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Morphophysiology and production of guava as a function of water salinity and salicylic acid[1]

Morfofisiologia e produção de goiabeira em função de salinidade da água e ácido salicílico

Cassiano N. de Lacerda[2*], Geovani S. de Lima[2], Lauriane A. dos A. Soares[3], Reynaldo T. de Fátima[2], Hans R. Gheyi[2] & Carlos A. V. de Azevedo[2]

[1] Research developed at Universidade Federal de Campina Grande, Centro de Tecnologia e Recursos Naturais, Campina Grande, PB, Brazil
[2] Universidade Federal de Campina Grande/Programa de Pós-Graduação em Engenharia Agrícola, Campina Grande, PB, Brazil
[3] Universidade Federal de Campina Grande/Unidade Acadêmica de Ciências Agrárias, Pombal, PB, Brazil

HIGHLIGHTS:

Salt stress reduces the CO_2 assimilation rate by the action of stomatal and non-stomatal factors.
The electrical conductivity of 3.2 dS m^{-1} is harmful for the cultivation of grafted guava.
Salicylic acid up to 3.6 mM does not alleviate salt stress in grafted guava at 390 days after transplanting.

ABSTRACT: The availability of water with low electrical conductivity for irrigation in the Northeastern semi-arid region is one of the limiting factors for the expansion of irrigated agriculture. Thus, it is necessary to use waters with high electrical conductivity, requiring the search for strategies to reduce the negative impacts of salts on plants. In this context, the objective of this study was to evaluate the morphophysiology and production of guava cv. Paluma subjected to irrigation with saline waters and foliar application of salicylic acid after grafting. The experiment was conducted under greenhouse conditions in Campina Grande - PB, Brazil, in a randomized block design, adopting a 2 × 4 factorial scheme, with two values of electrical conductivity of irrigation water - ECw (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. Irrigation with water of 3.2 dS m^{-1} reduced gas exchange, rootstock and scion diameters, crown diameter and volume, vegetative vigor index, polar and equatorial diameters of fruit, number of fruits, mean fruit weight, and fresh fruit weight of fruits of guava cv. Paluma. Salicylic acid application up to 3.6 mM did not mitigate the effects of salt stress on grafted guava cv. Paluma, at 390 days after transplanting.

Key words: *Psidium guajava* L., semi-arid region, salt stress

RESUMO: A disponibilidade de água com baixa condutividade elétrica para irrigação no semiárido nordestino é um dos fatores limitantes para a expansão da agricultura irrigada. Assim, é necessário o uso de águas com elevadas condutividades elétricas, requerendo a busca por estratégias para reduzir os impactos negativos dos sais nas plantas. Neste contexto, objetivou-se com esse trabalho avaliar a morfofisiologia e a produção de goiaba cv. Paluma submetida à irrigação com águas salinas e aplicação foliar de ácido salicílico após enxertia. O experimento foi conduzido sob condições de casa de vegetação em Campina Grande - PB, no delineamento experimental de blocos casualizados, em esquema fatorial 2 × 4, sendo dois valores de condutividade elétrica da água de irrigação - CEa (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. A irrigação com água de 3,2 dS m^{-1} reduziu as trocas gasosas, o diâmetro do porta-enxerto e do enxerto, o diâmetro e volume de copa, o índice de vigor vegetativo, o diâmetro polar e equatorial dos frutos, número de frutos, peso médio de frutos, e o peso fresco de frutos de goiaba cv. Paluma. As concentrações de ácido salicílico até 3,6 mM não mitigaram os efeitos do estresse salino em goiaba cv. Paluma, aos 390 dias após o transplantio.

Palavras-chave: *Psidium guajava* L., semiárido, estresse salino

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* Corresponding author - E-mail: cassianonogueiraagro@gmail.com
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Introduction

Guava (*Psidium guajava* L.) is among the most commercially exploited fruit crops throughout Brazil, due to the various possibilities of use, as it can be consumed fresh or processed as guava paste, jams, fruit in syrup, puree, base for beverages, soft drinks, juices, and syrups (Onias et al., 2018). Despite the importance of this fruit crop for the Northeast region, the climate characteristics, such as rainfall irregularities, high temperature, and high evapotranspiration rates, have posed limitations to obtaining a high yield, which has made irrigation practice indispensable (Silva et al., 2018; Lima et al., 2022). Besides this, the high concentrations of salts in water sources are obstacles to the expansion of irrigated agriculture (Souza et al., 2016).

The presence of salts in water and, or, soil triggers changes in the plant that begins by the reduction in the osmotic potential of the soil solution, restricting the absorption of water and nutrients, in addition to causing toxic effect of specific ions, such as sodium and chloride, which triggers nutritional imbalance/impacts (Bezerra et al., 2018a; Andrade et al., 2019). It should be considered that the effects of salt stress vary between species, cultivars, and edaphoclimatic conditions (Lima et al., 2022). Among the cultivation strategies that can increase the tolerance of plants to salt stress, the use of grafting stands out (Zhang et al., 2018).

