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Original Article

Mineral composition and production of guava under salt stress and salicylic acid

Composição mineral e produção de goiabeira sob estresse salino e ácido salicílico

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Abstract

The limitation in the quality of water sources for irrigation in the semi-arid region of northeastern Brazil is increasingly present, so it is necessary to use water with high concentrations of salts for agricultural production, which makes the use of elicitors essential to mitigate the harmful effects of salinity on plants. Given the above, the objective of this study was to evaluate the effects of foliar application of salicylic acid on the mineral composition and production of guava plants under salt stress conditions in the post-grafting phase. The experiment was carried out under greenhouse conditions, in a randomized block design, in a 2 × 4 factorial scheme, with two levels of electrical conductivity of irrigation water (0.6 and 3.2 dS m^{-1}) and four concentrations of salicylic acid (0, 1.2, 2.4, and 3.6 mM), with three replicates. During the flowering stage of guava, N, P, and K contents accumulated in the leaves according to the following order of concentration: N > K > P. Foliar application of 1.2 mM of salicylic acid increases the leaf contents of N, P, and K in guava plants grown under irrigation with water of 0.6 dS m^{-1}. Water salinity of 3.2 dS m^{-1} reduces the growth and production components of guava plants.

Keywords: *Psidium guajava* L., plant nutrition, abiotic elicitor.

Resumo

A limitação na qualidade das fontes hídricas para irrigação na região semiárida do Nordeste é cada vez mais presente, tornando-se necessário o uso de águas com altas concentrações de sais para produção agrícola, o que torna indispensável à utilização de elicitores para atenuar os efeitos deletérios da salinidade sobre as plantas. Diante do exposto, objetivou-se com esse trabalho avaliar os efeitos da aplicação foliar de ácido salicílico na composição mineral e na produção de plantas de goiabeira sob condições de estresse salino na fase pós-enxertia. O experimento foi conduzido em casa de vegetação, no delineamento experimental de blocos casualizados, em esquema fatorial 2 × 4, sendo dois níveis de condutividade elétrica da água de irrigação (0,6 e 3,2 dS m^{-1}) e quatro concentrações de ácido salicílico (0; 1,2; 2,4 e 3,6 mM), com três repetições. Durante a fase de floração da goiabeira, os teores de N, P, K, se acumularam nas folhas segundo a ordem de concentração N > K > P. A aplicação foliar de 1,2 mM de ácido salicílico aumentou os teores foliares de nitrogênio, fósforo e potássio nas plantas de goiabeira cultivadas sob irrigação com água de 0,6 dS m^{-1}. A salinidade da água de 3,2 dS m^{-1} diminuiu o crescimento e os componentes de produção das plantas de goiabeira.

Palavras-chave: *Psidium guajava* L., homeostase iônica, elicitor abiótico.

1. Introduction

Guava (*Psidium guajava* L.) is a fruit crop belonging to the Myrtaceae family, with great economic importance, produced in almost all national territory, and the Northeast region of the country stands out as the largest producer (Gollagi et al., 2019). Guava fruits have several forms of use, being consumed fresh or industrialized as jam, sweets, compote, among others (Oliveira et al., 2015).

In Brazil, guava production in the 2021 season was around 552,393 tons in an area of 22,353 hectares, resulting in an average yield of 24,953 kg ha^{-1}. The Northeast region has a great contribution to the national production, and the states of Pernambuco, Bahia, and Ceará stand out as the largest producers, with a production of 198,754, 46,836, and 22,062 tons and an average yield of 36,032, 21,386, and 15,792 kg ha^{-1}, respectively (IBGE, 2022).

Despite the importance of this fruit crop for the semi-arid region of northeastern Brazil, the intrinsic characteristics of climate such as high evapotranspiration rates and rainfall irregularity make irrigation an essential practice for agricultural production (Andrade and Nunes, 2017).

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However, the water sources found in this region commonly have high concentrations of salts (Silva Júnior et al., 1999; Lima et al., 2016).

