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Tolerance of tomato seedling cultivars to different values of irrigation water salinity[1]

Tolerância de cultivares de mudas de tomate a diferentes valores de salinidade da água de irrigação

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HIGHLIGHTS:
A low value of electrical conductivity of irrigation water does not affect the production of tomato seedlings.
Irrigation water with electrical conductivity above 2.31 dS m^{-1} impairs root growth and quality of tomato seedlings.
Maestrina and Coração de Boi were the tomato cultivars most tolerant to irrigation water with electrical conductivity of 3.0 dS m^{-1}.

ABSTRACT: The use of water with different salinity values in the production of vegetable seedlings is an issue of global concern; therefore, selecting tomato cultivars with tolerance to saline water is essential to improve the fruit quality and production. This study aimed to estimate the maximum electrical conductivity of irrigation water that does not harm the production of tomato seedlings and find cultivars with tolerance to the effects of salinity in this phase. In the first experiment, the treatments were arranged in a 3 × 8 factorial scheme (three tomato cultivars and eight values of electrical conductivity of irrigation water). The second experiment was arranged in a 10 × 3 factorial scheme (10 cultivars and three values of electrical conductivity of irrigation water). The 50% reduction in the root dry matter accumulation occurred with the electrical conductivity of irrigation water (ECw) of 2.31 dS m^{-1}. The reduction of more than 50% of the Dickson quality index was observed with an ECw of 6.38 dS m^{-1}. Irrigation with 3.0 dS m^{-1} impairs the complete emergence and growth of seedlings of all tomato cultivars. Coração de Boi, Dominador, Maestrina, Sheena, and Shanty were the tomato cultivars most tolerant to the irrigation water with 3.0 dS m^{-1} of ECw. The electrical conductivity of irrigation water higher than 2.31 dS m^{-1} impairs the root growth of tomato seedlings.

Key words: *Solanum lycopersicon*, salt stress, osmotic potential, root development

RESUMO: O uso de água salina na produção de mudas de hortaliças é uma questão de preocupação mundial, portanto, selecionar cultivares de tomate com tolerância à água salina é essencial para uma melhor qualidade e produção dos frutos. Este trabalho teve como objetivo estimar o nível máximo de salinidade da água de irrigação que não prejudique a produção de mudas de tomateiro e encontrar cultivares com tolerância aos efeitos da salinidade nesta fase. No primeiro experimento os tratamentos foram dispostos em esquema fatorial 3 × 8 (três cultivares de tomateiro foram cultivadas sob oito valores de condutividade elétrica da água de irrigação) e no segundo experimento em esquema fatorial 10 × 3 (com 10 cultivares e três valores de condutividade elétrica da água de irrigação). A redução de 50% no acúmulo de matéria seca radicular ocorreu com a condutividade elétrica da água de irrigação (CEa) de 2,31 dS m^{-1}. A redução de mais de 50% do índice de qualidade de Dickson foi observada com CEa de 6,38 dS m^{-1}. A irrigação com 3,0 dS m^{-1} prejudica a emergência e o crescimento de todas as plântulas das dez cultivares de tomateiro, sendo as cultivares Coração de Boi, Dominador, Maestrina, Sheena e Shanty as mais tolerantes a condições de irrigação salina com 3.0 dS m^{-1}. A condutividade elétrica da água de irrigação superior a 2,31 dS m^{-1} prejudica o crescimento radicular de mudas de tomateiro.

Palavras-chave: *Solanum lycopersicon*, estresse salino, potencial osmótico, desenvolvimento de raizes

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Introduction

The use of irrigation is essential in the production of tomato seedlings. Water quality is crucial for the better health and quality of tomato seedlings. Cultivating tomato plants on saline soils and irrigation with saline water is one of the main environmental challenges limiting global agricultural production. It must be addressed to obtain high yields (Oliveira et al., 2022).

Salinity affects plant growth at all growth stages; however, its sensitivity depends on the stage and genotype. The seed germination stage is more sensitive to salinity because increasing salinity severely inhibits seedling emergence (Fuller et al., 2012). Excessive salinity can cause ionic toxicity and water and nutrient deficiency, inhibiting plant growth (Acosta-Motos et al., 2017). Thus, the excessive salt concentration in soil solution and irrigation water negatively affects the physiology, growth, and yield of crops (El-Mogy et al., 2018).

The capacity of tolerance to salt stress ranges differently among the genotypes of tomatoes (Oliveira et al., 2022). It is possible to identify the most tolerant tomato genotypes to the effects of salinity based on the critical plant stage of cultivation (Kadoglidou et al., 2021).

Although there are many studies on salinity in tomatoes, there is lacking literature on the effects of salinity on seedling production of tomatoes. The seedlings are grown in a substrate where the salinity of the extract does not influence the production of tomato seedlings. However, the use of saline water can harm the production of seedlings. In this way, this study aimed to estimate the maximum electrical conductivity of irrigation water that does not harm the production of tomato seedlings and select cultivars that produce adequate quality seedlings even under saline irrigation conditions.

Material and Methods

The study was carried out in Cassilândia, state of Mato Grosso do Sul, at 19°05’28.6” S and 51°48’50.3” W, and an altitude of 539 m. The first experiment was carried out from March to May 2019 (Figure 1A), and the second was carried out from September to November 2019 (Figure 1B), both under protected environment conditions.