Foliar application of salicylic acid (SA) has also emerged as a promising alternative against different stresses of biotic and abiotic origin. Under salt stress conditions, SA acts in several physiological and biochemical processes, contributing to increasing photosynthetic activity, through improvements in antioxidant and metabolic defense, avoiding lipid peroxidation caused by reactive oxygen species - ROS (Silva et al., 2020; Roshdy et al., 2021). The objective of this study was to evaluate the morphophysiology and production of guava cv. Paluma subjected to irrigation with saline waters and foliar application of salicylic acid in the post-grafting stage.

Material and Methods

The experiment was carried out from April 2020 to May 2021, in an arch-shaped greenhouse, with 150-micron low-density polyethylene cover and sides covered with white screen at the Center of Technology and Natural Resources of the Federal University of Campina Grande, Paraiba, Brazil, located by the coordinates 07° 15' 18" S latitude, 35° 52' 28" W longitude and a mean altitude of 550 m. The maximum and minimum temperatures and relative air humidity collected during the experimental period are shown in Figure 1.

The experimental design was randomized blocks, in a 2 × 4 factorial arrangement, referring to two values 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 four replicates. The experimental unit consisted of one plant. The highest ECw was established based on studies conducted by Bezerra et al. (2019) with guava cv. Paluma. On the other hand, salicylic acid (SA) concentrations were based on a study conducted by Silva et al. (2020) with the soursop crop (*Annona muricata* L.).

Salicylic acid solutions were prepared in 30% of ethyl alcohol (95.5% purity), as it is a substance with low solubility in water at room temperature. In the preparation of the solution, the Wil fix adjuvant at the concentration of 0.5 mL L^{-1} was added to reduce the surface tension of the drops on the leaf surface (adaxial and abaxial sides). Salicylic acid applications started 45 days after transplanting (DAT) and extended up to the stage of full flowering (205 DAT). The frequency of application was at interval of 30 days and, during this period, on average 683.33 mL of the respective solution was applied per plant. The applications were performed at 17 hours and during the application, the plant was isolated using plastic curtains to prevent the solution from drifting.

'Crioula' guava seedlings were used in the present study as rootstock, coming from the seedling nursery located in Sousa, Paraíba, Brazil, whereas the scion was the cv. Paluma. Grafted seedlings were acquired at the age of 70 days after grafting. At the time of transplanting, the seedlings had a rootstock diameter of 11.42 mm, a graft diameter of 8.92 mm, and an average height of 35.16 cm.

Containers with a capacity of 200 L adapted as drainage lysimeters were used for planting. A 16-mm-diameter drain was installed at the base of each lysimeter to drain excess water

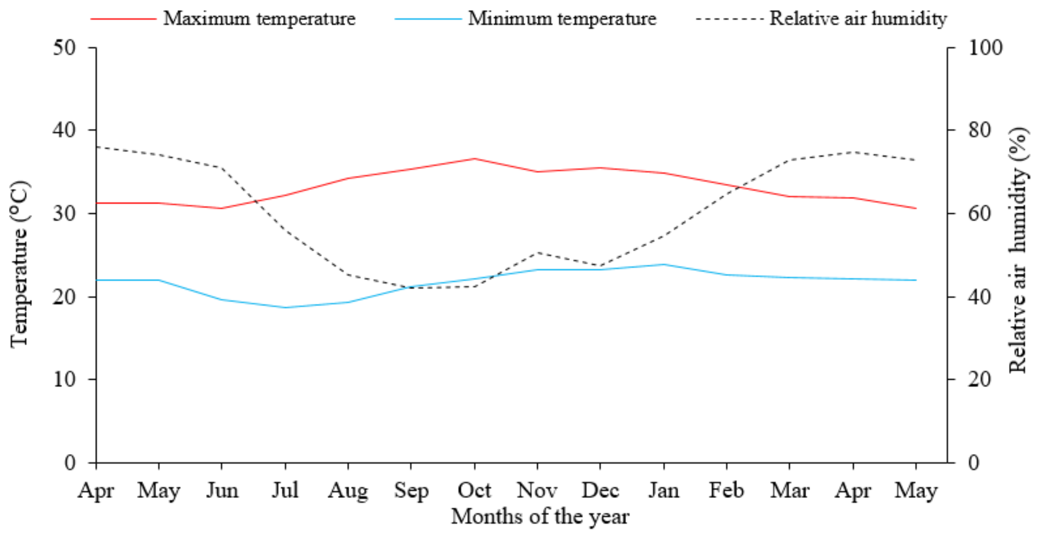


Figure 1. Maximum and minimum air temperature and relative air humidity during the experimental period

and connected to a container for collecting drained water to subsequently determine water consumption by the plants. The tip of the drain inside the pot was wrapped with a nonwoven geotextile (Bidim OP 30) to prevent clogging by soil materials.