High levels of salts in water and/or soil alter plant physiology and growth and limit production due to osmotic and ionic effects (Capitulino et al., 2022). The reduction in the osmotic potential of the soil has as a main consequence the decrease in the availability of water to plants, inducing more significant energy expenditure to maintain metabolic activities (Andrade et al., 2019). In addition, high concentrations of salts can lead to oxidative stress through the formation of reactive oxygen species (ROS) (Isayenkov and Maathuis, 2019).

Xavier et al. (2022a), in a study of guava subjected to irrigation with saline water (ECw of 0.6, 1.5, 2.4, and 3.3 dS m^{-1}) in the seedling formation phase, also observed deleterious effects of salt stress on carotenoid contents and quantum efficiency of photosystem II. In this context, the economic production of crops moderately sensitive to salinity, such as guava (Távora et al., 2001), under irrigation with saline water, depends on cultivation practices used to mitigate stress in plants. It is important to highlight that the deleterious effects of salt stress depend on the species, cultivar, form of propagation, cationic and/or anionic nature of water, intensity and duration of stress, irrigation and fertilization management, and climatic conditions of the region (Soares et al., 2018; Pinheiro et al., 2022; Souto et al., 2023).

Among the alternatives that have been used to reduce the effects of salt stress on plants is the exogenous application of salicylic acid (SA). SA is a phenolic compound that acts in the expression of genes responsible for mitigating biotic and abiotic stresses (Methenni et al., 2018; Silva et al., 2018; Oliveira et al., 2022). SA also participates in several physiological and metabolic processes such as photosynthesis, nitrogen metabolism, and synthesis of proline, glycine-betaine, and soluble sugars, which contributes to the maintenance of osmotic and ionic homeostasis, antioxidant activity, acting in the elimination of ROS, and regulation of hormones (Khan et al., 2012; Koo et al., 2020).

Several studies have highlighted foliar application of salicylic acid as a promising alternative to reduce the deleterious effects of salt stress on plants, as observed in melon (Soares et al., 2022), guava, (Xavier et al., 2022b) and soursop (Silva et al., 2020). In the literature, studies using the foliar application of salicylic acid in the guava crop under irrigation with saline water are incipient, mainly evaluating the effects on the NPK levels. Thus, it is extremely important to develop research that aims to quantify the levels of NPK in guava irrigated with saline water in the post-grafting phase. In view of the above, the objective of this study was to evaluate the mineral composition and production components of guava cultivated under irrigation with saline water and foliar application of salicylic acid.

2. Material and Methods

The experiment was carried out from April 2020 to December 2021 under greenhouse conditions, at the Center of Technology and Natural Resources of the Federal University of Campina Grande, Campina Grande, Paraíba, Brazil, located by the local coordinates 07°15’18” S, 35°52’28” W and average altitude of 550 m. The climate in the region is tropical with a dry season, type As, according to the Köppen-Geiger climate classification (Alvares et al., 2013), and an average annual precipitation of 802.7 mm, a maximum temperature of 27.5 °C, minimum temperature of 19.2 °C and mean relative humidity of the air 83%. The temperature (maximum and minimum) and relative humidity data collected during the experimental period are shown in Figure 1.

A randomized block design was used, in a 2 × 4 factorial arrangement (Table 1), whose treatments resulted from the combination of two factors: two levels of electrical conductivity of irrigation water - ECw (0.6 and 3.2 dS m^{-1}) and four concentrations of salicylic acid - SA (0, 1.2, 2.4, and 3.6 mM), with three replicates. The ECw level of 3.2 dS m^{-1} was established based on studies conducted by Bezerra et al. (2019) with guava cv. Paluma in the post-grafting phase under semi-arid conditions in which they observed that a salinity level greater than 3.2 dS m^{-1} alters the physiology and reduces crop production. The SA concentrations used were adapted according to a study conducted by Silva et al. (2020) with the soursop crop (*Annona muricata* L.).