Sowing was carried out in 128-cell polystyrene trays filled with 40 cm^3 of substrate for the seedling production of tomato. The substrate had the following chemical properties: pH (H_2O): 6.8, pH ($CaCl_2$): 5.6, organic matter: 200 g dm^{-3}, P (Mehlich^{-1}): 50.8 mg dm^{-3}, K^+: 1.04 $cmol_c$ dm^{-3}, Ca^{2+}: 15.51 $cmol_c$ dm^{-3}, Mg^{2+}: 10.45 $cmol_c$ dm^{-3}, H + Al: 4.00 $cmol_c$ dm^{-3}, Al^{3+}: 0.00 $cmol_c$ dm^{-3}, CEC: 31.00 $cmol_c$ dm^{-3}, Sum of basis: 27.00 $cmol_c$ dm^{-3}, Zn: 22.50 mg dm^{-3}, Cu: 0.20 mg dm^{-3}, Fe: 109.00 mg dm^{-3}, Mn: 54.30 mg dm^{-3}, B: 1.33 mg dm^{-3}, S: 15.20 mg dm^{-3}, base saturation: 87.1%, and electrical conductivity of the extract: 0.63 dS m^{-1}. The completely randomized design (CRD) with four replications was used in both experiments. The experimental unit consisted of 8 seedlings. The treatments in the first experiment were arranged in a 3 × 8 factorial scheme. The first factor consisted of three tomato cultivars (Santa Cruz Kada, Santa Adélia, and IPA 6). The characterizations of each tomato genotype are summarized in Table 1. The second factor consisted of eight values of electrical conductivity of irrigation water: 0.02 (control), 1, 2, 3, 4, 6, 8, and 10 dS m^{-1}. The preparation of water with distinct values of electrical conductivity was carried out according to the equation as previously described by Oliveira et al. (2022): $CE = 0.1676 + 2.0193\ Q_{NaCl}$ ($R^2 = 0.999$; $p \leq 0.01$). Where CE is the electrical conductivity of the solution (dS m^{-1}), and Q_{NaCl} is the concentration of NaCl (g L^{-1}).

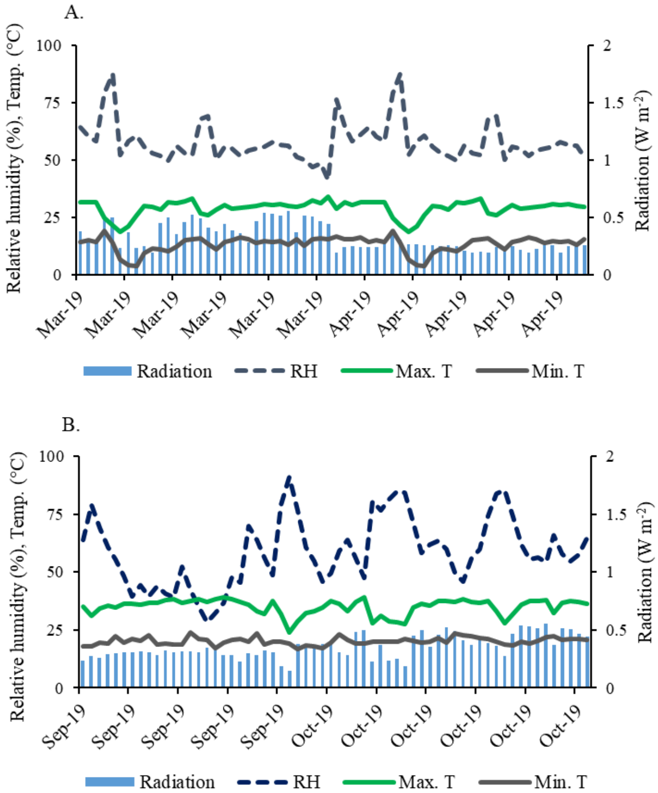


Figure 1. Relative air humidity (RH), maximum air temperature (Max. T), minimum air temperature (Min. T), and radiation during the first (A) and second experiment (B).

The treatments of the second experiment were arranged in a 10 × 3 factorial scheme and consisted of 10 tomato cultivars grown under eight salinity values of irrigation water. The water without NaCl was considered the control, with 0.02 dS m^{-1} of electrical conductivity. The other values of water electrical

Table 1. Characteristics of tomato cultivars evaluated in the experiments

Cultivars	Fruit shapes	Cycle	Growth habit
	Experiment 1		
Santa Cruz Kada	Round	120	Indeterminate
Santa Adélia	Roma	120	Determined
IPA 6	Round	115	Determined
	Experiment 2		
Santa Clara 5800	Round	110 days	Determined
Coração de Boi	Round	120 days	Indeterminate
IPA 6	Round	115 days	Determined
Maestrina	Round	125 days	Indeterminate
Onix	Round	125 days	Indeterminate
Dominador	Round	120 days	Indeterminate
Shanty	Italian	120 days	Determined
Sheena	Italian	115 days	Determined
Sperare	Italian	115 days	Indeterminate
Pizzamonty	Italian	120 days	Indeterminate

conductivity were obtained with the dilution of NaCl and correspond to 1.5 (low) and 3.0 dS m^{-1} (high). The typical characteristics of tomato cultivars are described in Table 1

The number of seedlings that emerged was recorded daily. The emergence speed index (ESI) was estimated according to the equation proposed by Maguire (1962). The percentage of emergence was estimated from the data of final counting. At 35 days after sowing, seedling height (SHT), stem diameter (SD), shoot dry matter (SDM), root dry matter (RDM), and total dry matter (TDM) were assessed. The seedling vigor index (SVI) was estimated according to Eq. 1, proposed by Abdul-Baki & Anderson (1973):

$$\text{SVI} = \text{seedling height (cm)} \times \text{emergence speed index (ESI)} \quad (1)$$

The Dickson quality index (DQI) was estimated according to the Eq. 2, proposed by Dickson et al. (1960) :

$$\text{DQI} = \frac{\text{TDM}}{\left[\left(\frac{\text{SHT}}{\text{SD}}\right) + \left(\frac{\text{SDM}}{\text{RDM}}\right)\right]} \quad (2)$$

The indexes in the equation demonstrated loss of seedling mass accumulation caused by increasing salinity of irrigation water (electrical conductivity of water). According to Steppuhn et al. (2005), the response of plants to salinity has a different behavior according to the increase in electrical conductivity and can be estimated according to the Eq. 3:

$$Y_r = \frac{1}{1 + \left(\frac{\text{ECw}}{\text{EC}_{50}}\right) \exp\left(s\text{EC}_{50}\right)} \quad (3)$$

where:

Y_r - relative yield of each evaluated seedling variable (g g^{-1});

ECw - electrical conductivity of irrigation water (dS m^{-1});

EC_{50} - electrical conductivity of irrigation water corresponding to 50% of the relative yield of each variable in the electrical conductivity of the control treatment (dS m^{-1}); and,

s - decrease in mass yield due to the ECw increase.