The lysimeters were filled by placing a 1.0 kg layer of crushed stone number 0, followed by 250 kg of an Entisol with sandy loam texture (0-20 cm depth), properly pounded to break up clods belonging to the rural area of Lagoa Seca, Paraíba. Its chemical and physical characteristics (Table 1) were obtained according to the methodologies recommended by Teixeira et al. (2017).

The water with the lowest electrical conductivity (0.6 dS m^{-1}) was obtained from the municipal supply system in Campina Grande. On the other hand, the highest 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 ratio of 7:2:1 among Na:Ca:Mg, a relation that is predominant in water sources used for irrigation in small properties in the Northeast, considering the relation between ECw and the concentration of salts (Richards, 1954), according to Eq. 1:

$$C = 10ECw \quad (1)$$

where:

C - concentration of salts to be applied ($mmol_c$ L^{-1}); and,

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

The transplanting was carried out on April 24, 2020 (20 days after the acquisition of the seedlings), to pits with dimensions of 20 × 20 × 20 cm. Before the transplanting, the soil moisture content was elevated until reaching the maximum water-holding capacity using water of ECw of 0.6 dS m^{-1} and the seedlings were checked if their roots were bounded. After transplanting, the seedlings were acclimated for 50 days, a period in which the plants were irrigated daily at 17:00 hours with water of 0.6 dS m^{-1} electrical conductivity. The volume of water applied to each lysimeter was determined by Eq. 2:

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

where:

VI - volume of water to be used in the next irrigation event, mL;

Va - volume applied in the previous irrigation event, mL;

Vd - volume drained in the previous event, mL; and,

LF - leaching fraction of 0.10.

Fertilization with nitrogen, potassium, and phosphorus was performed as recommended by Cavalcanti (2008), applying 100, 100 and 60 g per plant of N, P_2O_5, and K_2O, respectively, using urea (45% N), potassium chloride (60% K_2O), and monoammonium phosphate (50% P_2O_5, 11% N) as sources. Fertilization began at 15 DAT and was carried out in biweekly applications with equal doses.

Fertilizations with micronutrients were also performed fortnightly from 30 DAT by spraying the leaves on the adaxial and abaxial sides with a solution at the concentration of 1.0 g L^{-1} of Dripsol Micro® (1.2% magnesium, 0.85% boron, 3.4% iron, 4.2% zinc, 3.2% manganese, 0.5% copper, and 0.06% molybdenum). Formative pruning and phytosanitary control were carried out as recommended by Barbosa & Lima (2010).

At 390 DAT, gas exchange was analyzed through the CO_2 assimilation rate - A (mol CO_2 m^{-2} s^{-1}), transpiration – E (mmol H_2O m^{-2} s^{-1}), stomatal conductance - gs (mol H_2O m^{-2} s^{-1}), and intercellular CO_2 concentration - Ci (μmol CO_2 m^{-2} s^{-1}) using an infrared gas analyzer - IRGA (LCpro - SD model, from ADC Bioscientific, UK). Observations were performed between 7:00 and 9:00 a.m., on the third fully expanded leaf counted from the apical bud, under natural conditions of air temperature and CO_2 concentration, using an artificial radiation source of 1,200 μmol m^{-2} s^{-1}.

Also at 390 DAT, the following variables were determined: rootstock (RD) and scion diameter (SD), determined using a digital caliper; crown diameter (DCrown), obtained by the means of crown diameter observed in the directions of the planting row (DR) and interrow (DIR); crown volume (VCrown), calculated from plant height (H), DR and DIR; and vegetative vigor index (VVI), obtained according to Portella et al. (2016).

At the same time, the following variables were also measured: polar (FPD) and equatorial diameter (FED) of the fruit, total number of fruits per plant (TNF), mean fruit weight (MFW), and fresh fruit weight (FFW). Harvest was carried out from March to May 2021. The fruits were harvested based on their color, and the change from green to yellow color was considered to be the harvesting point (Bezerra et al., 2019).