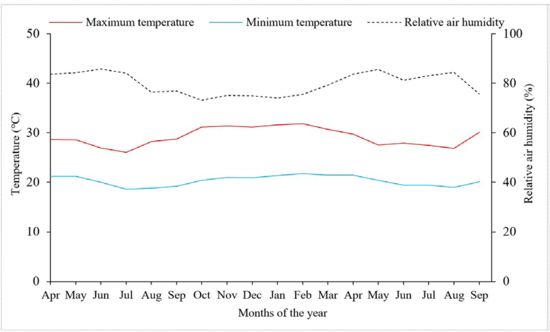

Figure 1. Maximum, minimum temperature and relative humidity of the air during the experimental period.

Table 1. Description of the treatments analyzed.

EC (dS m^{-1})	Salicylic Acid concentrations (SA) - mM			
	0	1	2	3
EC1 0.6	EC1SA1	EC1SA2	EC1SA3	EC1SA4
EC2 3.2	EC2SA1	EC2SA2	EC2SA3	EC2SA4

EC - electrical conductivity of irrigation water.

Recipients with a capacity of 200 L were used, adapted as drainage lysimeters. In each lysimeter, a drain of 16 mm in diameter was installed at the base, to allow excess water to drain. This drain was connected to a container to collect the drained water, in order to determine the water consumed by the plants. To avoid clogging the drain with material from the soil, the end of the drain inside the vessel was wrapped in non-woven geotextile, type Bidim OP 30.

The lysimeters were filled by placing a 1-kg layer of crushed stone nº zero, followed by 250 kg of a *Neossolo Regolítico* (Entisol) with sandy clay loam texture, properly pounded to break up clods and collected from the rural area of the municipality of Lagoa Seca, PB (0-20 cm depth), whose chemical and physical characteristics (Table 2) were obtained according to Teixeira et al. (2017).

In this study, the rootstocks used were seedlings of pineapple guava (*Acca sellowiana* (O. Berg.) Burret) and the scion was the cv. Paluma. Grafted seedlings were acquired at the age of 70 days after grafting. At the time of transplantation, the seedlings had a rootstock diameter of 11.42 mm, a scion diameter of 8.92 mm, and a mean height of 35.16 cm. Guava plants were transplanted 20 days after the acquisition of seedlings into holes with dimensions of 20 × 20 × 20 cm and, before being transplanted, they were assessed to check whether they were root bound. After transplanting, the seedlings were acclimatized for a period of 50 days, during which they were irrigated using water with electrical conductivity of 0.6 dS m^{-1}. The purpose of irrigation with an ECw of 0.6 dS m^{-1} was to guarantee the uniformity of the stand until the first pruning of formation.

The water with the lowest electrical conductivity (0.6 dS m^{-1}) was obtained from the water supply system of Campina Grande, PB, whereas the highest level of ECw (3.2 dS m^{-1}) was prepared by dissolving the salts NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$, in the equivalent proportion of 7:2:1 (similar to most waters used in irrigation in the Northeast), respectively, in water from the supply system of Campina Grande, PB, considering the relationship between ECw and concentration of salts (Richards, 1954), according to Equation 1:

$$Q \approx 10 \times ECw \tag{1}$$

where:

Q = quantity of salts to be dissolved ($mmol_c$ L^{-1}); and,
ECw = electrical conductivity of water (dS m^{-1})

Before transplanting the seedlings, the moisture content of the soil was increased until reaching its maximum water holding capacity using water with ECw of 0.6 dS m^{-1}. Salinity levels began to be applied at 75 days after transplantation (DAT), with daily irrigation performed at 5 p.m., and the volume of water to be applied in each lysimeter was determined by Equation 2 (Bernardo et al., 2019):

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

where:

VI - volume of water to be used in the irrigation event (mL);
Va - volume applied in the previous irrigation event (mL);
Vd - volume drained (mL); and,
LF - leaching fraction of 0.10 applied every 15 days.

