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Original Article

Methods of application of salicylic acid as attenuator of salt stress in cherry tomato

Métodos de aplicação de ácido salicílico como atenuantes do estresse salino em tomateiro cereja

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Abstract

Salt stress caused by excess salts present in irrigation water, is one of the biggest barriers in agricultural production, especially in semi-arid regions. Thus, the use of substances, such as salicylic acid, that minimize the deleterious effects of salinity on plants can be an alternative to ensure satisfactory production. In this context, the objective of this study was to evaluate the effects of different methods of application of salicylic acid on the growth, production and water use efficiency of cherry tomato plants under salt stress. The study was conducted in a greenhouse, using an *Entisol* soil with a sandy loam texture. The treatments were distributed in a completely randomized design, in a 2×4 factorial arrangement, corresponding to two levels of electrical conductivity of irrigation water - ECw (0.6 and 2.6 dS m^{-1}) and four methods of application of salicylic acid (Control - without application of SA; via spraying; via irrigation and via spraying and irrigation), with five replicates and one plant per plot. The salicylic acid concentration used in the different methods was 1.0 mM. Application of salicylic acid via foliar spraying increased the growth, production and water use efficiency of cherry tomato plants. The salt stress induced by the electrical conductivity of 2.6 dS m^{-1} was attenuated by the foliar application of salicylic acid. The use of water of 2.6 dS m^{-1} associated with the application of salicylic acid via irrigation water further intensified the adverse effects of salinity on cherry tomato plants.

Keywords: *Solanum lycopersicum* L., abiotic stress, brackish water, phytohormone.

Resumo

O estresse salino ocasionado pelo excesso de sais presentes na água de irrigação, é um dos maiores entraves para a produção agrícola, sobretudo em regiões semiáridas. Assim, a utilização de substâncias, como o ácido salicílico, que minimizem os efeitos deletérios da salinidade sobre as plantas pode ser uma alternativa para garantir uma produção satisfatória. Neste contexto, objetivou-se com este trabalho avaliar os efeitos de diferentes métodos de aplicação de ácido salicílico sobre o crescimento, a produção e a eficiência do uso da água de plantas de tomate cereja sob estresse salino. O estudo foi conduzido em casa de vegetação, utilizando-se de um solo *Entisol* de textura franco-arenosa. Os tratamentos foram distribuídos em delineamento inteiramente casualizados, em arranjo fatorial 2×4, sendo duas condutividades elétricas da água de irrigação - CEa (0,6 e 2,6 dS m^{-1}) e quatro métodos de aplicação de ácido salicílico (Testemunha - sem aplicação de AS; via pulverização; via irrigação e pulverização e irrigação), com cinco repetições e uma planta por parcela. A concentração de ácido salicílico utilizada nos diferentes métodos foi de 1,0 mM. A aplicação de ácido salicílico via pulverização foliar, aumentou o crescimento, a produção de plantas de tomate cereja, e a eficiência do uso da água. O estresse salino induzido pela condutividade elétrica de 2,6 dS m^{-1} foi amenizado pela aplicação foliar de ácido salicílico. O uso de água de 2,6 dS m^{-1} associado a aplicação de ácido salicílico via lâmina de irrigação, intensificou os efeitos adversos da salinidade nas plantas de tomate cereja.

Palavras-chave: *Solanum lycopersicum* L., estresse abiótico, águas salobras, fitormônio.

1. Introduction

Tomato (*Solanum lycopersicum* L.) is among the main horticultural crops grown in a protected environment, especially cherry tomatoes, which is appreciated for having a strong aroma and unique flavor, it has 1.7 times

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the vitamin C content of conventional tomatoes, and helps in immunity, reducing blood pressure and cholesterol, besides preventing cancer (Liu et al., 2018; Zeng et al., 2020). Cherry tomatoes also have a longer shelf time, around 18 days after harvest, making their commercialization more attractive (Matos et al., 2021).

Irrigation water quality is one of the most important factors for plants to express their maximum production potential, especially in protected cultivation, since in this production system there is no leaching of salts by rainwater, as occurs naturally in areas cultivated in the open fields (Guedes et al., 2015; Roque et al., 2022).