FPD and FED measurements were made through a representative sample of 12 fruits harvested from each plot, selected randomly. FPD was measured from the base to the apex of the fruit and FED was measured in the median region in the horizontal direction, using a digital caliper. TNF was determined by counting all the fruits harvested. FFW was obtained by summing the weight of all fruits produced per

Table 1. Chemical and physical characteristics of the soil used in the experiment, before the application of the treatments

Chemical characteristics								
pH (H_2O) 1:2.5	OM (dag kg^{-1})	P (mg dm^{-3})	K^+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H^+
			($cmol_c$ kg^{-1})					
6.5	8.1	79.00	0.24	0.51	14.90	5.40	0	0.90

Chemical characteristics				Physical characteristics				
				Particle size fraction (g kg^{-1})			Water content (kPa)	
EC_{se} (dS m^{-1})	CEC ($cmol_c$ kg^{-1})	SAR_{se} (mmol L^{-1})$^{0.5}$	ESP (%)	Sand	Silt	Clay	33.42[1]	1519.5[2]
							(dag kg^{-1})	
2.15	16.54	0.16	3.08	572.70	100.70	326.60	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; ECse - Electrical conductivity of saturation extract; CEC - Cation exchange capacity; SAR_{se} - Sodium adsorption ratio of saturation extract; ESP - Exchangeable sodium percentage; [1,2] referring to field capacity and permanent wilting point plant. MFW was obtained through the ratio between fresh fruit weight and the total number of fruits harvested.

The data were subjected to the normality test (Shapiro-Wilk test) followed by the analysis of variance. F test was applied to determine the difference between electrical conductivities of water ($p \leq 0.05$), and linear and quadratic polynomial regression analysis was performed for salicylic acid concentrations ($p \leq 0.05$) using the statistical program SISVAR (Ferreira, 2019).

Results and Discussion

There was a significant effect of water electrical conductivities on stomatal conductance (gs), transpiration (E), internal CO_2 concentration (Ci), and CO_2 assimilation rate (A) of guava plants, cv. Paluma, at 390 days after transplanting (Table 2). Salicylic acid concentrations and the interaction between factors (SL × SA) did not significantly influence any of the gas exchange variables analyzed.

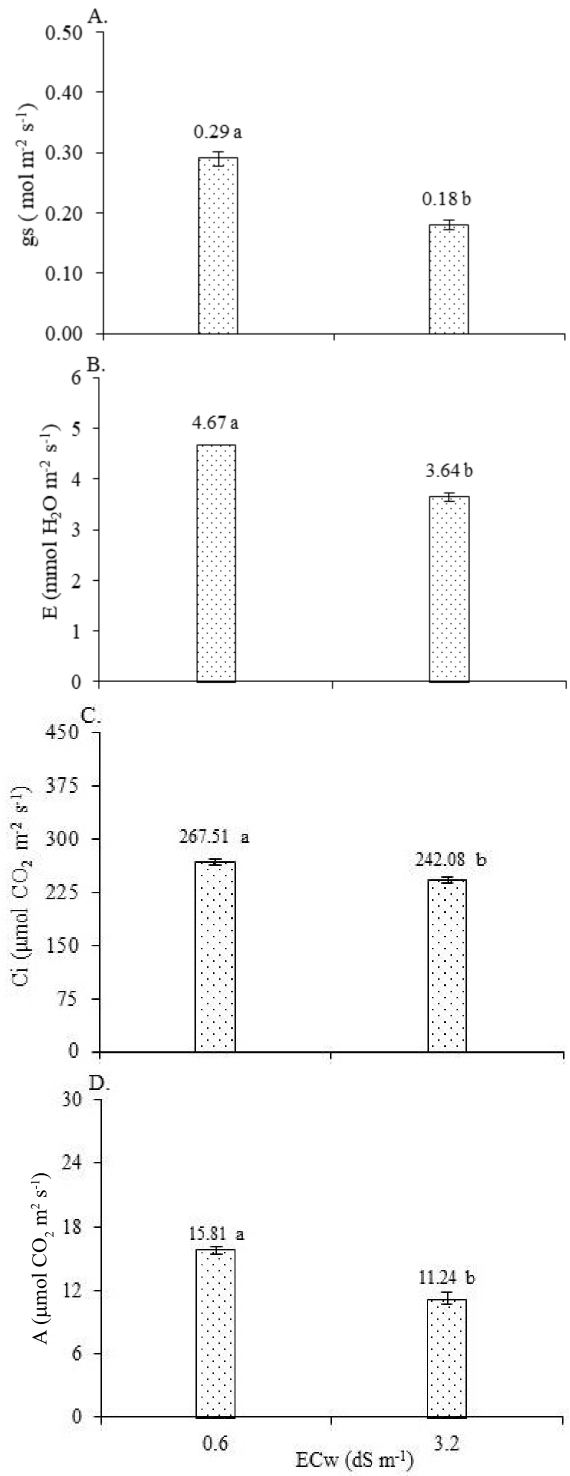
The increase in water electrical conductivity negatively affected the stomatal conductance of guava cv. Paluma (Figure 2A), and plants grown under ECw of 3.2 dS m^{-1} showed a reduction of 37.93% (0.11 mol m^{-2} s^{-1}) in gs compared to plants irrigated with electrical conductivity of 0.6 dS m^{-1}. This response is associated with water restrictions caused by the accumulation of salts in the soil, which results in the decrease of osmotic potential near the roots, with limitations in water absorption, and stomatal closure is a way to avoid water loss to the environment, maintaining the water potential in the leaves and avoiding the dehydration of guard cells (Sá et al., 2019; Lima et al., 2020a). The results obtained in this study are in line with those obtained by Bezerra et al. (2018a) with the guava cv. Paluma under irrigation with saline water (ECw from 0.3 to 3.5 dS m^{-1}), as these authors verified a decrease in gs of 0.139 mol m^{-2} s^{-1} in plants subjected to ECw of 3.5 dS m^{-1} in comparison to those which received the lowest electrical conductivity, at 300 DAT.