The data were preliminarily submitted to the tests of normality and homoscedasticity. The data from electrical conductivity was submitted to the regression analysis ($p \leq 0.05$). The Tukey test compared the means of cultivars ($p \leq 0.05$) in the first experiment. In the second experiment, the tomato cultivars were grouped by the Scott-Knott clustering test ($p \leq 0.05$).

A dendrogram of dissimilarity pattern was obtained by unweighted pair group method with arithmetic mean (UPGMA) based on Gower distance described by Oliveira et al. (2022) among tomato genotypes for each electrical conductivity of irrigation water

Results and Discussion

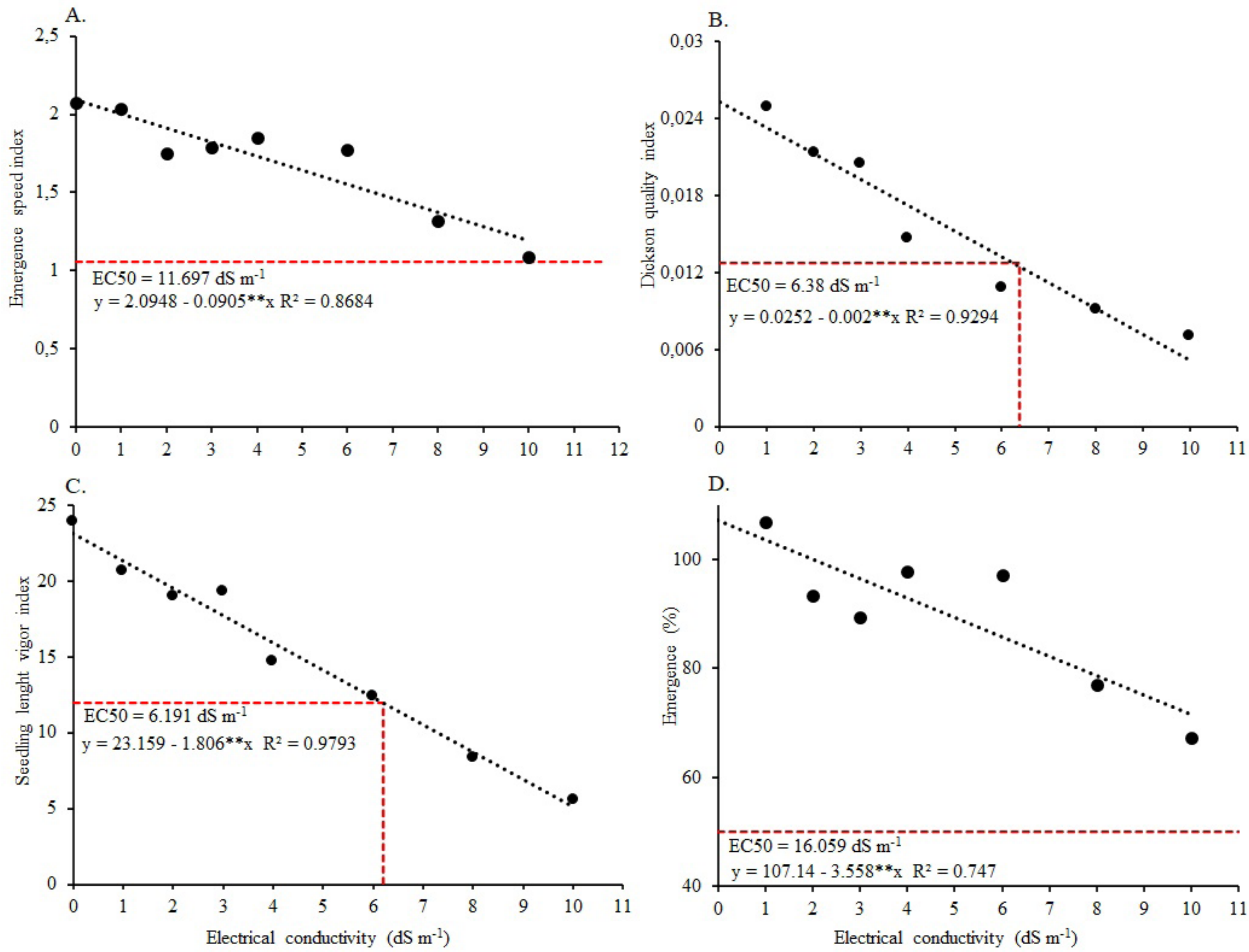
In the first experiment, the growth characteristic of tomato seedlings was decreased with the increased electrical conductivity (ECw) of irrigation water. The emergence speed index, Dickson quality index, and seedling vigor index of tomato cultivars were reduced by 47, 69, and 76%, respectively, in irrigation water with ECw of 10 dS m^{-1} compared to control treatments (Figure 2). There was a 50% reduction in emergence speed index, Dickson quality index, and seedling vigor index at an estimated electrical conductivity of 11.69 dS m^{-1} (Figure 2A), 6.38 dS m^{-1} (Figure 2B), and 6.19 dS m^{-1} (Figure 2C), respectively. The seedling emergence was 33% lower with the ECw of 10 dS m^{-1} concerning the control treatment. A reduction of 50% in the emergence percentage of tomato seedlings was found at an estimated ECw of 16.06 dS m^{-1} (Figure 2D).