The solutions of salicylic acid were prepared by dissolving it in 30% ethyl alcohol, as it is a substance with low solubility in water at ambient temperature. In the preparation of the solution, the adjuvant Wil fix® at a concentration of 0.5 mL L^{-1} of the solution was also used to reduce the surface tension of the drops on the leaf surface (adaxial and abaxial sides). Salicylic acid applications started at 45 DAT and extended until the full flowering stage (205 DAT). Salicylic acid applications started at 45 DAT with the aim of inducing the plant tolerance mechanisms to salt stress.

The frequency of application was 30 days and, during this period, an average value of 683.33 mL of the respective solutions was applied per plant. The applications were carried out at 5 p.m. In each application event, the plant was isolated using plastic curtains to prevent the SA solution from drifting.

Formative pruning was carried out when the plants reached 50 cm height, by cutting the branch with apical dominance to stimulate the production of lateral branches. With the emergence of the new branches, secondary branches were selected in a well-distributed and balanced manner, and later these lateral branches were cut when they reached 40 cm in length, as described by Lacerda et al. (2022).

Table 2. Chemical and physical characteristics of the soil used in the experiment.

Chemical characteristics								
pH H_2O	**OM**	**P**	**K^+**	**Na^+**	**Ca^{2+}**	**Mg^{2+}**	**$Al^{3+} + H^+$**	**N**
1:2.5	**g dm^{-3}**	**mg dm^{-3}**	**.........$cmol_c$ kg^{-1}.........**					**(%)**
6.5	8.1	79	0.24	0.51	14.90	5.40	0.90	0.09

.... Chemical characteristics............						.... Physical characteristics...........				
EC_{se}	CEC	SAR_{se}	ESP	SB	V	Particle-size fraction (g kg^{-1})			Moisture content (dag kg^{-1})	
dS m^{-1}	$cmol_c$ kg^{-1}	(mmol $L^{-1})^{0.5}$	%	$cmol_c$ kg^{-1}	%	Sand	Silt	Clay	33.42 kPa[1]	1519.5 kPa[2]
2.15	21.95	0.16	3.08	21.05	95.89	572.7	100.7	326.6	25.91	12.96

pH - Hydrogen Potential; 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; $Al^{3+} + H^+$ - extracted with 0.5 M CaOAc at pH 7.0; EC_{se} - electrical conductivity of saturation extract; CEC - cation exchange capacity; SAR_{se} - sodium adsorption ratio of saturation extract; ESP - exchangeable sodium percentage; SB - sum of bases ($K^+ + Ca^{2+} + Mg^{2+} + Na^+$); V - base saturation ([SB/CEC] × 100); [1,2] - correspond to field capacity and permanent wilting point, respectively

Nitrogen, potassium, and phosphorus fertilization was performed according to the recommendation of Cavalcanti (2008), applying 100, 100, and 60 g per plant of N, P2O5 and K2O, respectively, and using urea (45% N), potassium chloride (60% K), and monoammonium phosphate (50% P and 11% N) as sources of nutrients. Fertilization started at 15 DAT and was performed in fortnightly applications.

Fertilization with micronutrients was also performed fortnightly through the leaves, starting at 30 DAT, on the adaxial and abaxial sides, considering the nutritional requirements of the crop, with a concentration of 1 g L^{-1} of Dripsol Micro® (0.85% boron, 3.4% iron, 4.2% zinc, 3.2% manganese, 0.5% copper, and 0.06% molybdenum).

Phytosanitary control was carried out preventively to control the possible emergence of pests: psyllid (*Triozoida limbata*), fruit flies (*Anastrepha* spp., *Ceratitis capitata*), passionvine bug (*Leptoglossus gonagra*), and Florida wax scale (*Ceroplastes floridensis*), through selective chemicals based on Imidacloprid and Abamectin, using 1 g to 10 L and 2.5 mL to 10 L in the preparation of the solution, respectively.