The semi-arid region of Northeast Brazil presents water restrictions in terms of quality and quantity, making the production of vegetable crops dependent on irrigation, which is often carried out with water that has a high salt content (Silva et al., 2024). Irrigation with saline water can cause the accumulation of sodium (Na^+) and chloride (Cl^-) ions, and their excess restricts the absorption of water and nutrients by the roots of plants, compromising their growth and development (Hussain et al., 2021). Salt stress also causes several plant disorders, including reduction in stomatal conductance, inhibition of photosynthesis, reduction in protein synthesis, impairment of enzymatic activities and chlorophyll degradation (Liang et al., 2018).

Salicylic acid (SA) is a plant hormone that plays several physiological roles in plants, including promoting growth, floral induction, nutrient absorption, ethylene biosynthesis, stomatal closure and photosynthesis (Silva et al., 2020). The SA activates the plant's defense response by inducing tolerance to abiotic stresses, such as salt stress, by improving physiological processes, accelerating plant growth and reducing oxidative damage (Jayakannan et al., 2015; Oliveira et al., 2022).

In recent years, studies have reported that the application of salicylic acid can attenuate the effects of salt stress in several vegetables, for example, Veloso et al. (2021) found that foliar application of SA at a concentration of 1.6 mM increased chlorophyll biosynthesis, and the number of sweet pepper fruits; Sousa et al. (2024) observed that foliar application of SA at a concentration of 1 mM reduced cell membrane damage and increased the relative water content of eggplant leaves. In basil, Silva et al. (2022) found improvements in gas exchange as a function of the application of SA (1 mM). However, these studies are limited to application of salicylic acid through a single method.

The beneficial effect of SA application depends on the plant species, stage of development, outype of cultivation, concentration applied and the method of application used (Ferrareze et al., 2019). In this context, the objective of this study was to evaluate the effects of the methods of SA application on the growth, production and water use efficiency of cherry tomato plants under salt stress, in a protected environment.

2. Material and Methods

2.1. Localization and treatments

The experiment was carried out between October 2020 and February 2021, in a greenhouse, belonging to the Academic Unit of Agricultural Engineering - UAEA of the Federal University of Campina Grande - UFCG, in Campina Grande, Paraíba, Brazil, located at the geographical coordinates 7°15'18" South latitude, 35°52'28" West longitude and mean altitude of 550 m. The greenhouse used is of the arched type, 22 m long and 6.5 m wide, with a ceiling height of 3.0 m and a low density infrared treated polyethylene cover (150 microns). The data of temperature (maximum and minimum) and average relative air humidity of the experimental site are shown in Figure 1.

The treatments resulted from the combination of two levels of electrical conductivity of irrigation water - ECw (S1= 0.6 dS m^{-1} and S2= 2.6 dS m^{-1}) and four methods of application of salicylic acid - MA (M1= Control - without application of SA, M2= via spraying, M3= via irrigation and M4=via spraying and irrigation), in a 2×4 factorial arrangement (Table 1), distributed in a completely randomized design, with five replicates each consisting of one plant.

The SA concentration used in the different application methods was same (1.0 mM), based on studies conducted by Jahan et al. (2019) and Poursakhi et al. (2019) with tomato crop. The levels of electrical conductivity of irrigation water (0.6 and 2.6 dS m^{-1}) were selected in accordance with the results of a study reported by Vieira et al. (2016) on cherry tomatoes keeping in view salt tolerance of crop).

2.2. Plant material

The cherry tomato cultivar used was 'Carolina', which has indeterminate growth, fruits with red color and small size, weighing from 10 to 12 g, and a cycle of 110 to 120 days, being resistant to verticillium wilt (*Verticillium albo-atrum* and *Verticillium dahliae*) and fusarium (*Fusarium oxysporum*). The fruit has longer shelf life, around 18 days after harvest (Matos et al., 2021).

2.3. Establishment and management of the experiment

The experiment was conducted using Citropote® pots of 8 dm^3 volume and 4 dm^2 area, covered with a geotextile

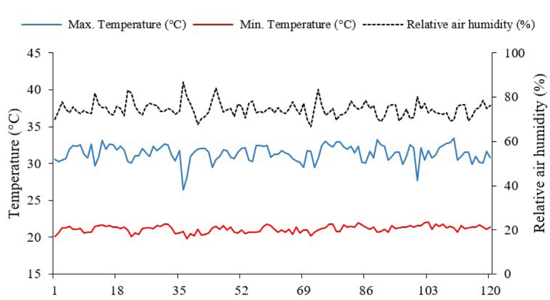

Figure 1. Air temperature (maximum and minimum) and mean relative air humidity observed in the internal area of the greenhouse during the experimental period.