The emergence speed index and emergence percentage of tomato seedlings were reduced with the increasing salinity of irrigation water (Figure 2). The delay in the germination process might be due to the osmotic potential of saline water. Kaveh et al. (2011) indicated that low salt concentrations of irrigation water did not influence the emergence percentage of tomato seedlings, while severe salinity has delayed the germination process by disturbing water balance leading to the higher water potential of the substrate. The losses related to seedling emergence constitute a large part of crop production cost. Krohling et al. (2018) reported that seeds for the production of seedlings contribute about 32% of the total effective cost of tomato production. Royo et al. (1991) exhibited that the EC_{50} is the most consistent index for assessing plant tolerance to salinity since it represents the biological effect of salinity on plant growth.

The higher salt concentration of irrigation water hindered seedling vigor and Dickson quality index due to the stressful effect of saline water irrigation during seedlings (Figures 2B, 2C, and 2D). In this sense, the seedling vigor index contributes to the growth and speed of seedling emergence. In contrast, the Dickson quality index contributes to all morphological growth parameters and dry matter accumulation of seedlings under abiotic stress. The current results indicated that the decrease in all variables has contributed to reducing the quality of seedlings under saline water. A previous study reported that excessive salt concentrations suppress plant growth and affect morphology and functioning, consequently decreasing plant dry matter accumulation (Oliveira et al., 2019).

The lowest emergence percentage, emergence speed index, and seedling vigor index were observed in the cultivar Santa Adélia. There was no difference between tomato cultivars for the Dickson quality index (Table 2).

The shoot, root, and total dry matter of tomato seedlings were lower according to the increase in the electrical conductivity of irrigation water, with a decrease of around 70, 80, and 77% using water with 10 dS m^{-1} (Figure 3). The 50% reduction of the dry matter accumulation of shoot, root, and total was estimated at 7.10 dS m^{-1} (Figure 3A), 5.89 dS m^{-1} (Figure 3B), and 2.31 dS m^{-1} (Figure 3C), respectively. The height of seedlings irrigated with saline water with ECw of 10 dS m^{-1} was 56% lower than that of the control treatment. The height loss of 50% was estimated with an ECw of 8.72 dS m^{-1} (Figure 3D).



ns - Not significant by F-test; *, ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by F test, respectively. EC50 - electrical conductivity corresponding to 50% of the relative value of each variable compared to the control treatment (0.02 dS m^{-1})

Figure 2. Emergence speed index (A), Dickson quality index (B), seedling vigor index (C), and percentage of emergence (D) of tomato seedlings according to the electrical conductivity of irrigation water

Table 2. F-values and means of emergence percentage (EMER), emergence speed index (ESI), seedling vigor index (SVI) and Dickson quality index (DQI) of seedlings from three tomato cultivars under different salinity values

Sources of variation	EMER	ESI	SVI	DQI
Cultivar (C)	6.28**	12.89**	20.02**	0.42^{ns}
Salinity (S)	8.04**	10.58**	32.97**	35.63**
Interaction (C×S)	0.52^{ns}	0.97^{ns}	1.09^{ns}	0.72^{ns}
Linear	40.68**	64.27**	226.03**	220.59**
Quadratic	3.10^{ns}	2.56^{ns}	0.36^{ns}	3.95*
Cultivar	**EMER (%)**	**ESI**	**SVI**	**DQI**
Santa Cruz	71.85 a	1.83 a	16.97 a	0.0159 a
Santa Adélia	61.48 b	1.45 b	11.98 b	0.0169 a
Ipa 6	66.07 a	1.86 a	17.50 a	0.0163 a
CV (%)	17.81	21.14	24.85	24.84

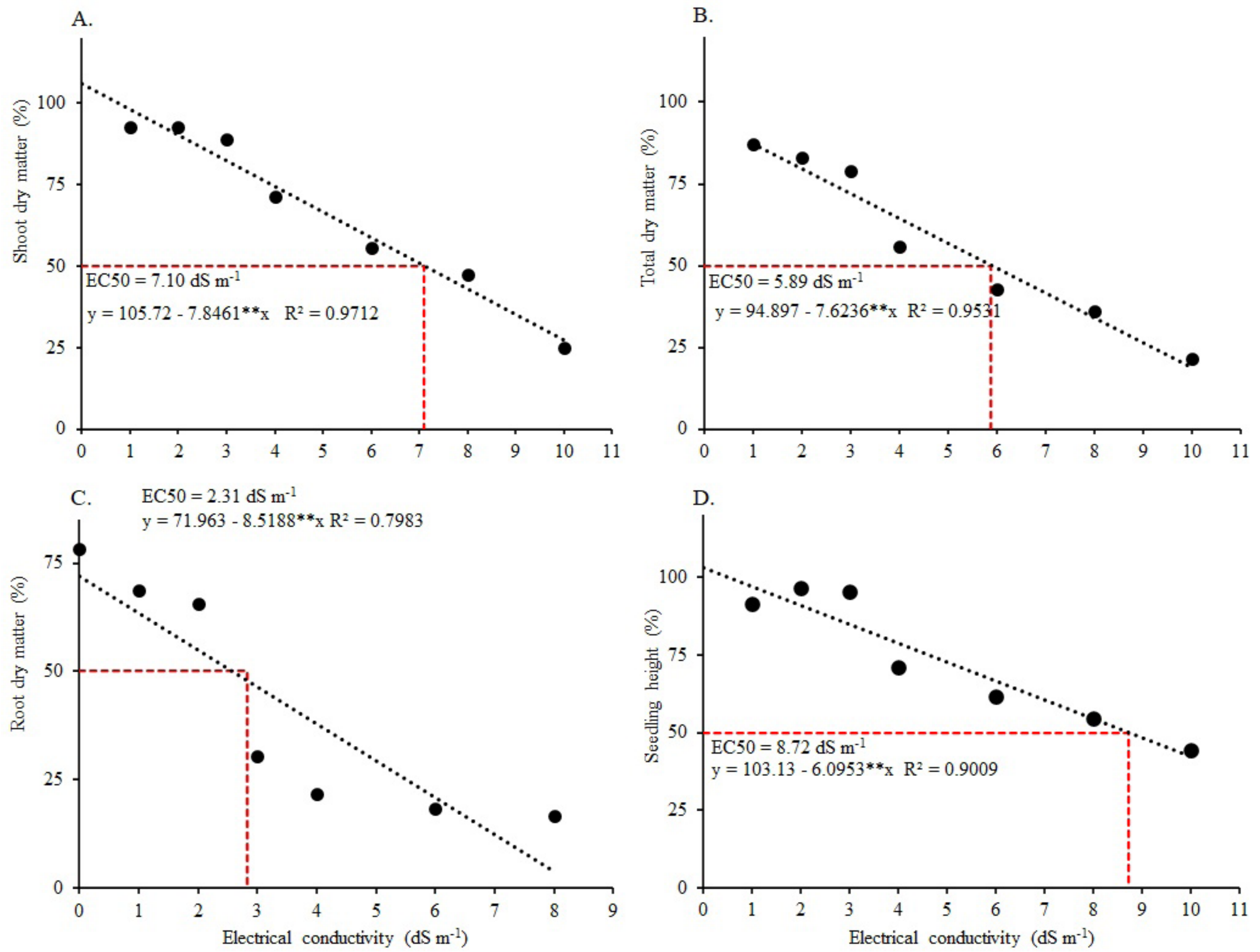
ns - Not significant by F-test; *, ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by F-test, respectively. Means followed by distinct letters in the column differ by the Tukey test at $p \leq 0.05$

