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Cherry tomato cultivation under different levels of irrigation water salinity and root management system

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ABSTRACT

The use of saline water is a challenge of modern agriculture since the use of this type water reduces crop quality and yield. From this perspective, this study aimed to analyze the performance of cherry tomato under different levels of irrigation water salinity and partial root-zone irrigation. The experiment was conducted in a plant nursery at the Engineering and Agricultural Sciences Campus of the Federal University of Alagoas, in Rio Largo, Alagoas, Brazil. The experimental design was completely randomized, in a 4 x 2 factorial arrangement corresponding to four levels of irrigation water salinity (0.5 (control), 1.5, 2.5, and 3.5 dS m^{-1}) and two root management systems (with and without root system division), with five replications. The plants were evaluated for growth, dry mass accumulation, and yield. The irrigation water salinity of 3.5 dS m^{-1} intensely reduces the plant height, number of fruits, and shoot dry mass of cherry tomato. The shoot fresh mass of cherry tomato was reduced by with root system division. However, this treatment increased the plant height and the number of fruits per plant. Root system division in cherry tomato plants mitigates the deleterious effects of irrigation water salinity up to the electrical conductivity of 1.5 dS m^{-1}, especially on the fruit mass per plant.

Keywords: *Lycopersicon esculentum* L, Salt stress, Root management.

Cultivo do tomateiro cereja sob diferentes níveis de salinidade da água de irrigação e manejo do sistema radicular

RESUMO

A utilização de água salina é um desafio da agricultura atual, tendo em vista que o uso dessa água gera diminuição na qualidade e produtividade das culturas. Assim, objetivou-se analisar o desempenho do tomateiro cereja sob salinidade da água de irrigação e manejo do sistema radicular. O experimento foi conduzido em casa de vegetação da unidade experimental do Campus de Engenharias e Ciências Agrárias da Universidade Federal de Alagoas, em Rio Largo, AL. O delineamento experimental utilizado foi o inteiramente casualizado em esquema fatorial 4 x 2, sendo quatro níveis de salinidade da água de irrigação (0,5 (testemunha); 1,5; 2,5 e 3,5 dS m^{-1}) e dois manejos do sistema radicular (com divisão e sem divisão do sistema radicular) com 5 repetições. As plantas foram avaliadas quanto ao crescimento, acúmulo de massa e rendimento. A divisão do sistema radicular influenciou as variáveis morfológicas de desenvolvimento, porém em condição sem divisão foi obtido maiores valores no número e massa dos frutos. O cultivo de tomate cereja foi afetado negativamente pelo uso de água com salinidade acima de 0,5 dS m^{-1}, resultando em uma redução significativa no crescimento das plantas. Além disso, na fase de frutificação, o desempenho das plantas foi ainda mais afetado a partir da salinidade de 1,5 dS m^{-1}. O uso de águas de baixa salinidade, sem divisão do sistema radicular, mostrou-se mais adequado para o cultivo de tomate cereja, apresentando melhor desempenho.

Palavras-chave: *Lycopersicon esculentum* L, Estresse Salino, Manejo radicular.

1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the main vegetables produced in Brazil and worldwide. However, several factors decrease the yield of this crop, including excess salts dissolved in the soil solution or irrigation water (Medeiros et al., 2012). Due to the shortage of water resources, there is often a need to employ low-quality water for agricultural irrigation, usually containing high salt concentrations (Dias et al., 2016; Safdar et al., 2019). However, salt excess in the soil solution changes the ability of plants to absorb, transport, and use the nutrients they require for their growth and development due to the osmotic effect, water deficit, ion toxicity, and nutrient imbalance, thus limiting the yield (Dias et al., 2016; Safdar et al., 2019).

Tomato plants are moderately sensitive to salinity effects, showing a threshold salinity level, in terms of electrical conductivity of the saturation extract (ECe), of 2.5 dS m^{-1}, with a relative reduction of 9.0% per unit increase in the ECe (Rhoades et al., 2000). According to Dias et al. (2016), the success in the use of saline water for irrigation requires adequate management practices such as selecting salinity-tolerant crops and adopting irrigation strategies that prevent salt accumulation in the soil and/or maintain the salt concentration in the root zone below the levels tolerated by the crop of interest.

Therefore, it is essential to generate knowledge to allow the use of saline water in agriculture, partial root-zone irrigation. This system has been studied in various crops, with emphasis on the increase in water-use efficiency, and the results obtained so far have demonstrated its viability (Yang et al., 2012; Sun et al., 2013). The use of root system division could be an alternative when using saline water is inevitable.

