threshold salinity of 4.08 dS $m^{-1}$ with the cultivar 'Florida Market'; Lima et al. (2015) observed that the salinity above 0.5 dS.$m^{-1}$ reduced plant growth and fruit production in eggplant. According to these authors, the crop is sensitive to salinity. On the other hand, Queiroz et al. (2013) has reported that in eggplant cultivation with the application of nutrient solutions with salinity levels ranging from 0.5 to 6.0 dS $m^{-1}$, did not show any significant effect of salinity on plant growth. Such divergence in the case of the reports corroborates that salinity tolerance varies depending on genetic factors of the cultivars, adopted cultural management and local edaphoclimatic conditions where the crop is grown (Moura and Carvalho, 2014; Oliveira et al., 2014; Lima et al., 2015) and evidences the importance of studying potential cultivars more tolerant to salinity in each region. Given the above, this study aimed to evaluate the initial growth and tolerance of eggplant cultivars under saline water irrigation.

## MATERIALS AND METHODS

The experiment was carried out from August to September 2014 in a protected environment (green house), at the Center of Science and Agrifood Technology (CCTA) of the Federal University of Campina Grande (UFCG) located in the municipality of Pombal-PB, Brazil (6°47'20'' S; 37°48'01'' W; 194 m).

The experiment was set in a completely randomized design, in a 2 × 5 factorial scheme, which corresponded to two eggplant cultivars ($C_1$ - 'Comprida Roxa' and $C_2$ - 'Preta Comprida/Enbu') and five levels of irrigation water salinity (0.6, 1.2, 1.8, 2.4 and 3.0 dS $m^{-1}$), with four replicates and five plants per replicate.

Eggplant plants were cultivated on trays with 30 cells, with the capacity for 0.1 $dm^3$ of substrate, until 30 days after sowing (DAS). The substrate used for the production of seedlings was composed of soil (Entisol fluvisol) and commercial substrate, mixed at the proportion of 1:1, and its chemical characterization is presented in Table 1.

For sowing, five tray cells were used in each treatment, so that each cell received two seeds, in a total of 10 seeds per treatment. At the end of plant emergence, thinning was performed, leaving only the most vigorous plant per cell. The seeds of both cultivars were obtained at a commercial house, with 99% of purity and 95% of germination.

Irrigation was daily performed in order to maintain the soil close to its maximum holding capacity, based on the drainage lysimetry method, and the applied water depth was summed to a leaching fraction of 20%. The applied volume ($V_a$) per container was obtained by the difference between the previously applied volume ($V_{prev}$) and the drained volume (d), divided by the number of containers (n), as indicated in Equation 1.

$$V_a = \frac{V_{prev} - D}{n(1 - FL)} \tag{1}$$

The preparation of irrigation waters corresponding to the respective salinity levels was based on the relationship between $EC_w$ and the concentration of salts (10 * meq $L^{-1}$ = 1 dS $m^{-1}$ of $EC_w$), according to Rhoades et al. (1992), valid for $EC_w$ of 0.1 to 5.0 dS $m^{-1}$, which encompasses the tested levels. Freshwater from the local supply system ($EC_w$ = 0.3 dS $m^{-1}$), whose chemical characteristics are shown in Table 2, was used in the preparation of the other irrigation waters, after mixing with NaCl, according to necessity. The desired level of electrical conductivity was measured using a portable microprocessor-based conductivity meter, with automatic temperature adjustment.

After preparation, the waters corresponding to each salinity level were stored in 30-L plastic containers, which were covered to avoid evaporation, entry of rainwater and contamination with materials that could compromise quality.