Plants subjected to salt stress activate different mechanisms and begin transporting more ions to roots due to competition of low osmotic potential that may affect plant physiology and consequently decrease shoot growth of the plants (Kaveh et al., 2011). The higher salinity can cause water deficiency which decreases the metabolic activity of the plants and contributes to the reduction of plant growth (Oliveira et al., 2022). In addition, tomato plants submitted to low saline concentrations stimulate growth through defense mechanisms that allow the plants to perform osmotic adjustments in stressful conditions (Kahlaoui et al., 2018).

The root system of tomato seedlings is more critical in the initial growth stage since it is responsible for the efficient absorption of water and nutrients for the support and establishment of seedlings in the field without yield loss (Silva et al., 2021). The seedlings had difficulty absorbing water due to higher water retention in the substrate solution, which reduced growth and dry matter accumulation in seedling roots under salinity conditions.

Santa Cruz and Ipa 6 had the tallest seedlings, 14% higher than Santa Adélia. The shoot and total dry matter accumulation of Santa Cruz and Ipa 6 were 18 and 11% higher than the Santa Adélia cultivar. Root dry matter accumulation was not different for the cultivars (Table 3).

The accumulation of root dry matter and the development of the root system are significant for the development of plants since roots can absorb water for seedling maintenance, support, and nutrient absorption. Also, it is the essential structure for establishing seedlings in the field and increasing the uniformity of the plant stand. The use of saline water irrigation impaired the root system of tomato seedlings, thus,



ns - Not significant by F-test; *, ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by F test, respectively. EC50 - Electrical conductivity corresponding to 50% of the relative value of each variable in the control treatment (0.02 dS m^{-1})

Figure 3. Shoot dry matter (A), total dry matter (B), root dry matter (C), and seedling height (D) of tomato seedlings according to the electrical conductivity of irrigation water

Table 3. F-values and means of seedling height (SHT), root dry matter (RDM), shoot dry matter (SDM), and total dry matter (TDM) of seedlings from three tomato cultivars under different salinity values

Sources of variation	SHT	RDM	SDM	TDM
Cultivar (C)	15.459*	0.388^{ns}	10.256**	7.425**
Salinity (S)	77.82**	137.54**	60.66**	112.24**
Interaction (C×S)	0.721^{ns}	2.20^{ns}	1.22^{ns}	0.795^{ns}
Linear	500.24**	518.74 **	414.53**	754.32**
Quadratic	0.111^{ns}	79.45**	0.816^{ns}	10.33**
Cultivar	**SHT**	**RDM**	**SDM**	**TDM**
	(cm)	**(mg seedling^{-1})**		
Santa Cruz	8.98 a	34.84 a	90.65 a	125.49 a
Santa Adélia	7.86 b	33.83 a	76.29 b	110.11 b
Ipa 6	9.07 a	33.45 a	90.63 a	124.08 a
CV (%)	17.22	17.81	17.05	14.72

ns - Not significant by F-test; *, ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by F-test, respectively. Means followed by distinct letters in the column differ by the Tukey test at $p \leq 0.05$

reducing the accumulation of root dry matter with increasing values of salinity, which delayed the performance of the crop, reducing its yield and consequently decreasing the profitability of producers (Figure 4).

In the second experiment, the highest seedling emergence was found in the cultivars Sperare, Pizzamonty, Santa Clara, Coração de Boi, Dominador, Sheena, and Shanty, at least 13% higher than other cultivars. Coração de Boi, Dominador, Sheena, and Shanty had a higher emergence speed index, around 8% higher than other cultivars. Sperare, Pizzamonty, Ipa 6, and Santa Clara took more time to complete the emergence. They needed at least 0.6 days longer to emerge than other tomato cultivars, which took less time to complete the emergence and thus started growth processes in advance (Table 4).