(Bidim OP 30) and filled with a 0.3-kg layer of crushed stone (n° = 0) followed by 8 kg of soil classified as *Entisol* (USDA, 2014), collected at a depth of 0-30 cm, from the municipality of Riachão do Bacamarte-PB, whose physico-chemical attributes (Table 2) were determined according to Teixeira et al. (2017).

Irrigation waters with different levels of electrical conductivity were prepared by dissolving NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$ salts, in the equivalent proportion of 7:2:1, respectively, in water from the local supply system (ECw = 0.32 dS m^{-1}). This proportion is commonly found in sources of water used for irrigation in small properties in the Northeast (Medeiros et al., 2003). The irrigation waters were prepared considering the relationship between ECw and concentration of salts, according to Richards (1954), as shown in Equation 1:

$$C \approx 10 \times \text{ECw} \quad (1)$$

where: C - concentration of salts ($mmol_c$ L^{-1}); ECw - electrical conductivity of water (dS m^{-1}).

Sowing was carried out by placing three tomato seeds at 2 cm depth, distributed equidistantly, in 250-mL disposable plastic cups; at 10 days after sowing (DAS), thinning was performed in order to leave only one plant per cup with the greatest vigor. Transplanting to Citropote® pot was performed at 20 days after sowing.

At 30 DAS, irrigation with saline waters began to be applied, adopting a two-day irrigation interval, applying adequate volume of water to maintain soil moisture close to field capacity. The volume to be applied was determined according to the water requirement of the plants, estimated by the water balance, as shown in Equation 2:

$$VI = \frac{(Va - Vd)}{(1 - LF)} \quad (2)$$

where: VI - volume of water to be applied in irrigation (mL); Va - volume applied in the previous event of irrigation (mL); Vd - volume drained after previous event of irrigation (mL); LF - leaching fraction of 0.15, applied every 20 days.

The concentration of salicylic acid (SA) was obtained by dissolution of product in ethyl alcohol (30%), since it is a substance with low solubility in water at room temperature, and the pH of salicylic acid after the preparation of the 1.0 mM concentration was 2.2. To reduce the surface tension of the drops on the leaf surface, the adjuvant Wil fix at the concentration of 0.5 mL L^{-1} was used in the preparation of the solution.

The applications of SA began five days before irrigation with saline water, that is, at 25 DAS, spraying the abaxial and adaxial sides of the leaves. Subsequent applications were performed at intervals of 15 days, up to 85 DAS, using a sprayer between 17:00 and 17:30 hours, with an average volume of 150 mL applied per plant in each spraying. Plants subjected to the method of application via irrigation were irrigated with a volume of 50 mL of SA on the same days of the spraying and in application by irrigation and spraying same doses and procedres were used.

Fertilization with nitrogen, potassium and phosphorus was performed through top-dressing, using doses recommended by Novais et al. (1991). 0.76 g of urea, 2.0 g of potassium chloride and 3.87 g of monoammonium phosphate, equivalent to 100, 150 and 300 mg kg^{-1} of N, K_2O and P_2O_5, respectively, were applied in four equal applications via fertigation, at intervals of 15 days, with

Table 1. Description of the analyzed treatments.

ECw (S)	Methods of application of salicylic acid (M) – 1.0 mM			
	M1- Control	M2 - Via spraying	M3 - Via irrigation	M4 - Via spraying + irrigation
S1 - 0.6 dS m^{-1}	S1M1	S1M2	S1M3	S1M4
S2 - 2.6 dS m^{-1}	S2M1	S2M2	S2M3	S2M4

ECw: electrical conductivity of irrigation water; M1- Control: without application.

Table 2. Chemical and physical attributes of the soil (0-0.30 m layer), used in the experiment, before the application of the treatments. Campina Grande, PB.