During the experiment, plants were monitored with respect to emergence through the daily count of emerged plantlets, that is, with the cotyledons above the soil level, generating a cumulative

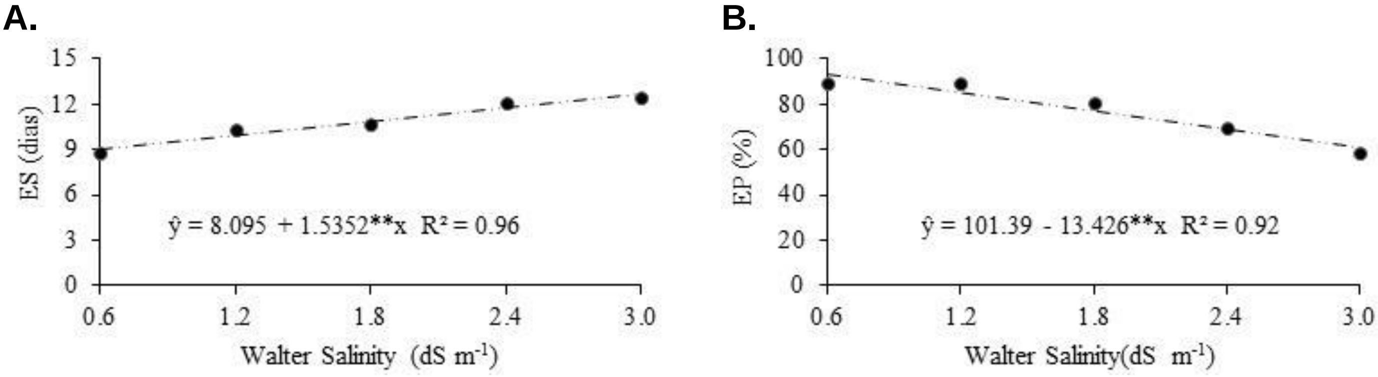

**Figure 1.** Emergence speed (ES) (A) and emergence percentage (EP) (B) of eggplant cultivars under different levels of

value. Thus, the number of emerged plantlets for each count was obtained by the subtraction of the value read. With the value read on the previous day and the number of emerged plants referring to each reading, emergence speed (ES) (days) was calculated according to Equation 2, described in Schuab et al. (2006).

$$ES = \frac{(N_1G_1)+(N_2G_2)+...+(N_nG_n)}{G_1+G_2+...+G_n} \quad (2)$$

Where, ES = emergence speed (days); G = number of emerged plantlets observed in each count; N = number of days from sowing to each count.

After stabilization of emergence, emergence percentage (EP) (%) was determined through the relationship between the number of emerged plants and the number of planted seeds.

Morphological evaluation of plantlet growth, at 30 DAS, was performed with the determination of plant height (PH) (cm), measured with a graduated ruler as the distance from the soil to the apex of the plant, stem diameter (SD), measured with a digital caliper, 1 cm high from the soil surface, and number of leaves (NL), through the count of mature leaves. After morphological analyses, plants were collected and separated into shoots and roots, which were dried in a forced-air oven at 65°C until constant mass, for the determination of shoot dry matter (SDM) (g) and root dry matter (RDM) (g) on an analytical scale. Total dry matter (TDM) (g) corresponded to the sum of SDM and RDM.

The data of total dry matter production were used to calculate the percentages partitioned between the vegetative organs and the salinity tolerance index (STI), comparing the saline treatments with the control ($EC_w$ = 0.6 dS.m$^{-1}$) through Equation 3.

$$STI(\%) = \frac{\text{TDM production in the saline treatment}}{\text{TDM production in the control treatment}} x100 \quad (3)$$

The data were subjected to analysis of variance by F test and, when significant, regression analyses were applied for the factor levels of irrigation water salinity and Tukey test for the factor cultivars, both at 0.05 probability level, using the statistical program SISVAR® (Ferreira, 2011).

## RESULTS AND DISCUSSION

Emergence speed (ES) data were best fitted to a linear model and increased as the levels of irrigation water salinity increased; at the highest level (3.0 dS m$^{-1}$), there was an increment of 42% in the ES of eggplant plants (Figure 1A). As to emergence percentage (EP), a linear reduction was observed as salinity increased, which was equal to 52.4% (58.3%) when plants were irrigated with $EC_w$ of 3.0 dS m$^{-1}$, in comparison to the control (0.5 dS m$^{-1}$) (Figure 1B).