The largest stem diameter of tomato seedlings was observed in the cultivars Dominator, Maestrina, and Sheena, around 9% (0.3 mm) larger than others. The lowest height of seedlings was found in the cultivars Sperare and Ipa 6, 10% (1.22 cm) smaller than other tomato cultivars. Higher seedling height was observed in eight cultivars, indicating a genotypic superiority over the other two cultivars. Seedling height and stem diameter are related to the accumulation of solutes in the cell vacuole. The seedlings of Pizzamonty, Santa Clara, Coração de Boi, Dominador, Sheena, and Shanty had the highest seedling vigor index, demonstrating a higher chance of success of seedlings to field conditions after transplanting (Table 4).

The adaptation of cultivars to different environments is entirely related to phenotypic characteristics of the genotype;

Figure 4. Influence of electrical conductivity of irrigation water on the growth of tomato seedlings

Table 4. F-values and means of percentage of emergence (EMER), emergence speed index (ESI), mean emergence time (MET), stem diameter (DIAM), seedling height (SHT), and seedling vigor index (SVI) of seedlings of tomato cultivars in three values of electrical conductivity of irrigation water

Sources of variation	EMER	ESI	MET	DIAM	SHT	SVI
Cultivar (C)	1381**	0.24**	3.14**	0.76**	7.83*	46.56**
Salinity (S)	1312**	1.17**	25.67**	5.91**	178.4**	459.7**
C×S	322^{ns}	0.09^{ns}	0.55^{ns}	0.09^{ns}	1.93^{ns}	6.94^{ns}
Cultivars	**(%)**	**-**	**(days)**	**(mm)**	**(cm)**	**-**
Sperare	77.78 a	0.86 b	7.80 a	2.68 b	10.97 b	9.74 b
Pizzamonty	81.94 a	0.92 b	7.28 a	2.60 b	13.62 a	13.01 a
Ipa 6	63.89 b	0.73 b	7.60 a	2.84 b	11.10 b	8.21 b
Santa Clara	84.72 a	0.98 b	7.55 a	2.90 b	12.32 a	12.58 a
Coração	81.94 a	1.06 a	6.62 b	2.89 b	12.63 a	14.33 a
Dominador	90.28 a	1.13 a	6.68 b	3.41 a	12.83 a	14.61 a
Maestrina	65.28 b	0.79 b	6.86 b	3.39 a	13.88 a	11.22 b
Sheena	90.27 a	1.15 a	6.54 b	3.37 a	12.21 a	13.85 a
Onix	63.88 b	0.88 b	6.64 b	3.08 b	12.55 a	11.77 b
Shanty	100.0 a	1.22 a	5.92 b	2.97 b	12.83 a	15.41 a
Electrical conductivity ($dS\ m^{-1}$)						
0.02	85.00 a	1.14 a	6.29 b	2.61 c	12.16 b	13.99 a
1.5	82.50 a	1.01 a	6.53 b	3.49 a	15.08 a	15.40 a
3.0	72.50 b	0.76 b	8.00 a	2.94 b	10.24 c	8.03 b
CV (%)	16.93	25.32	10.22	13.01	15.63	31.60

ns - Not significant by F-test; *, ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by F-test, respectively. Means followed by distinct letters in the column are different by the Tukey test for salinity and Scott-Knott clustering test for cultivars at $p \leq 0.05$

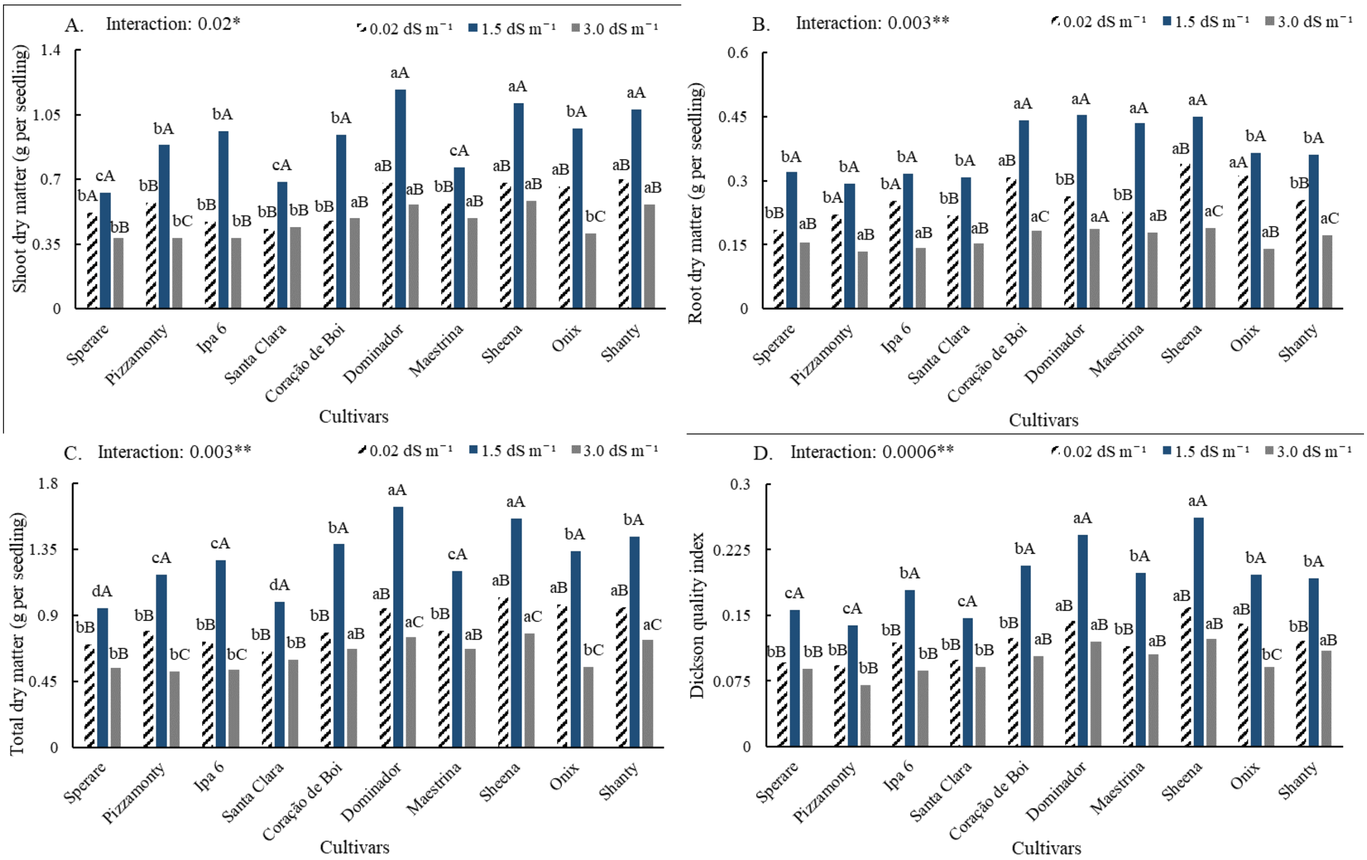
thus, imposition of stressful conditions can select tomato cultivars with greater tolerance to salt stress (Oliveira et al., 2022). Some traits such as plant height and stem diameter are related to the quality of seedlings that allow a better settling of the seedlings in field conditions (Oliveira et al., 2019).