At the flowering stage (510 DAT), because it is a phase in which the crop has a greater nutritional demand, and its objective is to guide possible corrections in fertilization (Souto et al., 2023), leaf samples were collected in the middle third of each treatment and after collection, the plant material was dried in an oven with forced air circulation at 65 °C for 48 hours, processed in a Wiley mill, and subsequently submitted to determinations of N, P, and K. To determine the nutrient contents, nitric (P, K) and sulfuric (N) digestions were performed according to the methodology of Silva (1999). Nitrogen content was determined by the Kjeldahl method and, after distillation the data were obtained by titration. Potassium content was determined by the flame photometry technique and phosphorus content by the molybdate-vanadate colorimetric method, in a spectrophotometer.

The following parameters were also determined: rootstock stem diameter (RSD) and scion stem diameter (SCD), measured using a digital caliper; crown diameter (DCrown), obtained by the average crown diameter observed in the row direction (RD) and interrow direction (IRD); crown volume (VCrown), calculated using plant height (H), RD and IRD, according to Equation 3; and VVI, obtained according to Portella et al. (2016), using Equation 4:

$$\text{VCrown} = \left(\frac{\eth}{6}\right) \text{x H x RD x IRD} \tag{3}$$

where:
VCrown – crown volume (m^3);
H – plant height (m);
RD – crown diameter in the row direction (m); and
IRD – crown diameter in the interrow direction (m).

$$\text{VV I} = \frac{\left[\text{H} + \text{DCrown} + \left(\text{RSD x 10}\right)\right]}{100} \tag{4}$$

where:
VVI – vegetative vigor index;
H – plant height (m);
DCrown – crown diameter (m); and,
RSD – rootstock stem diameter (m).

The following parameters were also measured: the number of fruits per plant (NF), average fruit weight (AFW), and total fruit weight (TFW). Harvest was carried out from October to November 2021. The fruits were harvested based on color, considering the change from green to yellow as the harvest point. NF was determined by counting the harvested fruits. TFW was obtained by summing the weight of all fruits produced per plant. AFW was obtained through the ratio between the fresh weight of fruits and the total number of fruits harvested.

The multivariate structure of the results was evaluated with 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).

Before the analysis, the original data of the variables of each component were submitted to dimension reduction, through the technique of multivariate analysis of variance (MANOVA) with the Hotelling test (Hotelling et al., 1947) at 0.05 probability level for salinity levels and salicylic acid concentrations, as well as for the interaction between them. Only variables with correlation coefficient greater than or equal to 0.65 were maintained in each principal component (PC) (Hair et al., 2009). Statistical analyses were performed using Statistica software v. 7.0 (Statsoft, 2004).

3. Results and Discussion

According to the results presented in Table 3, the two main components selected together explained 85.8% of the total variation of the analyzed variables. PC1 explained 66.49% of the total variation, being composed of most of the analyzed variables, while PC2 explained 19.31% of the remaining total variation, being composed only of the AFW variable.

There was a significant effect ($p \leq 0.01$) of the interaction between electrical conductivity of water (ECw) and salicylic acid concentrations (SA) for PC1 and PC2 (Table 3). Significant effects ($p \leq 0.01$) of ECw levels and salicylic acid concentrations were also observed when analyzed individually.

The effects of treatments and variables are expressed in Figures 2A and 2B for the first and second principal components (PC1 and PC2). In the first principal component (PC1), there was possibly an interaction between water salinity levels and salicylic acid concentrations. It was observed that the correlation coefficients were higher than 0.64 for the variables of N, P, K, VCrown, DCrown, VVI, TFW, and NF.

According to PC1, guava plants had higher values of N, P, and K when irrigated with water of 0.6 dS m^{-1} and submitted to a concentration of SA of 1.2 mM (EC1SA2), with values of 10.27, 3.72, and 10.42 g kg^{-1}, respectively. When compared with the EC2SA4 treatment, there was an increase of 31.45, 51.08, and 54.79% in N, P, and K contents, respectively.