Considering that the germination process depends on the absorption of water and energy, through heat, the reduction in the osmotic potential due to the increase in NaCl contents in the soil decreases soil water potential, reducing the energy of the water in the soil and causing the plant to perform osmotic adjustment (Sá et al., 2013). In addition, the increase in the concentration of NaCl ions causes toxicity to plants and may cause damages to the radicle, thus limiting the seed imbibition process and the absorption of water by the plantlet (Munns and Tester, 2008; Voigt et al., 2009; Taiz and Zaiger, 2013). Similar results were observed in other vegetables such as melon (Secco et al., 2010), broccoli (Lopes et al., 2014), beet (Oliveira et al., 2015a) and cabbage (Oliveira et al., 2015b).

For the variables plant height (PH), stem diameter (SD) and number of leaves (NL), there were progressive reductions in the data, which were best fitted to a linear model, with decreases of 76% (1.87 cm) in PH (Figure 1A), 14.1% (1.06 mm) in SD (Figure 2C) and 69.1% (2.17) in NL (Figure 1D) for plants under $EC_w$ of 3.0 dS.m$^{-1}$, in comparison to the control (0.6 dS m$^{-1}$). The inhibition of growth caused by salinity is due to the osmotic effect, because it promotes physiological drought. Likewise, there may be a toxic effect, resulting from the concentration of ions in the protoplasm. Hence, the reduction in the water potential of the tissues caused by the excess of salts in the soil solution leads to restrictions in elongation and cell division rates, thus reducing plant growth (Munns and Tester, 2008; Queiroz et al., 2013; Taiz and Zaiger, 2013; Sá et al., 2013; Oliveira et al., 2015a).

The factor cultivars influenced the variables shoot dry matter (SDM), root dry matter (RDM) and total dry matter