The high salinity value (3.0 dS m^{-1}) of irrigation water has negatively affected the traits, emphasizing a reduction in the emergence percentage (10%) and emergence speed index (32%) while increasing the mean emergence time of seedlings by 23%, which exposed seeds for a longer time to the effect of soil pathogens and pests. The height and stem diameter of tomato seedlings were increased by 24 and 33%, respectively, under the salinity of 1.5 dS m^{-1} concerning the control treatment, showing the capacity of tomato species to adapt to the conditions of low salinity of irrigation water and may even improve the quality of seedlings produced (Table 4).

The osmotic adjustment performed by tomato plants under saline stress can favor the absorption of saline water and drive sodium and chlorine ions to the cellular vacuole of the leaves (Oliveira et al., 2022). Thus, it may not reduce shoot dry matter accumulation due to reduced turgidity and closure of stomata that reduce water losses (Safdar et al., 2019). Plants accumulate various metabolites (solute) in the cytoplasm of cells as a strategy to increase tolerance to water loss induced by salt stress (Taiz et al., 2018).

The irrigation of tomato cultivars with water with ECw of 1.5 dS m^{-1} provided a greater accumulation of shoot dry matter (54%), root dry matter (101%), and total dry matter (66%) concerning ECw of 3.0 dS m^{-1} (Figures 5A, 5B, and 5C). The Dickson quality index was 40% higher at the salinity value of 1.5 dS m^{-1} compared to control the treatment and 61% higher concerning 3.0 dS m^{-1} (Figure 5D). Chlorine (Cl), even in a small amount in the water with ECw of 1.5 dS m^{-1}, can act as a permeable substance to enhance water flow from soil to plant (Geilfus, 2018). The accumulation of Cl in plants increases N use efficiency and promotes its assimilation by 80% in tomato plants by reducing nitrate (NO^{3-}) distribution (Rosales et al., 2020). The tomato plants can store Na in vacuole without compromising K absorption and maintain adequate water balance for optimal plant growth due to low Na concentrations (Maathuis et al., 2014).

The Dominador, Sheena, Onix, and Shanty had the highest shoot dry matter (16%) compared to other cultivars under control conditions (without salinity). The shoot dry matter of Dominador, Shanty, and Sheena was increased by 14% at the salinity of 1.5 dS m^{-1} concerning other cultivars. In addition,



Means followed by distinct uppercase letters are different by the Tukey test for salinity within each cultivar; equal lowercase letters indicate that cultivars belong to the same cluster by the Scott-Knott clustering test within each salinity value *and ** - Significant at $p \leq 0.05$ and $p \leq 0.01$ by F test, respectively

Figure 5. Shoot dry matter (A), total dry matter (B), root dry matter (C), and Dickson quality index (D) of tomato seedlings of 10 cultivars in three values of electrical conductivity of irrigation water

under high salinity (3.0 dS m^{-1}) conditions, Coração de Boi, Dominador, Maestrina, Sheena, and Shanty were more efficient at accumulating shoot dry matter (10%) as compared to other cultivars (Figure 5A), total dry matter followed the similar behavior (Figure 5C).

The production of tomato seedlings under high salinity conditions (3.0 dS m^{-1}) harmed the root development in all cultivars. Coração de Boi, Sheena, and Onix showed the greatest (16%) root development under control conditions compared to other cultivars. In addition, Coração de Boi, Dominador, Maestrina, and Sheena, when submitted to saline irrigation (1.5 dS m^{-1}), had root dry matter 19% greater than other cultivars (Figure 5B).

The salinity of irrigation water reduces the osmotic potential of the substrate to the osmotic potential of plant root cells, which hinders/prevents water absorption and leads to the death of plants in severe cases (Braz et al., 2019). The osmotic potential is the main reason for reducing the growth of new roots and root and shoot dry matter by reducing the uptake of nutrients and water that disrupt the physiological processes of plants (Oliveira et al., 2022).

Dominador, Sheena, and Onix had seedlings with the best quality according to the Dickson quality index under irrigation without salinity. These results were similar under low saline conditions (1.5 dS m^{-1}) except for Onix. In addition, under high salinity (3.0 dS m^{-1}) conditions, Coração de Boi, Dominator, Maestrina, Sheena, and Shanty showed the best quality compared to the other tomato cultivars (Figure 5D).