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

	Principal Components (PCs)	
	PC1	**PC2**
Eigenvalues (λ)	5.98	1.74
Percentage of total variance (S^2%)	66.49	19.31
Hotelling test (T^2) for electrical conductivity (EC)	0.01	0.01
Hotelling test (T^2) for salicylic acid (SA)	0.01	0.01
Hotelling test (T^2) for interaction (EC × SA)	0.01	0.01

PCs	Correlation coefficient										
	N	P	K^+	VCrown	DCrown	VVI	RSD	SCD	TFW	NF	AFW
PC1	-0.79	-0.65	-0.64	-0.94	-0.95	-0.94	-0.85	-0.74	-0.92	-0.86	-0.44
PC2	0.44	0.48	0.60	-0.28	-0.18	-0.24	0.03	-0.29	-0.16	0.31	-0.71

	Mean values										
	N	P	K^+	VCrown	DCrown	VVI	RSD	SCD	TFW	NF	AFW
EC1SA1	10.27	2.42	8.56	4.384	3.283	5.562	39.897	31.797	3759.33	63.33	61.64
EC2SA1	9.57	1.88	7.60	3.487	2.917	5.053	38.653	31.213	1019.67	23.67	49.94
EC1SA2	10.27	3.72	10.42	3.989	3.233	5.425	37.857	31.830	3132.87	60.67	61.77
EC2SA2	7.45	2.09	8.69	3.063	2.750	4.865	36.520	30.607	1066.33	34.67	55.43
EC1SA3	8.43	2.36	8.05	4.152	3.250	5.426	38.290	32.713	2685.73	34.33	87.10
EC2SA3	7.31	2.21	6.83	3.338	2.817	5.010	37.047	31.523	1825.07	30.00	64.19
EC1SA4	8.11	2.01	6.33	4.110	3.133	5.431	38.397	33.083	3007.67	41.33	67.55
EC2SA4	7.04	1.82	4.71	3.215	2.833	4.982	34.560	28.283	1111.00	20.67	57.48

EC – Electrical conductivity of water, EC1 (0.6 dS m^{-1}); EC2 (3.2 dS m^{-1}); SA – Salicylic acid - SA1 (0 mM); SA2 (1.2 mM); SA3 (2.4 mM); SA4 (3.6 mM); N (Nitrogen - g kg^{-1}); P (Phosphorus - g kg^{-1}); K^+ (Potassium - g kg^{-1}); VCrown (Crown volume - m^3); DCrown (Crown diameter - m^2); VVI (Vegetative vigor index); RSD (Rootstock diameter - mm); SCD (Scion diameter - mm); TFW (Total fruit weight - g per plant); NF (Number of fruits); AFW (Average fruit weight - g per fruit).

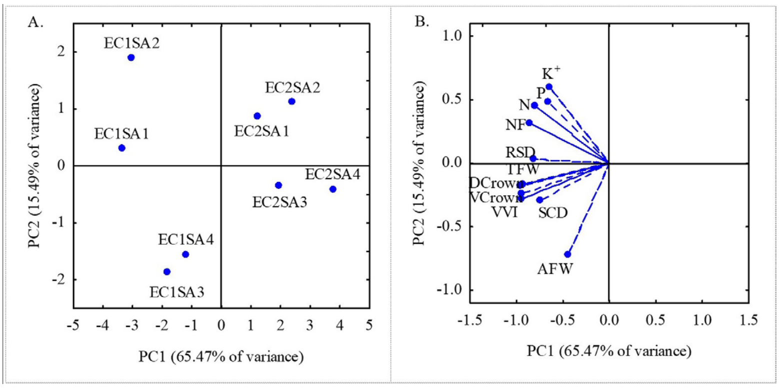

Figure 2. Two-dimensional projection of the scores of the principal components for the factors water electrical conductivity levels - EC and salicylic acid concentrations - SA (A) and the variables analyzed (B) in the two principal components (PC1 and PC2).