Chemical characteristics									
pH (H_2O) 1:2.5	OM dag kg^{-1}	P Mg kg^{-1}	K^+	Na^+	Ca^{2+}	Mg^{2+}	$Al^{3+} + H^+$	ESP %	ECse dS m^{-1}
			....................$cmol_c$ kg^{-1}....................						
5.90	1.36	6.80	0.22	0.16	2.60	3.66	1.93	1.87	1.0
Physical-hydraulic characteristics									
Particle-size fraction (g kg^{-1})			Textural class	Moisture (kPa)		AW	Total Porosity %	BD	PD
Sand	Silt	Clay		33.42*	1,519.5** dag kg^{-1}			kg dm^{-3}	
732.9	142.1	125.0	SL	11.98	4.32	7.66	47.74	1.39	2.66

OM: organic matter: Walkley-black wet digestion; Ca^{2+} and Mg^{2+}: extracted with 1 M KCl at pH 7.0; Na^+ and K^+: extracted with 1 M NH_4OAc at pH 7.0; Al^{3+} and H^+: extracted with 0.5 M CaOAc at pH 7.0; ESP: exchangeable sodium percentage; ECse: electrical conductivity of saturation extract; SL: sandy loam; AW: available water; BD: bulk density; PD: particle density. *Field capacity; **Permanent wilting point.

the first application being performed at 40 days after sowing (DAS).

A micronutrient solution was applied fortnightly at the concentration of 1.0 g L^{-1} of the commercial product Dripsol® micro containing: Mg (1.1%); Zn (4.2%); B (0.85%); Fe (3.4%); Mn (3.2%); Cu (0.5%); Mo (0.05%), on the leaves, covering their adaxial and abaxial sides, using a backpack sprayer.

During the experiment, all cultural practices and phytosanitary treatments recommended for the crop were carried out, monitoring the emergence of pests and diseases and adopting appropriate control measures when necessary.

2.4. Traits measured

Growth was evaluated based on plant height (PH), stem diameter (SD), relative growth rates in plant height (RGR_{PH}) and stem diameter (RGR_{SD}); production variables: number of fruits per plant (NF), averagemean fruit weight (mFW), total production per plant (TPP), polar (PD) and equatorial diameter (ED) of the fruit; water consumption (WC) and water use efficiency (WUE).

Growth was measured at 80 (PH_1 and SD_1) and 110 DAS (PH_2 and SD_2). Plant height was measured using as reference the distance from the plant collar to the apical meristem, and stem diameter (mm) was measured two centimeters above the plant collar. The data of PH (PH_1 and PH_2) and SD (SD_1 and SD_2) were used to determine the relative growth rate, a variable that indicates the growth rate of the plants when the final height/diameter is compared with the initial one. The relative growth rate was determined according to the methodology described by Benincasa (2003).

Ripe fruits were harvested from 90 DAS, extending up to 120 DAS, when the number of fruits per plant was counted and the mean fruit weight as well as total production per plant were determined. PD and ED were obtained with a digital caliper. Water consumption by the plants was obtained by summing up the water volume applied throughout the crop cycle (120 days), subtracting the sum of the drained water volume. Water use efficiency (kg m^{-3}) was determined by the ratio of total production per plant (kg) and water consumption (m^3) per plant, according to Guan et al. (2015).

2.5. Statistical analysis

The multivariate structure of the results was evaluated by means of principal component analysis (PCA), synthesizing the amount of relevant information contained in the original data set in a smaller number of dimensions, resulting from linear combinations of the original variables generated from the eigenvalues ($\lambda \geq 1.0$) in the correlation matrix, explaining a percentage greater than 10% of the total variance (Govaerts et al., 2007).

From the reduction of dimensions, the original data of the variables of each component were subjected to multivariate analysis of variance (MANOVA) by the Hotelling test (Hotelling et al., 1947) at 0.05 probability level for the electrical conductivity of irrigation water and the methods of salicylic acid application, as well as for the interaction between them.

Only variables with correlation coefficient greater than or equal to 0.6 were maintained in each principal component (PC) (Hair et al., 2009). Statistical analyses were performed using the software program Statistica v. 7.0 (Statsoft, 2004).

3. Results and Discussion

The multidimensional space of the original variables was reduced to two principal components (PC_1 and PC_2) with eigenvalues greater than $\lambda \geq 1.0$, according to Kaiser (1960). The eigenvalues and percentage of variation explained for each component (Table 3) together represent 87.9% of the total variation. PC_1 explained 71.61% of the total variance, formed by most of the variables analyzed, except for the relative growth rates. PC_2 represented 16.25% of the remaining variance, being formed by the variables RGR_{PH}, RGR_{SD} and WC.