The highest quality of seedlings under low salinity conditions (1.5 dS m^{-1}) was verified due to the ability of plants to perform the osmotic adjustment and use water in these saline conditions. It was reported in a previous study that tomato cultivars distinctly responded to saline conditions where the cultivars did not show tolerance. However, some cultivars still indicated higher growth under salt stress conditions (Fariduddin et al., 2012). The low salinity conditions stimulated plant growth and the accumulation of salts in the cell walls of some tomato cultivars (Kadoglidou et al., 2021).

It was also indicated that plants have osmotic tolerance mechanisms to facilitate adaptation to osmotic stress over a longer period through osmotic adjustment; however, there was a lack of initial signaling processes in plant development (Meng et al., 2018).

The group composed of the cultivar Onix had high similarity with the group formed by the cultivars Sheena, Dominador, and Shanty. Santa Clara, Ipa 6, and Sperare had high similarity with Coração de Boi. In addition, Santa Clara, Sperare, and Ipa 6 had high dissimilarity with Onix under control conditions (Figure 6A). The similarity in treatments without stressful effects can show the genetic variability between cultivars for further stability analysis under salt stress conditions.

The group composed of Dominador and Sheena had a high dissimilarity from the group of Shanty, Pizzamonty, and Santa Clara. In contrast, the group of Dominador and Sheena had high similarity with the group of Coração de Boi, Maestrina, and Onix under low salinity conditions (Figure 6B).

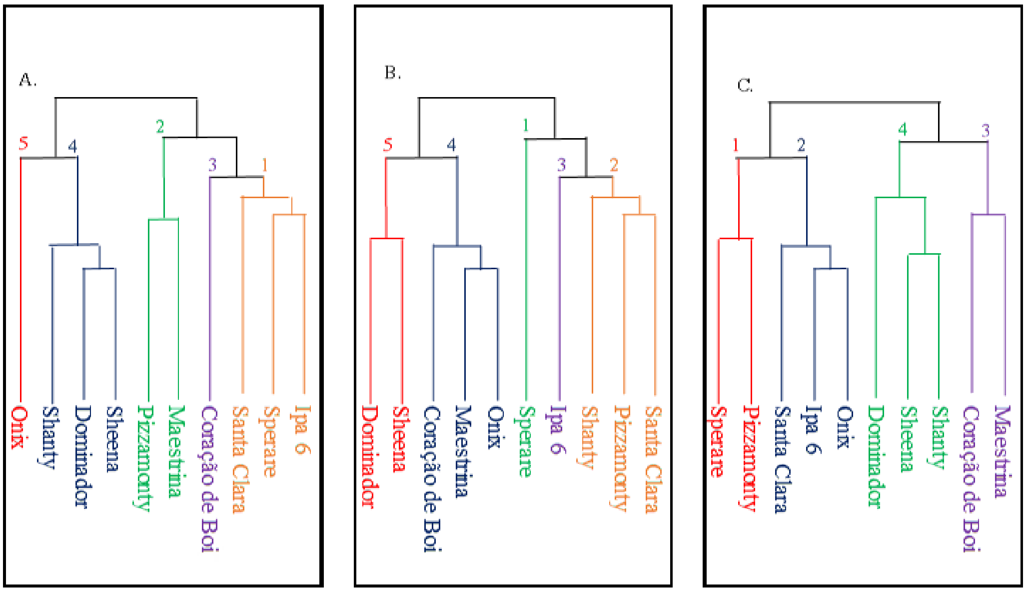


Figure 6. Dendrogram of dissimilarity pattern obtained by unweighted pair group method with arithmetic mean (UPGMA) based on the Gower distance of 10 tomato cultivars under control treatment conditions - without salinity (A), the low salinity value of irrigation water (B) and higher salinity value of irrigation water (C)

The characterization of genetic divergence under salt stress conditions demonstrated the stability of cultivars in different environments. The groups formed under ideal conditions accurately show the relatedness of the genotypes. It was observed that the cultivars Dominador and Sheena had high stability to form a similarity group under conditions of low salinity value.

The group of Sperare and Pizzamonty tomato cultivars had a high dissimilarity from the group of Coração de Boi and Maestrina. In contrast, the group with Dominador, Sheena, and Shanty had a high similarity with a group of Coração de Boi and Maestrina under higher electrical conductivity (Figure 6C). The groups under ideal conditions accurately show the relatedness of the genotypes. It was observed that the cultivars Coração de Boi and Maestrina had high stability to form a similarity group under conditions of high salinity value.

The UPGMA clustering method based on generalized Gower distance is the most consistent and dedicated to characterizing the genetic divergence among genotypes and providing greater precision in selecting resistant cultivars (Araújo et al., 2014). Also, the UPGMA clustering method demonstrated great precision under abiotic stress conditions in tomato genotypes to select possible parents for plant breeding programs (Oliveira et al., 2022).

The distinct results between tomato cultivars are attributed to the intrinsic genetic traits of each cultivar. All results obtained from tests with cultivars in the same environmental conditions are intended to identify individuals with greater adaptability. The genetic expression of plants and their interaction with environmental conditions is crucial to defining genotype to be used based on performance, vigor, yield, and tolerance to adverse conditions (Cruz et al., 2012).

Conclusions

1. The electrical conductivity of irrigation water higher than 2.31 dS m^{-1} impairs the root growth of tomato seedlings. The tomato cultivars Santa Cruz and Ipa 6 gave rise to higher quality seedlings.

2. Irrigation water with electrical conductivity of 3.0 dS m^{-1} impaired the vigor and growth of tomato seedlings. Irrigation water with electrical conductivity of 1.5 dS m^{-1} did not compromise the vigor and growth of tomato seedlings.

3. The cultivars Coração de Boi, Dominador, Maestrina, Sheena, and Shanty, had the highest tolerance to conditions of high salinity (3.0 dS m^{-1}) of irrigation water. The cultivars Dominador, Sheena, and Shanty had the best performance under low salinity conditions (1.5 dS m^{-1}) of irrigation water.

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