As expected, the transpiration of plants irrigated with water of higher electrical conductivity was lower than that found in plants irrigated using water with ECw of 0.6 dS m^{-1} (Figure 2B), with a decrease of 22.05% (1.03 mmol H_2O m^{-2} s^{-1}) in E. The decrease in transpiration is a consequence of the stomatal closure caused by water restriction, reducing the outflow of water vapor, and entry of CO_2 inside the cell (Lacerda et al., 2020). Bezerra et al. (2018a), in a study with the guava cv. Paluma cultivated with saline water (ECw varying from 0.3 to 3.5 dS m^{-1}), observed that transpiration was reduced with increasing water salinity, with a decrease of 0.1798 mmol H_2O m^{-2} s^{-1} between plants irrigated with ECw of 3.5 and 0.3 dS m^{-1}, at 300 DAT.

Table 2. Summary of the F test for stomatal conductance (gs), transpiration (E), intercellular CO_2 concentration (Ci), and CO_2 assimilation rate (A), of guava cv. Paluma, subjected to irrigation with water of different electrical conductivities and foliar application of salicylic acid, 390 days after transplanting

Source of variation	F test			
	gs	E	Ci	A
Salinity levels (SL)	**	**	**	**
Salicylic acid (SA)	ns	ns	ns	ns
Linear regression	ns	ns	ns	ns
Quadratic regression	ns	ns	ns	ns
Interaction (SL × SA)	ns	ns	ns	ns
Blocks	ns	ns	ns	ns
CV (%)	10.91	7.21	3.14	10.78

** - Significant at $p \leq 0.01$; [ns] - Not significant; CV - Coefficient of variation



Means followed by different letters indicate significant difference between treatments by F test ($p \leq 0.05$). Vertical bar represents the standard error of the mean (n = 3)

Figure 2. Stomatal conductance - gs (A), transpiration - E (B), intercellular CO_2 concentration - Ci (C), and CO_2 assimilation rate - A (D) of guava cv. Paluma, as a function of electrical conductivity of irrigation water (ECw) at 390 days after transplanting

The intercellular CO_2 concentration of guava plants was also affected by irrigation water electrical conductivity (Figure 2C), decreasing from 267.51 μmol CO_2 m^{-2} s^{-1} at ECw of 0.6 dS m^{-1} to 242.08 μmol CO_2 m^{-2} s^{-1} at electrical conductivity of 3.2 dS m^{-1}, resulting in a loss of 9.51% in Ci. The reduction demonstrates that salinity affects mainly the photosystem under conditions of high salinity, reducing the CO_2 consumption of the substomatal chambers. This situation was observed in the CO_2 assimilation rate (Figure 2D), for which higher water salinity caused a decrease of 28.90% (4.57 mol CO_2 m^{-2} s^{-1}) when compared to plants that received the water of 0.6 dS m^{-1}.

Therefore, the effects of salinity on gas exchange stem from the osmotic effect, which reduces the stomatal opening for the entry of CO_2, and the ionic effect, which limits the absorption of nutrients and causes toxicity in the cell, leading to the production of ROS, which results in the denaturation of proteins, with damage to photochemical efficiency and the activity of Ribulose 1,5-bisphosphate carboxylase/oxygenase – RuBisCO (Arif et al., 2020). These effects have also been verified by Fernandes et al. (2021) in custard apple (*Annona squamosa* L.), Silva et al. (2020) in soursop (*Annona muricata* L.), and Bezerra et al. (2018a) in guava (*Psidium guajava* L.).