According to the multivariate analysis of variance (Table 3), there was a significant effect of the interaction between salinity levels (NS) and the methods of application of salicylic acid (MA). Salinity levels also influenced the two PCs. On the other hand, the methods of application of SA caused significant effect ($p \leq 0.01$) only on PC_1.

The two-dimensional projections of the effects of treatments and variables in the first and second principal component (PC_1 and PC_2) are shown in Figures 2A and 2B. In the first principal component (PC_1), a process possibly characterized by the effect of the interaction between irrigation water salinity and the methods of application of salicylic acid was identified, and it is also verified that the correlation coefficients between PH_1, PH_2, SD_1, SD_2, NF, MFW, TPP, PD, ED and WUE were higher than 0.70.

In the principal component 1, it is possible to observe that cherry tomato plants irrigated with water of 0.6 dS m^{-1} and cultivated with foliar spraying of salicylic acid (treatment S1M2) stood out from those of the other treatments, considering that the highest values (Table 3) of PH_2 (89.6 cm), SD_2 (13.0 mm), NF (37), MFW (3.3 g), TPP (114.5 g per plant), PD (20.4 mm), ED (16.6 mm) and WUE (4.6 kg m^{-3}) were obtained. Plants irrigated with water of 2.6 dS m^{-1} and subjected to SA application via spraying (treatment S2M2) obtained the highest growth in PH_1 (67 cm) and SD_1 (11.1 mm).

When comparing the results obtained in plants of the S1M2 treatment to those of plants of the S1M1 treatment, there were increments of 3.94, 7.44, 42.31, 6.45, 45.67, 3.03, 4.40 and 43.75% in PH_2, SD_2, NF, MFW, TPP, PD, ED and WUE, respectively, demonstrating beneficial effect of salicylic acid spraying on the growth and production of cherry tomato plants.

Also in the principal component 1, it is verified that the lowest values of PH_1 (55 cm), PH_2 (70.60 cm), SD_1 (8.1 mm), SD_2 (9.9 mm), NF (10), MFW (2.2 g), TPP (30 g per plant), PD (17.7 mm), ED (14.3 mm) and WUE (1.6 kg m^{-3}) were found in the treatment S2M3, thus highlighting that the SA application via irrigation depth intensifies the deleterious effects of salt stress.

When analyzing the principal component 2 (PC_2), it can be verified that the relative growth rates in plant

Table 3. Eigenvalues, percentage of total variance explained in the multivariate analysis of variance (MANOVA) and coefficient of correlations (r) between original variables and the principal components.

	Principal components	
	PC_1	PC_2
Eigenvalues (λ)	9.31	2.11
Percentage of total variance (S^2%)	71.61	16.25
Hotelling test (T^2) for salinity levels (SL)	0.01	0.01
Hotelling test (T^2) for methods of application (MA)	0.01	0.92
Hotelling test (T^2) for interaction (SL×MA)	0.01	0.05

PCs	Coefficient of correlation (r)												
	PH_1	PH_2	SD_1	SD_2	RGR_{PH}	RGR_{SD}	NF	MFW	TPP	PD	ED	WC	WUE
PC_1	-0.81	-0.91	-0.73	-0.90	-0.30	-0.50	-0.95	-0.91	-0.90	-0.92	-0.95	-0.60	-0.92
PC_2	-0.11	0.10	-0.60	-0.10	0.63	0.82	0.11	-0.10	-0.21	-0.20	0.10	0.75	-0.20