The variables crown volume and crown diameter were higher when the plants were irrigated with the lowest salinity level and received no application of salicylic acid (EC1SA1), with mean values of 4.384 m^3 and 3.283 m, respectively. The vegetative vigor index showed the same behavior as crown volume and crown diameter. Rootstock diameter obtained the highest mean value when plants were subjected to water of lower salinity and absence of salicylic acid (EC1SA1) (39.89 mm); compared to the lowest mean value, observed in the EC2SA4 treatment, there was a decrease of 5.33 mm. For scion diameter, the highest value observed was 33.08 mm, when plants were irrigated with water of 0.6 dS m^{-1} and received an SA concentration of 3.6 mM (EC1SA4); compared to plants that obtained the smallest stem diameter, there was a reduction of 4.81 mm.

The reduction in the growth of guava plants may be associated with the osmotic and toxic effects of Na^+ and Cl^- ions, which become harmful when accumulated in stem tissues during plant growth (Lima et al., 2019).

Plants irrigated with 0.6 dS m^{-1} water, without the application of salicylic acid (0 mM) (EC1SA1), obtained the highest values of total fruit mass (3,759.33 g per plant) and an average number of fruits (63.33 fruits per plant). When compared with the highest value found in EC1SA1 treatments, there were reductions of 72.87 and 67.33% in TFW and NF, respectively, in the lowest value found in EC2SA1 treatments.

When analyzing PC2, it was observed that the average fruit weight (AFW) was higher in guava plants grown under an SA concentration of 2.4 mM and ECw of 0.6 dS m^{-1} (EC1SA3), standing out when compared to the lowest values found in the EC2SA1 treatment, with a difference of 37.16 g per fruit. The reduction in production variables may be associated with changes in the processes of absorption, transport, assimilation, and distribution of nutrients in the plant caused by osmotic and ionic effects (Lima et al., 2022).

The reduction in N and K contents in the leaf tissues of guava plants can be explained by the concentrations of Cl^- and Na^+ present in irrigation water, which may have induced a decrease in the absorption of NO_3^- and K^+, due to their antagonistic effect (Ribeiro et al., 2016).

Nutrient accumulations in the leaves of plants vary according to their stage of development (Natale et al., 2002). Thus, the adequate levels of macro and micronutrients depend on the requirement of the plant in each development stage. According to Natale et al. (2002), adequate leaf levels of N, P, and K^+ for guava crops at full flowering are 20 to 23 g kg^{-1} of N, 1.4 to 1.8 g kg^{-1} of P, and 14 to 17 g kg^{-1} of K, respectively. Thus, the values obtained in the present study, except for P, are below those required by the guava crop. The reduction of N and K may be associated with their antagonistic effect with Na^+ and Cl^- ions, as they compete for the same cell absorption sites (Fernandes et al., 2002). Thus, excess salts in water can interfere with the absorption and translocation of these nutrients, promoting nutritional imbalance in plants (Sá et al., 2017).

Unlike the results obtained in this study for N contents, Souza et al. (2019) studied the noni crop (*Morinda citrifolia*) and found that the increment in water salinity resulted in an increase in leaf N contents, but they observed a reduction in K contents, corroborating the data found here. Freire et al. (2020), when evaluating the effects of salt stress (ECw of 0.5 and 3.5 dS m^{-1}) on sour passion fruit, also found a reduction in leaf K contents in plants irrigated with water of electrical conductivity from 3.2 dS m^{-1}, but there was an increase in N contents.

Water salinity up to 3.2 dS m^{-1} significantly influenced leaf P contents in the guava plants. The results obtained for the P contents corroborate those reported by Natale et al. (2002), they indicate that the desired amount of P for the guava crop should be within the range from 1.4 to 1.8 g kg^{-1}. The highest P value observed in this study was 1.8 g kg^{-1}, hence being considered adequate for guava crop. In another study with eggplant crop, Bosco et al. (2009) found that, under conditions of salt stress, there was no reduction in P contents, but N and K contents decreased with the increase in irrigation water salinity.

The adequate levels of nutrients in guava plants are important for the maintenance of ionic homeostasis, especially the most required ones such as N, P, and K, since N acts on several organic compounds, such as amino acids, proteins, chlorophyll, among others, which help in osmotic adjustment, making the conditions more favorable to water absorption by plants (Costa et al., 2020). K is a macronutrient that is part of the translocation and maintenance of water balance, participating in various biochemical and physiological functions, including stomatal opening and closing, enzyme activation, photosynthesis, osmoregulation, and synthesis of proteins (Ahanger et al., 2017), while P acts in energy supply and root development (Diniz et al., 2018).