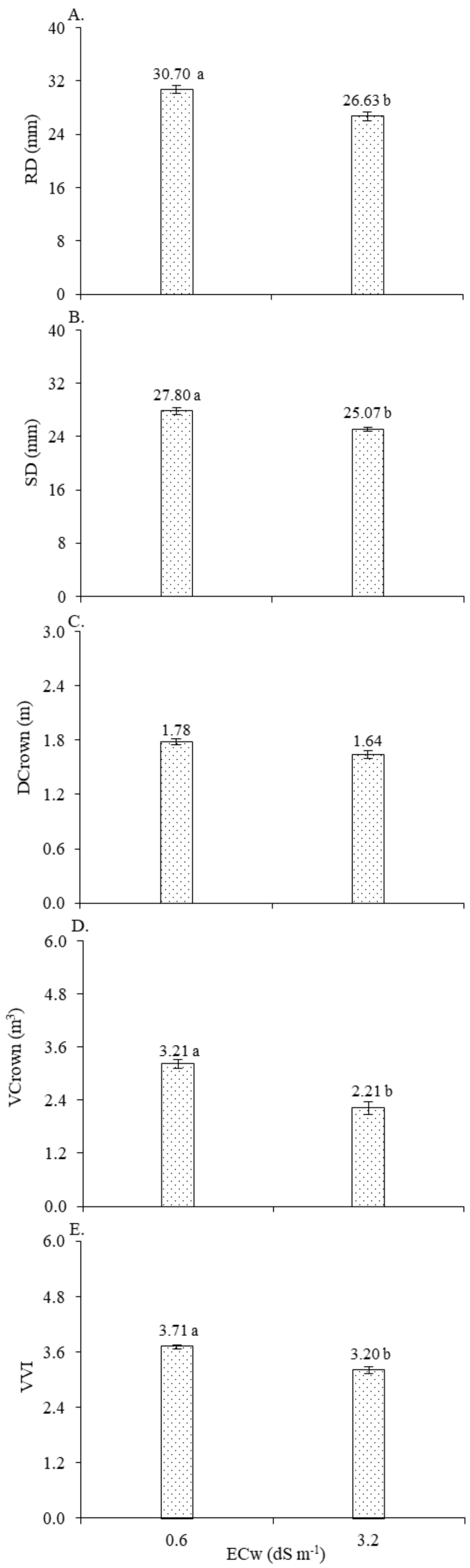
There was a significant effect of electrical conductivity of water on rootstock (RD) and scion diameter (SD), crown diameter (DCrown) and volume (VCrown), and vegetative vigor index (VVI) of guava cv. Paluma, at 390 DAT (Table 3). Salicylic acid concentrations and the interaction between factors (SL × SA) did not significantly influence any of the variables analyzed, indicating that the behavior of plants at the two levels of water electrical conductivity was similar under different concentrations of salicylic acid. The coefficients of variation were low (< 12%), which is indicative that the data obtained in this study were homogeneous.

Water salinity reduced rootstock diameter (Figure 3A) and scion diameter (Figure 3B) by 13.25 and 9.82%, respectively, in guava plants cv. Paluma irrigated with ECw of 3.2 dS m^{-1} compared to those subjected to the lowest electrical conductivity (0.6 dS m^{-1}). This demonstrates the effects of limiting water absorption by reducing the osmotic potential, which when associated with the accumulation of Na^+ and Cl^- results in decreased pectin crosslinking by the induced deficiency of Ca^{2+}, leading to loss of cell turgor, elongation, and division, interfering directly in the stem diameter expansion process (Ferreira et al., 2020).

Table 3. Summary of the F test for rootstock (RD) and scion diameter (SD), crown diameter (DCrown) and volume (VCrown), and vegetative vigor index (VVI) of guava cv. Paluma, subjected to irrigation with water of different electrical conductivities and foliar application of salicylic acid, 390 days after transplanting

Source of variation	F test				
	RD	SD	DCrown	VCrown	VVI
Salinity levels (SL)	**	**	**	**	**
Salicylic acid (SA)	ns	ns	ns	ns	ns
Linear regression	ns	ns	ns	ns	ns
Quadratic regression	ns	ns	ns	ns	ns
Interaction (SL × SA)	ns	ns	ns	ns	ns
Blocks	ns	ns	ns	ns	ns
CV (%)	4.91	4.99	4.81	11.47	4.53

** - Significant at 0.01 probability level; ns - Not significant; CV - Coefficient of variation



Means followed by different letters indicate significant difference between treatments by F test ($p \leq 0.05$). Vertical bar represents the standard error of the mean (n = 3)

Figure 3. Diameter of rootstock - RD (A) and scion - SD (B), crown diameter - DCrown (C), crown volume - VCrown (D), and vegetative vigor index - VVI (E) of guava cv. Paluma, as a function of electrical conductivity of irrigation water (ECw) at 390 days after transplanting

Similar results were reported by Bezerra et al. (2018b), who studied guava cv. Paluma subjected to water salinity (ECw from 0.3 to 3.5 dS m^{-1}) and observed that the increase in electrical conductivity of water led to reductions of 4.60 and 5.35 mm (corresponding to 5.54 and 6.06% per unit increase in water salinity) in stem diameter, at 255 and 300 days after transplanting, respectively. Souza et al. (2016), studying the formation of rootstock in guava under salt stress (ECw: 0.3 to 3.5 dS m^{-1}), observed a decrease of 13.28% in the rootstock diameter of guava plants irrigated with ECw of 3.2 dS m^{-1} compared to those under the lowest salinity level (0.3 dS m^{-1}) at 190 days after transplanting.