	Means												
	PH_1 (cm)	PH_2 (cm)	SD_1 (mm)	SD_2 (mm)	RGR_{PH}	RGR_{SD}	NF	MFW (g)	TPP (g)	PD (mm)	ED (mm)	WC (mm)	WUE kg m^{-3}
S1M1	63	86.2	10.5	12.1	0.0073	0.0057	26	3.1	78.6	19.8	15.9	619.8	3.2
S2M1	59	71.0	9.70	10.6	0.0062	0.0030	15	2.8	45.0	18.9	15.5	473.5	2.1
S1M2	64	89.6	10.2	13.0	0.0055	0.0073	37	3.3	114.5	20.4	16.6	619.8	4.6
S2M2	67	82.2	11.1	12.3	0.0038	0.0023	25	3.1	85.4	19.8	16.5	473.5	3.5
S1M3	57	75.2	8.9	10.7	0.0054	0.0063	20	2.6	63.1	18.9	15.2	619.8	2.6
S2M3	55	70.6	8.1	9.9	0.0065	0.0033	10	2.2	30.0	17.7	14.3	473.5	1.6
S1M4	64	78.8	9.5	11.3	0.0125	0.0088	23	2.8	68.3	19.2	15.4	619.8	2.8
S2M4	56	73.8	8.7	10.9	0.0062	0.0038	16	2.5	42.0	18.6	14.7	473.5	2.2

S - ECw, S1: 0.6 dS m^{-1}; S2: 2.6 dS m^{-1}; M: methods of application, M1: control - without application of SA; M2: application of SA via spraying; M3: application of SA via irrigation; M4: application of SA via spraying and irrigation; PH_1: plant height at 80 days after sowing; PH_2: plant height at 110 days after sowing; SD_1: stem diameter at 80 days after sowing; SD_2: stem diameter at 110 days after sowing; RGR_{PH}: relative growth rate in plant height - cm cm^{-1} dia^{-1}; RGR_{SD}: relative growth rate in stem diameter - mm mm^{-1} dia^{-1}; NF: number of fruits per plant; MFW: mean fruit weight; TPP: total production per plant; PD: polar diameter; ED: equatorial diameter; WC: water consumption; WUE: water use efficiency.

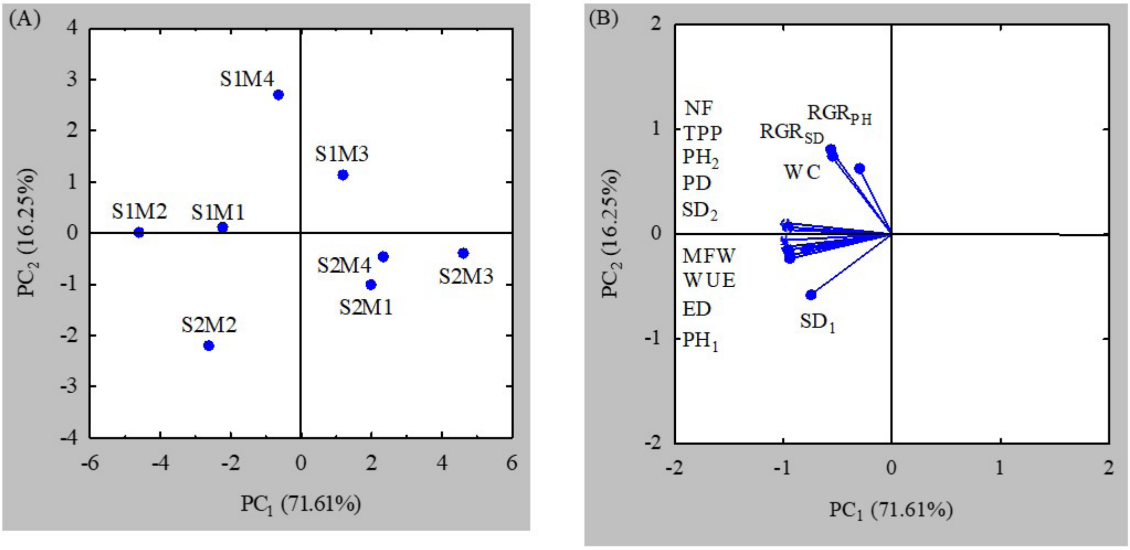

Figure 2. Two-dimensional projection of the scores of the principal components for the factors salinity levels (S) and methods of application of salicylic acid (M) (A) and the variables analyzed (B) in the first two principal components (PC_1 and PC_2).

height and stem diameter and water consumption are the most important variables for the second principal component, due to the higher values of correlation observed (Table 3). Cherry tomato plants irrigated with water of 0.6 dS m^{-1} and subjected to spraying and irrigation with salicylic acid simultaneously obtained the highest value of RGR_{PH} (0.0125 cm cm d^{-1}), RGR_{SD} (0.0088 mm mm d^{-1}) and WC (619.8 mm).