In this system, the water potential of plants whose roots are partly under high salinity can be equalized by the water potential of plants growing under low salinity, ensuring the regular physiological and biochemical functions for plant growth and development (Bazihizina et al., 2012; Alves et al, 2018). From this perspective, this study aimed to analyze the performance of cherry tomato under treatments with irrigation water salinity and root management systems.

2. Material and Methods

The experiment was conducted in a plant nursery at the Engineering and Agricultural Sciences Campus of the Federal University of Alagoas (CECA-UFAL), located at the coordinates 9° 27’ 55’’ S and 35° 49’ 46’’ W, at an elevation of 127 meters, with temperatures ranging from 29 °C to 21 °C. The mean annual rainfall in the region is 1.800 mm (Souza et al., 2004). The experimental design adopted was completely randomized, with a 4 x 2 factorial arrangement corresponding to four salinity levels of irrigation water (0.5 (control), 1.5, 2.5, and 3.5 dS m^{-1}) and two root management systems (with and without root system division), with five replications.

The root system division was adopted using a plastic bag inside the pots to divide the root system and thus perform the management desired. The salinity levels were chosen based on the threshold salinity of tomato: 2.5 dS m^{-1} (Rhoades et al., 2000). The chemical soil analysis was performed before the experiment, and the results are presented in Table 1. According to the chemical analysis (Table 1) and following the recommendation of the Agronomical Institute of Campinas (IAC), liming was performed using limestone (FILLER®) with a total relative neutralizing value of 90%. Fertilization was performed using NPK. The nitrogen, phosphorus, and potassium sources were urea, monoammonium phosphate, and potassium chloride, respectively.

The soil was placed in 6 dm^3 plastic pots over a gravel layer (200 g), 2 cm of coarse send, and a nylon net to facilitate the drainage of excess water. Next, soil moisture was increased to field capacity; for that purpose, a pot was weighed and the soil was saturated with water and wrapped with plastic to force water loss by drainage only (Gervásio et al., 2000). Once drainage ceased (24 hours after saturation), the plastic was removed, and the pots were weighed in an electronic balance, thus obtaining the moisture corresponding to the level close to field capacity (control weight of 200 mL of water). Seedling production was performed using 200 mL disposable plastic cups filled with a commercial substrate. Cherry tomato seeds produced by Isla® were used in the experiment, and the seedlings were thinned to one plant per cup 11 days after sowing (DAS).

Table 1. Chemical attributes of the soil (0 to 20 cm) used in the experiment

pH	P	Na	K	Al	Ca + Mg	H+Al	SB	CEC	BS	OM
	.....mg dm^{-3}......		................cmolc dm^{-3}...................				.......%.........			g kg^{-1}
6.0	81	10	0.21	0.03	5.84	80	81.94	10.29	59	26.7

pH (H_2O)- potential of hydrogen; P- phosphorus; H+Al: hydrogen + aluminum; Al- aluminum; Ca+Mg- calcium + magnesium; K- potassium; Na- sodium; SB- sum of bases; CEC- cation exchange capacity; BS- base saturation; OM- organic matter. Source: Central Analítica LTDA Laboratory.

Then, the seedlings were transplanted to the pots 25 DAS. For the root system division treatments, the roots were split into two parts: the tip of the main root was removed, and the remaining roots were divided to equalize the number of roots on both sides of the pots. Irrigation was performed following the weighing method, in which one pot from each treatment was daily weighed and then irrigated with the respective saline solutions. Every 15 days, plant growth was compensated for by adding 100 mL.

Throughout the experiment, the crop was kept free of weeds by manually controlling spontaneous plants and sprouts that appeared before the insertion of the first flower. The plants were trained and monitored for pests and diseases by adopting control measures whenever necessary. The data obtained were subjected to analyses of variance by the F test, and the means were compared by Tukey test ($p \leq 0.05$). The results obtained as a function of the salinity levels of irrigation water were then subjected to linear and quadratic regression. The analyses were performed with the software ASSISTAT (Silva & Azevedo, 2016).

3. Results and Discussion

According to the summary of the analysis of variance (Table 2), the isolated factor referring to root system division had a significant effect on the Nfruit, RGRph, and SFM variables of cherry tomato. On the other hand, for the factor referring to irrigation water salinity, there was a significant effect of the linear regression on the RGRph, Nfrutos, and SDM parameters and an effect of the quadratic regression ($p \leq 0.001$) on the PH variable. The interaction between factors was only significant ($p \leq 0.001$) for the MFruit, indicating that, for this variable, the type of management influences the salinity level.