The crown diameter (Figure 3C), crown volume (Figure 3D), and vegetative vigor index (Figure 3E) of guava cv. Paluma irrigated with water of higher electrical conductivity were statistically lower compared to the values of plants that were subjected to ECw of 0.6 dS m^{-1} and showed reductions of 7.85, 31.15, and 13.74%, respectively.

According to Oliveira et al. (2017), reduction in crown diameter and crown volume stands out as a defense mechanism of plants to decrease the transpiring surface and consequently reduce the transpiration rate. Furthermore, such reductions are possibly related to energy expenditure to maintain the production of secondary metabolites, associated with antioxidant defense against free radicals and reduced osmotic potential of the roots to absorb water and nutrients (Zvanarou et al., 2020). This was also reported by Lima et al. (2021), who observed an increase in the contents of the metabolites superoxide dismutase (SOD), catalase (CAT), and ascorbate peroxidase (APX) in cowpea plants (*Vigna unguiculata* L. Walp) when irrigated with saline water.

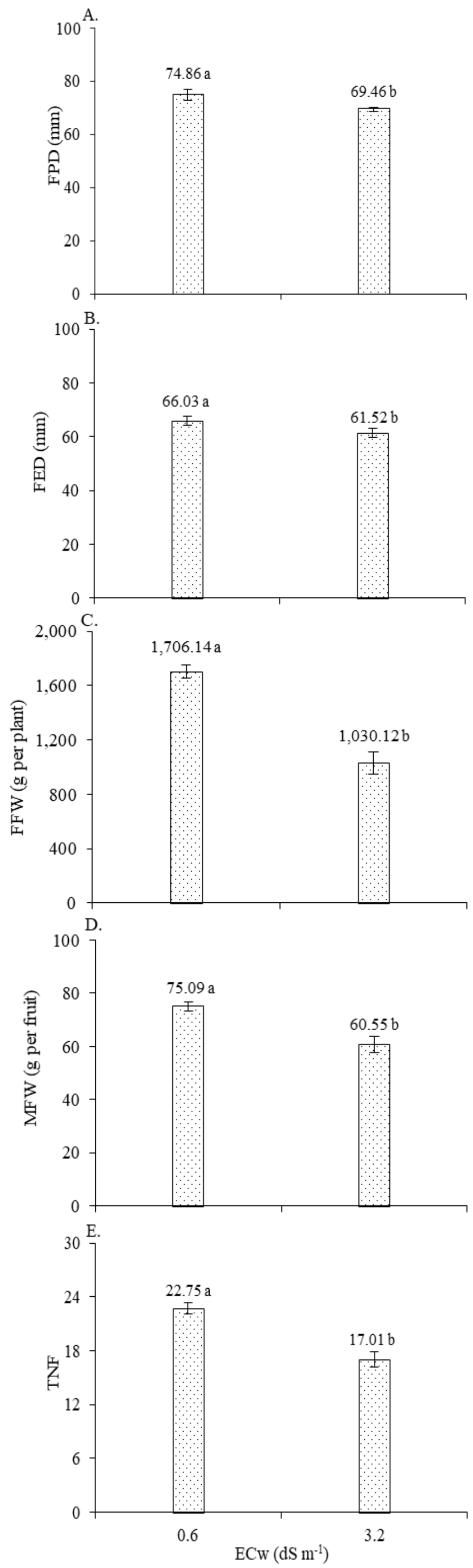
There was a significant effect of water electrical conductivity (Table 4) on fruit polar (FPD) and equatorial (FED) diameters, the total number of fruits (TNF), mean fruit weight (MFW), and fresh fruit weight (FFW) of guava plants cv. Paluma. Salicylic acid concentrations and the interaction between factors (SL × SA) did not influence any of the variables measured. The coefficients of variation were low (< 11%), which is indicative that the data obtained in this study were homogeneous.