It is possible to observe in this study that spraying with salicylic acid also mitigated the deleterious effects of irrigation water salinity on the growth and production of cherry tomatoes (Table 3), and plants irrigated with water of 2.6 dS m^{-1} and sprayed with SA (S2M4) showed increments of 13.6, 15.8, 14.4, 16.0, 66.7, 10.7, 89.7, 4.8, 6.5 and 66.7% in PH_1, PH_2, SD_1, SD_2, NF, MFW, TPP, PD, ED and WUE, respectively, compared to plants irrigated with the same salinity level and without application of SA (S2M1).

Salt stress is one of the main factors that reduce plant growth and yield. In this study, it was verified that growth and production compromised in plants exposed to salt stress. At high concentrations, water and/or soil salinity affects the absorption of water and nutrients and all physiological processes of plants (Kamanga and Mndala, 2019).

According to Assaha et al. (2017), Na^+ and K^+ ions compete for the same binding sites due to their similar physical-chemical properties, so that excess Na^+ in the growth medium results in the substitution of K^+ in some biochemical reactions, which can inhibit enzymatic functions and compromise membrane integrity. In addition, salt stress induces excessive generation of reactive oxygen species (ROS) (Abdelaziz et al., 2018). Vieira et al. (2016), in a study with cherry tomatoes under saline stress (0.3 to 4.5 dS m-1), observed reductions of 27.4% (45.52 cm) in plant height and 21.3% (2.96 mm) in stem diameter in plants irrigated with water with higher electrical conductivity. Naeem et al. (2020) evaluated the cherry tomato crop under salt stress (0 to 90 mM) and found a 71,6% reduction in production variables when plants were exposed to higher salinity levels.

Despite the deleterious effect of salinity on cherry tomato plants, it was verified in the present study that the application of salicylic acid by foliar spraying favored their growth, production and water use efficiency. Spraying of SA was able to mitigate the negative effects caused by salt stress on the variables: PH_1, PH_2, SD_1, SD_2, NF, MFW, TPP, PD, ED and WUE.

Yildirim and Dursun (2009) observed higher growth and yield and better quality of tomato in response to foliar application of SA under greenhouse conditions. Souri and Tohidloo (2019), in a study evaluating the efficacy of different methods of salicylic acid application in the growth characteristics of tomato under salt stress, verified that foliar application of SA promoted increased growth in plant height and leaf area, and foliar spraying with SA also reduced the concentration of Na^+ in leaves.

The positive effects of salicylic acid on the mitigation of salt stress can be attributed to higher absorption of water and nutrients, membrane protection and increased photosynthetic activity, as it can also interact with signaling pathways of ROS and reduce oxidative stress (Saleem et al., 2021).

Salicylic acid also acts by regulating physiological and biochemical processes in plants, preventing the reduction of auxin and cytokinin levels, leading to a better cell division of the root apical meristem, thus promoting plant growth and yield (Osama et al., 2019).

The increase in growth variables as a function of foliar application of salicylic acid also resulted in higher production of cherry tomato fruits and, consequently, in the increase of water use efficiency. Salicylic acid optimizes nutrient absorption by plants and increases photosynthetic activity and biochemical processes, directly contributing to plant growth and development under salt stress (Tahjib-Ul-Arif et al., 2018; Oliveira et al., 2022).

In this study, it was also found that the application of salicylic acid via irrigation depth was harmful to the cherry tomato crop, especially when irrigated with water of 2.6 dS m^{-1}. This result may be related to the acidity (pH = 2.2) of the SA solution, which in direct contact with the root system may have compromised the development and, consecutively, the absorption of nutrients by plants.

In general, it can be inferred that the use of salicylic acid via foliar spraying can be an alternative to increase the yield of cherry tomatoes in a protected environment, also helping to reduce the harmful effects of salt stress.

4. Conclusions

Application of salicylic acid via foliar spraying increases the growth, production and water use efficiency of cherry tomato plants. The salt stress induced by the electrical conductivity of 2.6 dS m^{-1} is alleviated by the foliar application of salicylic acid. The use of water of 2.6 dS m^{-1}, combined with salicylic acid application via irrigation depth, intensifies the harmful effects of salinity.

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