According to Figure 1A, the increase in the electrical conductivity of irrigation water (ECw) had a significant effect on the PH of cherry tomato plants. The model that best fit the set of mean data for this variable was the quadratic polynomial model, with an R^2 of 0.98. The maximum electrical conductivity of irrigation water estimated for this variable was 0.93 dS m^{-1}, which, when applied, resulted in a plant height of 173.27 cm, according to the model. Concentrations higher than the maximum estimated value reduce plant height.

For the relative growth rate in plant height (RGRph) (Figure 1B), the root system division treatment increased the RGRph by 12% in relation to the control treatment. Figure 1C shows a linear reduction of 34% in the RGRph when comparing the electrical conductivities of irrigation water of 0.5 dS m^{-1} and 3.5 dS m^{-1}. The results demonstrate that partial root-zone irrigation in this crop increases its growth rate, which could be an essential practice since a higher plant size could mean higher yields. However, this practice did not influence the salinity levels of irrigation water.

Table 2. Summary of the analysis of variance for plant height (PH), number of leaves (NL), leaf area (LA), relative growth rate in plant height (RGRph), absolute growth rate in plant height (AGRph), shoot fresh mass (SFM), shoot dry mass (SDM), number of fruits (NFruit), and fruit mass (MFruit) of cherry tomato grown under different irrigation water salinities and root system division.

SV	MS					
	DF	PH	NL	LA	RGRph	Nfruit
Root management (M)	1	30.63^{ns}	133.22^{ns}	249956.1^{ns}	0.0019*	93.02**
Salinity (S)	3	1514.23^{--}	57.62^{--}	429377.5^{--}	0.0042^{--}	87.75^{--}
M x S	3	42.16^{ns}	61.89^{ns}	153919.6^{ns}	0.0008^{ns}	25.55^{ns}
L. regression	1	2611.21**	0.810^{ns}	210313.9^{ns}	0.0045**	75.69*
Q. regression	1	321.05**	1.25^{ns}	294759.2^{ns}	0.000^{ns}	11.25^{ns}
Residual	32	24.41	102.37	234079.7	0.0004	10.18
Total	39	-	-	-	-	-
CV (%)	-	5.58	22.68	20.90	17.03	24.51

		Mfruit	SFM	SDM
Root Management (M)	1	2255.04**	13505.62**	52.90^{ns}
Salinity (S)	3	2724.66^{--}	1722.02^{--}	129.90^{--}
M x S	3	741.64**	468.22^{ns}	13.76^{ns}
L. regression	1	6348.10**	5227.3^{ns}	282.24**
Q. regression	1	0.182^{ns}	54.45^{ns}	0.001^{ns}
Residual	32	57.96	1181.17	13.62
Total	39	-	-	-
CV (%)	-	15.34	17.72	11.17

SV – Source of variation; DF – Degrees of freedom; MS – Mean square; CV- Coefficient of variation; $^{--}$ - The treatment is quantitative, the F-test does not apply; ns- not significant; *, ** - Significant at 5 and 1% of probability, respectively, by the F-test.