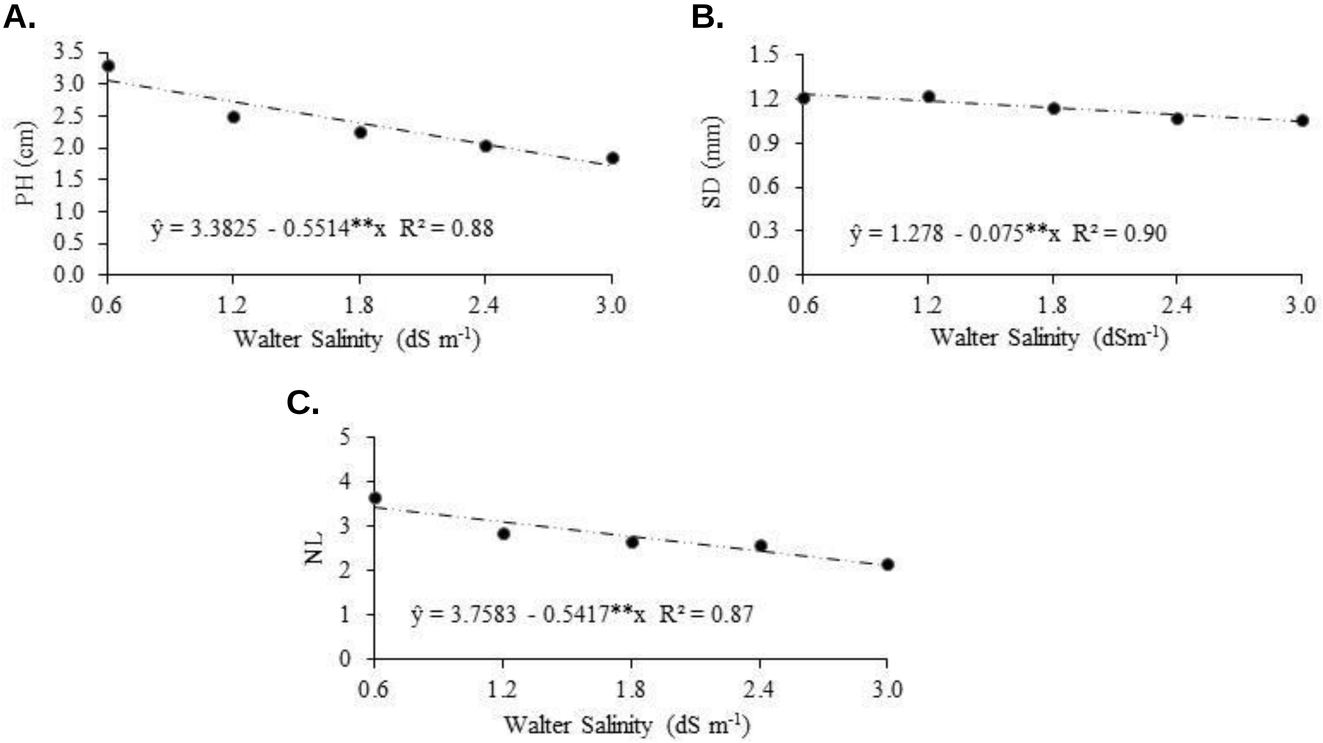

**Figure 2.** Plant height (PH) (A), stem diameter (SD) (B) and number of leaves (NL) (C) of eggplant cultivars under different levels of irrigation water salinity. ** = Significant at 0.01 probability level.

(TDM). For these variables, in the comparison between cultivars, it was observed that the cultivar ‘Preta Comprida/Enbu’ stood out with accumulations of 0.0086, 0.0028 and 0.0114 g for SDM, RDM and RDM, respectively (Figure 3B, D and F). Additionally, for the factor Salinity, according to the regression equations, the linear model indicated decreases in dry matter production with the increment in irrigation water EC, which were equal to 29.7% (0.0074 g) in SDM (Figure 3A), 129.4% (0.0017 g) in RDM (Figure 3C) and 48.3% (0.0091 g) in TDM (Figure 3E), in plants under $EC_w$ of 3.0 dS $m^{-1}$, in relation to the control.

Considering that saline water irrigation increases the index of salinization of the soils and the abundant presence of toxic ions in these soils, due to the accumulation of salts, especially $Na^+$ salts, there might occur nutritional imbalance, modification in the osmotic potential of the plant and physiological alterations that interfere with the accumulation of photoassimilates and, consequently, with the accumulation of dry matter (Munns and Tester, 2008; Esteves and Suzuki, 2008; Garcia et al., 2012; Sá et al., 2013; Silva et al., 2013; Lima et al., 2015). Similar results have been reported in the literature. Lima et al. (2015), studying the tolerance of the eggplant hybrid ‘Ciça’ to irrigation water salinity, observed that the crop was sensitive to salinity. These authors reached such a conclusion after observing that crop development was already negatively affected at salinity levels above 0.6 dS $m^{-1}$. On the other hand, in a study with the same hybrid, Silva et al. (2013) observed significant reduction in dry matter production of eggplant only at salinity levels above 3.3 dS $m^{-1}$.

As to the root/shoot ratio (R/S), according to the regression equation, the data were best fitted to a decreasing linear model, and the highest level of irrigation water salinity (3.0 dS $m^{-1}$) led to a reduction of 78.3% (0.23) in R/S, compared with the control (Figure 4). For Sá et al. (2013), this response is related to the greater reduction in root growth, compared with the shoots, aiming to reduce the absorption of salts from the environment, especially in environments with higher salinity levels. This fact was confirmed in the present study, considering the drastic reductions observed in RDM accumulation (Figure 3B). Similar results were observed by Oliveira et al. (2015b), evaluating phytomass accumulation of cabbage plants under saline stress.