The electrical conductivity of irrigation water also caused reductions in polar (Figure 4A) and equatorial (Figure 4B) diameters of fruits of guava plants cv. Paluma, with

Table 4. Summary of the F test for fruit polar (FPD) and equatorial diameters (FED), mean fruit weight (MFW), fresh fruit weight (FFW), and the total number of fruits (TNF) of guava plants cv. Paluma, subjected to irrigation with water of different electrical conductivities and foliar application of salicylic acid, 390 days after transplanting

Source of variation	F test				
	FDP	FED	MFW	FFW	TNF
Salinity levels (SL)	**	**	**	**	**
Salicylic acid (SA)	ns	ns	ns	ns	ns
Linear regression	ns	ns	ns	ns	ns
Quadratic regression	ns	ns	ns	ns	ns
Interaction (SL × SA)	ns	ns	ns	ns	ns
Blocks	ns	ns	ns	ns	ns
CV (%)	4.26	4.49	10.69	9.29	8.83

** - Significant at 0.01 probability level; ns - Not significant; CV - Coefficient of variation



Means followed by different letters indicate significant difference between treatments by F test (p ≤ 0.05). Vertical bar represents the standard error of the mean (n = 3)

Figure 4. Fruit polar - FPD (A) and equatorial diameter - FED (B), fresh fruit weight - FFW (C), mean fruit weight - MFW (D), and the total number of fruits per plant - TNF (E) of guava cv. Paluma as a function of electrical conductivity of irrigation water (ECw) at 390 days after transplanting

respective losses of 7.21 and 6.83% compared to the values obtained in plants irrigated with water of 0.6 dS m^{-1} electrical conductivity. The decrease in fruit diameters is a consequence of the restrictions that occurred in gas exchange and the low translocation of photoassimilates, largely due to limitations in the absorption of nutrients and water, including the competition at the absorption sites for Na^+ and K^+, which limits the expansion of fruits (Ferreira et al., 2020).

This situation explains the results obtained for fresh fruit weight (Figure 4C) and mean fruit weight (Figure 4D), which showed reductions caused by irrigation with the water of higher salinity (3.2 dS m^{-1}), with losses of 39.62% (676.02 g per plant) and 19.36% (14.54 g per fruit), respectively, when compared with the values obtained for plants grown with ECw of 0.6 dS m^{-1}. Lima et al. (2020b) add that the losses of fruit growth under conditions of high salinity are consequences of metabolic and physiological disorders that reduce the production of sugars and, perhaps, their movement in phloem vessels, with the emergence of new sap sinks, in addition to the fruits, for the maintenance of growth. Similar responses to salinity in fruit development have also been reported in guava cv. Paluma (*Psidium guajava* L.) by Bezerra et al. (2019) and yellow passion fruit (*Passiflora edulis* f. Flavicarpa) by Andrade et al. (2019).

The effects of salinity were also observed on the total number of fruits per plant of guava cv. Paluma (Figure 4E), with losses of 25.23% (5.74 fruits per plant) compared to plants that received water with ECw of 0.6 dS m^{-1}. Such response may be related to the high rate of flower abortion (not quantified) caused by the condition of salt stress, as observed by Bezerra et al. (2019) in guava cv. Paluma and Dias et al. (2021) in West Indian cherry (*Malpighia emarginata* Sesse & Moc. ex DC), who associated such losses with the effects of salts on soil water absorption, proven by the limitations in stomatal opening and CO_2 assimilation rate, as observed in the present study. According to Barbosa & Lima (2010), the Paluma cultivar has large fruits (above 200 g), a piriform shape, a short 'neck', and smooth skin. Thus, it can be seen that the weight of the fruits obtained in this study is not within the expected standards for this cultivar. It should be noted that this divergence may be related to the form of cultivation of this fruit tree, considering that, in this study, the plants were grown in plastic pots with a capacity of 200 L, limiting their maximum production potential. In addition, the crop was grown in a protected environment, that is, with changes in relative air humidity and temperature conditions.

In general, it can be verified from the data of growth, physiology, and production of guava cv. Paluma, at 390 DAT, that the foliar application of salicylic acid at concentrations of up to 3.6 mM until the full flowering stage (205 DAT) did not mitigate the effects of salt stress. The absence of significant effect of SA concentrations in this study corroborates the observations made by Poór et al. (2019), according to whom the effect and efficacy of this phytohormone depend on some factors, such as application mode, concentration, crop, and development stage of plants. Li et al. (2014) add that the improvement in salt stress tolerance by exogenous application of salicylic acid also depends on the genotype and concentration used. Another factor that can also interfere with the effectiveness of SA is the local environmental conditions. Thus, the realization of new studies to evaluate the effects of foliar application of salicylic acid in different stages of crop development is essential to elucidate its role in mitigating salt stress.

Conclusions

1. Irrigation using water with electrical conductivity of 3.2 dS m^{-1} reduces the diameter of rootstock and scion, crown diameter, crown volume, and vegetative vigor index, as well as gas exchange and production components of guava cv. Paluma, at 390 days after transplanting.

2. Foliar spraying with salicylic acid concentrations ranging up to 3.6 mM does not mitigate the effects of salt stress on guava plants cv. Paluma.

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