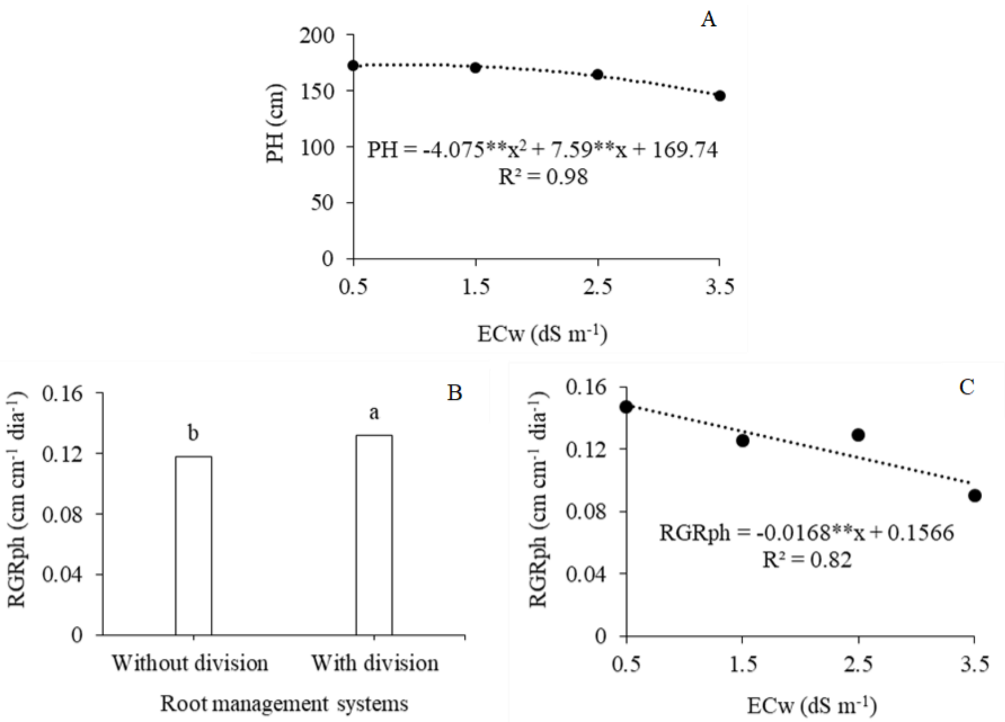

Figure 1. Plant height and relative growth rate in plant height of cherry tomato under root management systems (B) and electrical conductivity levels of irrigation water (A and C). Bars with identical letters do not differ by Tukey test (0.05)

Figure 2A shows that the root system division resulted in the highest mean value for the number of fruits (14.55) in relation to plants grown without this condition (11.5), corresponding to an increase of approximately 26% in the number of fruits. However, in Figure 2B, there was a linear reduction in response to the increase in irrigation water salinity, with the lowest Nfruit (9.1) being achieved at the ECw of 3.5 dS m^{-1}, corresponding to a reduction of approximately 37% compared to the ECw of 0.5 dS m^{-1}, which resulted in 14.4 fruits per plant.

For the fruit mass (Mfruit) (Figure 2C), the root system division treatment was superior to its absence. However, in the treatment with root system division, there was a linear reduction in response to the increase in irrigation water salinity, achieving the lowest Mfruit (33.5 g) at the ECw of 3.5 dS m^{-1}, corresponding to a reduction of approximately 58.9% compared to the ECw of 0.5 dS m^{-1}, which resulted in 81.04 grams per plant. Fruits produced under salt stress seem to grow normally during the cell division phase. However, harmful effects are observed during cell expansion, thus reducing fruit weight (Cuartero & Fernández-Muñoz, 1999).

According to some studies, the presence of salt stress can reduce fruit production in tomato plants (Blanco et al., 2008; Medeiros et al., 2012). This phenomenon is also observed in other Solanaceae bell pepper and eggplant, as evidenced by other studies (Leonardo et al., 2007; Silva et al., 2013; Oliveira et al., 2014). With regard to the management without partial root-zone irrigation, the maximum electrical conductivity of irrigation water estimated for these variables was 1.33 dS m^{-1}, which, when applied, resulted in 52.8 g per plant. Root system division was responsible for a reduction of 36.86 g in the shoot fresh mass of tomato compared to plants cultivated without this practice (Figure 3A).

The shoot dry mass (Figure 3B) was influenced by the electrical conductivity of irrigation water, with a reduction of 8.9 g per unit increase in salinity, totaling 23.5% between the lowest and highest salinity. The reduction in fresh and dry matter production due to the significant increase in salt stress is one of the main effects of salinity, which affects several crops and has been observed by many authors. Taiz et al. (2017) explain that salt excess in the soil solution modifies the metabolic activities of cells during cell elongation, thus limiting the elasticity of the cell wall and affecting plant growth (Taiz et al., 2017). However, this process can also be affected by damage caused to the CO_2 fixative enzymatic system as a result of ion toxicity (Neves et al., 2009).

The negative effect of salinity on plant development occurs due to the reduction in soil water availability, decreasing the water potential of leaves and resulting in the loss of turgor and stomatal closure, which can affect biomass production (Munns & Tester, 2008). The production of biomass, fruits, and seeds depends on a high water flow in the plant, which increases the nutrient uptake and provides higher photosynthetic rates.