The reduction in the growth variables observed in this study may be related to the reduction in N and K contents in the plant and the decrease in the energy state of free water and the genetic alterations caused by the increase in water salinity. When there is an increase in the concentration of salts in the soil solution, free water becomes less available to the plant, which can affect the growth and development of the roots and, consequently, of the aerial parts. Furthermore, salinity can also affect the synthesis of important cell wall components, such as suberin, lignin, and polysaccharides, which are directly involved in elongation and cell division rates (Li et al., 2014; Byrt et al., 2018).

This decrease observed in crown volume and diameter when the plant was subjected to the highest salinity may be related to its defense mechanism against salt stress, reducing the transpiring surface and consequently reducing water loss (Oliveira et al., 2017). Lacerda et al. (2022), in a study with guava under salinity, also observed that crown volume and diameter were reduced in plants subjected to water from 3.2 dS m^{-1} electrical conductivity.

In the present study, a reduction was observed in the rootstock and scion diameters of guava cv. Paluma, which may be a consequence of changes in soil water potential due to excess salts, which reduces water absorption and, consequently, turgor pressure and cellular activity, inhibiting cell expansion and elongation (Lopes et al., 2019).

Similar results were reported by Bezerra et al. (2018), who studied the guava crop cv. Paluma subjected to irrigation with saline water (ECw from 0.3 to 3.5 dS m^{-1}) and found a reduction of stem diameter at 255 and 300 days after transplantation. Xavier et al. (2022b), when studying the formation of guava rootstock under salinity (ECw of 1.5, 2.4, 3.3, and 4.2 dS m^{-1}), observed a decrease in stem diameter with the increase in salinity level at 180 DAT.

The reductions in the number of fruits, average fruit weight, and total fruit weight may be related to osmotic and/or ionic effects, leading to changes in the absorption, transport assimilation, and distribution of nutrients in the plant (Lima et al., 2022). In studies conducted with the passion fruit crop, Lima et al. (2022) observed that irrigation using water with electrical conductivity of 4.0 dS m^{-1} led to reductions in the yield of plants subjected to salt stress in the flowering stage.

The highest values of average fruit weight were obtained when salicylic acid was used at a concentration of 2.4 mM and under ECw of 0.6 dS m^{-1}. The increase in AFW reflects the physiological role of salicylic acid in maintaining the Na^+/K^+ ratio, contributing to photosynthetic activity and translocation of photoassimilates to fruits (Gunes et al., 2007; Tufail et al., 2013).

Silva et al. (2022), in a study with custard apple under irrigation with saline water (ECw of 0.8 and 3.0 dS m^{-1}), concluded that the increase in ECw levels reduced the number of fruits, and fruit fresh weight. Lacerda et al. (2022) also found that irrigation with water of 3.2 dS m^{-1} negatively affected the production components of guava plants, reducing the polar and equatorial diameters of the fruits, average fruit weight, total fruit weight, and the number of fruits at 390 days after transplanting.

Based on the results found, the levels of N, P, and K in guava leaves in full bloom followed the decreasing order of N > K > P, which is in line with other studies in the literature, such as that by Natale et al. (2002), who also observed that the accumulation of N, P, and K in guava follows the sequence of N > K > P.

4. Conclusions

In the flowering stage of guava, N, P, and K contents accumulate in the leaves according to the following order of concentration: N > K > P, independent of the level of electrical conductivity of the water.

Foliar application of 1.2 mM of salicylic acid increases the leaf contents of nitrogen, phosphorus, and potassium in the guava plants cultivated with water of 0.6 dS m^{-1} during the flowering phase.

Water salinity of 3.2 dS m^{-1} reduces the growth, total fruit weight, number of fruits, and average fruit weight of guava plants.

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