Regarding the salinity tolerance index (STI), there were reductions in the tolerance of the cultivars as irrigation water salinity increased, reaching approximately 48.1% in plants irrigated with $EC_w$ of 3.0 dS $m^{-1}$, in relation to the control (Figure 5A). For the factor Cultivars, it can be noticed that the cultivar ‘Comprida Roxa’ obtained the highest indices of tolerance, equal to 83.99 and 6.87% higher than that of ‘Preta Comprida/Enbu’ (Figure 5B). Although higher phytomass accumulations were observed in the cultivar 'Preta Comprida/Enbu', these plants

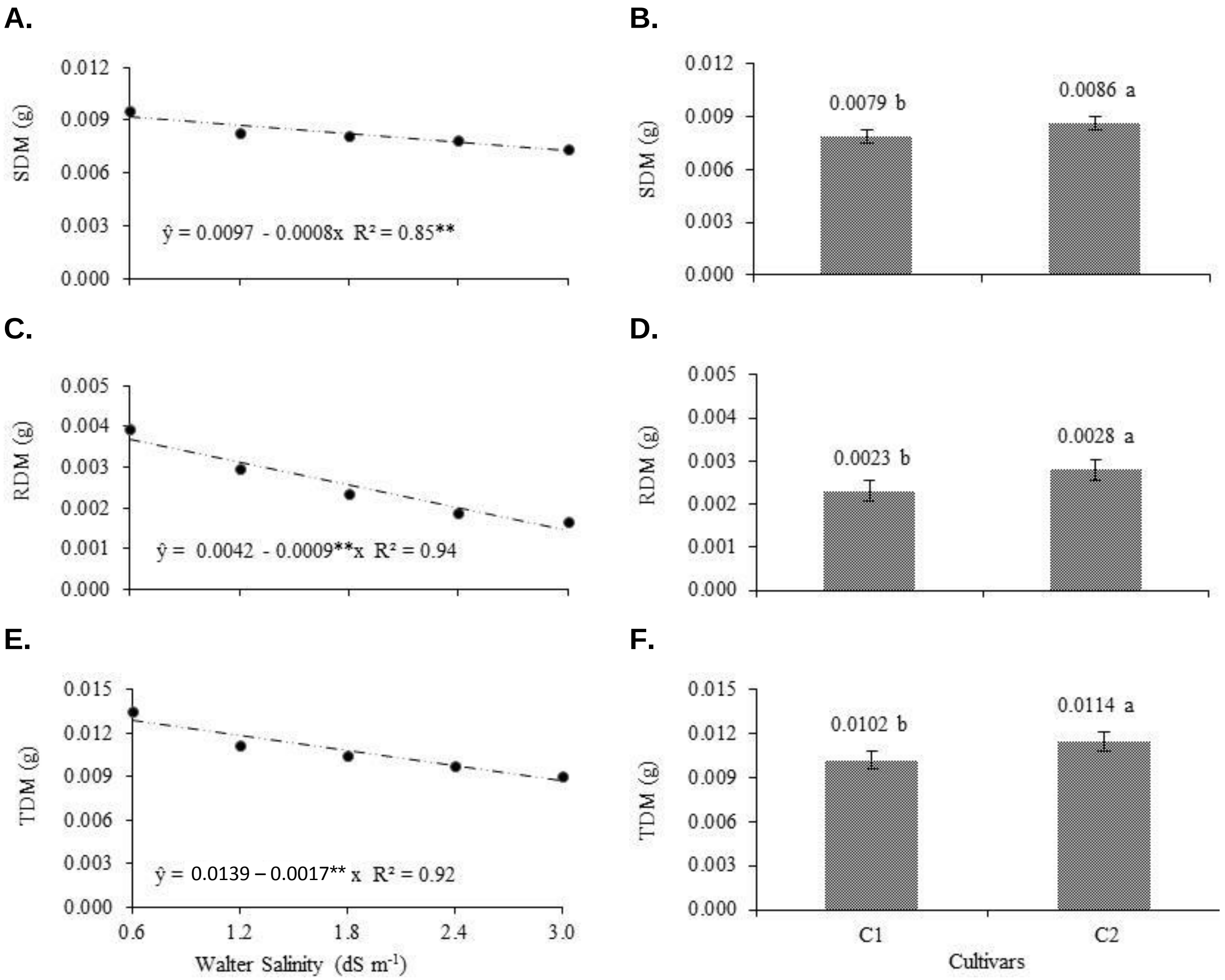

**Figure 3.** Shoot dry matter (SDM) (A and B), root dry matter (RDM) (C and D) and total dry matter (TDM) (E and F) of eggplant cultivars ($C_1$ - 'Comprida Roxa' and $C_2$ - 'Preta Comprida/Enbu') under different levels of irrigation water salinity. ** = Significant at 0.01 probability level; Equal letters do not differ by Tukey test at 0.05 probability level.