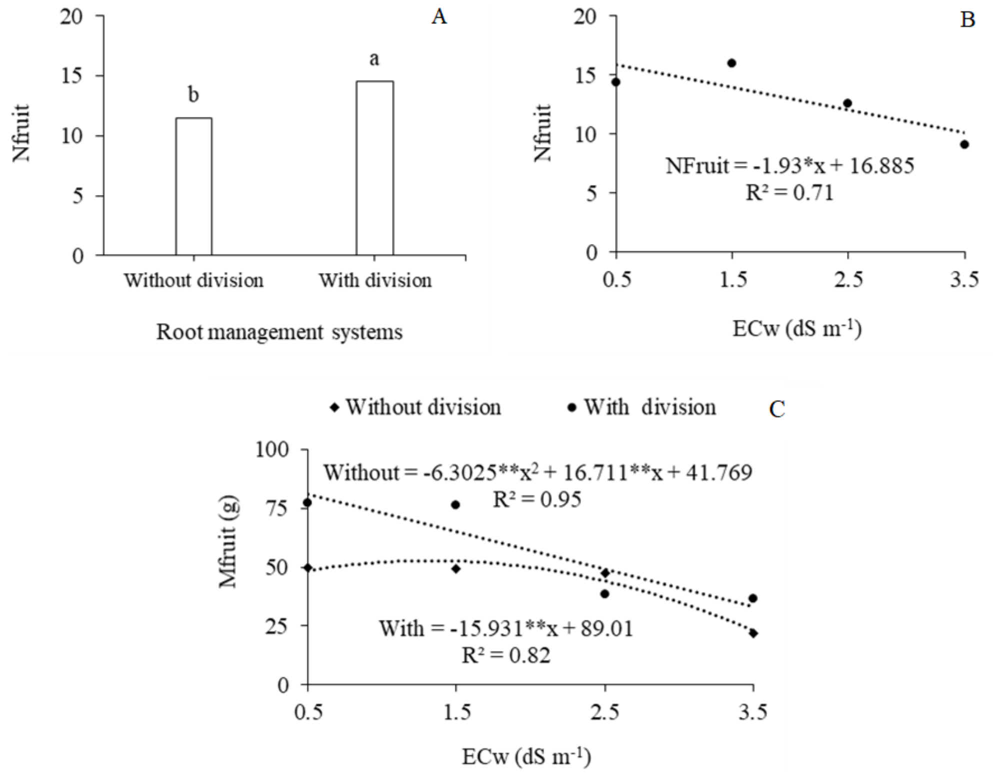

Figure 2. Root management systems (A) and electrical conductivity of irrigation water on the number of fruits (B) and unfolding of the M x S interaction on the fresh fruit mass of cherry tomato (C)

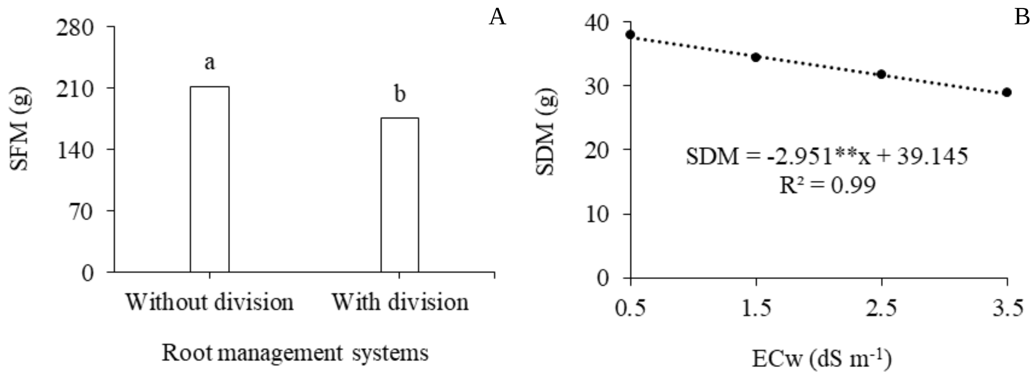

Figure 3. Shoot fresh mass of cherry tomato plants under root management (A) and shoot dry mass under irrigation water salinity (B).

4. Conclusions

The irrigation water salinity of 3.5 dS m^{-1} intensely reduces the plant height, number of fruits, and shoot dry mass of cherry tomato. The shoot fresh mass of cherry tomato was reduced by with root system division. However, this treatment increased the plant height and the number of fruits per plant. Root system division in cherry tomato plants mitigates the deleterious effects of irrigation water salinity up to the electrical conductivity of 1.5 dS m^{-1}, especially on the fruit mass per plant.

Authors' Contribution

Rilbson Henrique Silva dos Santos contributed to the execution of the experiment, data collection, analysis and interpretation of results, writing and final correction of the manuscript. Mirandy dos Santos Dias contributed to the analysis and interpretation of results, writing and final correction of the manuscript. Lígia Sampaio Reis contributed to the analysis and interpretation of results, writing and final correction of the manuscript.

Reinaldo de Alencar Paes contributed to the data analysis and final correction of the manuscript. Francisco de Assis da Silva contributed to the analysis and interpretation of results, writing and final correction of the manuscript. Saniel Carlos dos Santos contributed to the writing of the manuscript. Each of the authors provided critical feedback and helped with shape the research, analysis, writing and final correction of the manuscript

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