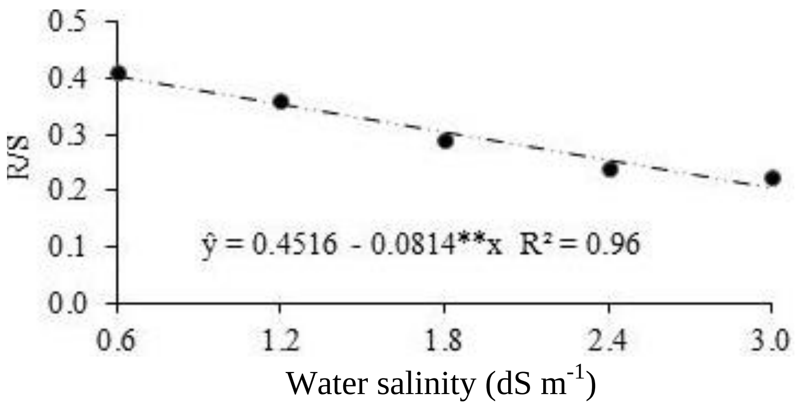

**Figure 4.** Root/shoot ratio (R/S) of eggplant cultivars under different levels of irrigation water salinity. ** = Significant at 0.01 probability level.

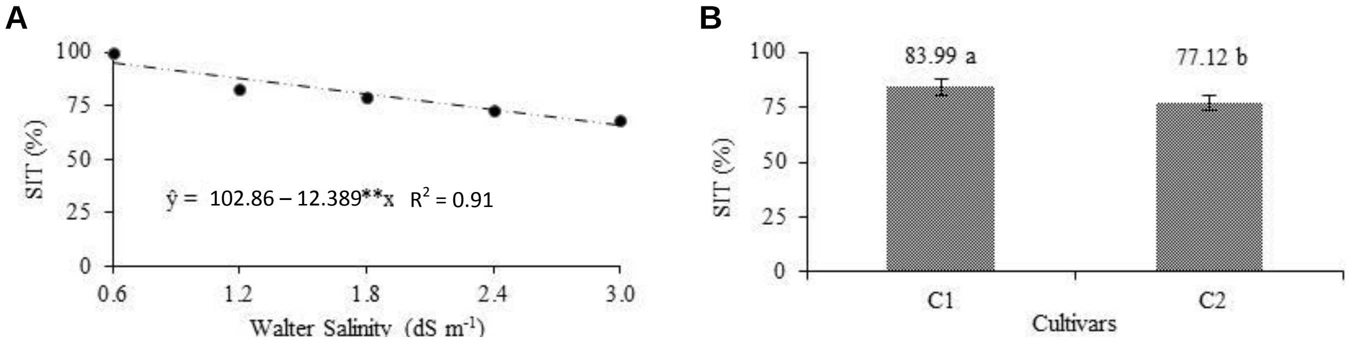

**Figure 5.** Salinity tolerance index (STI) of eggplant cultivars ($C_1$ - 'Comprida Roxa' and $C_2$ - 'Preta Comprida/Enbu') under different levels of irrigation water salinity. ** = Significant at 0.01 probability level; Equal letters do not differ by Tukey test at 0.05 probability level.

greater losses in phytomass accumulation as water salinity progressively increased. These reductions were higher than those observed in the cultivar 'Comprida Roxa', which presents itself as more tolerant to salinity.

## Conclusions

Emergence, growth and dry matter accumulation of the eggplant cultivars were negatively affected by the increase in irrigation water salinity. The cultivar 'Comprida Roxa' shows higher tolerance to irrigation water salinity in comparison to 'Preta Comprida/Enbu'.

## Conflict of Interests

The authors have not declared any conflict of interests.

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