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# Saline stress and salicylic acid on growth and quality of guava 'Paluma' seedlings

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**ABSTRACT:** High salt concentrations affect plant growth and development, making it necessary to use methods to reduce the effects of saline stress. In the light of the above, the growth and seedling quality of guava 'Paluma' under water salinity and salicylic acid conditions were evaluated in this experiment. The experiment was conducted in a protected environment. The treatments were obtained by combining the electrical conductivity of irrigation water (0.3, 0.8, 1.9, 3.0, and 3.5 dS $m^{-1}$) and salicylic acid (0, 0.3, 1.0, 1.7, and 2.0 mol $L^{-1}$), in the $2^2 + 2 \times 2 + 1$ scheme, according to the Central Box Composite matrix, using a randomized block design, with four repetitions and five seedlings per plot. The increase in the electrical conductivity of irrigation water and salicylic acid alone inhibited the growth, biomass accumulation, and quality of the seedlings, with the exception of height, number of leaves, and dry biomass of roots and stem that were stimulated with the acid. Salicylic acid intensified the inhibition of seedling growth and quality under saline stress, but it attenuated the salt effect on biomass accumulation. Guava 'Paluma' seedlings are sensitive to salinity, and can be produced with water up to 0.8 dS $m^{-1}$.

**Key words:** $C_7H_6O_3$; seedling production; stress mitigation; water salinity

# Estresse salino e ácido salicílico no crescimento e qualidade de muda de goiabeira 'Paluma'

**RESUMO:** As altas concentrações de sais afetam o crescimento e o desenvolvimento das plantas, sendo necessário a utilização de métodos que diminuam os efeitos do estresse salino. Diante do exposto, avaliaram-se neste experimento o crescimento e a qualidade de muda de goiabeira 'Paluma' em condições de salinidade hídrica e ácido salicílico. O experimento foi conduzido em ambiente protegido. Os tratamentos foram obtidos da combinação entre condutividade elétrica da água de irrigação (0,3; 0,8; 1,9; 3,0 e 3,5 dS $m^{-1}$) e ácido salicílico (0; 0,3; 1,0; 1,7 e 2,0 mol $L^{-1}$), no esquema $2^2 + 2 \times 2 + 1$, de acordo com a matriz Composto Central de Box, utilizando-se o delineamento de blocos ao acaso, com quatro repetições e cinco mudas por parcela. O aumento na condutividade elétrica da água de irrigação e do ácido salicílico, isoladamente, inibiram o crescimento, o acúmulo de biomassa e a qualidade das mudas, com exceção da altura, número de folhas e biomassa seca das raízes e do caule que foram estimulados com o ácido. O ácido salicílico intensificou a inibição do crescimento e da qualidade das mudas sob estresse salino, porém, atenuou o efeito salino sobre o acúmulo de biomassa. As mudas de goiabeira 'Paluma' são sensíveis a salinidade, podendo ser produzidas com água de até 0,8 dS $m^{-1}$.

**Palavras-chave:** $C_7H_6O_3$; produção de mudas; atenuante de estresse; salinidade hídrica

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## Introduction

Saline stress negatively affects both the growth (Silva et al., 2017a; Bezerra et al., 2018a) and physiological aspects (Silva et al., 2017b; Bezerra et al., 2018b) of guava seedlings, and the yield of the plants in the field (Bezerra et al., 2018c). This salinity problem stems from interference with physiological and biochemical processes in plants, caused by the osmotic and toxic effects of excess soluble salts (Taiz et al., 2017). The osmotic effect results from the decrease in the free energy of the water, reducing the osmotic potential, making uptake by the roots more difficult. The toxic effects of specific ions, such as sodium, chloride, and boron, among others, cause characteristic symptoms of injury, associated with the excessive accumulation of the specific ion in the plant.

These factors can also be noticed in guava (*Psidium guajava* L.), and some researchers who evaluated the growth of seedlings irrigated with saline water, found that the increase in water salinity inhibited the height, stem diameter, number of leaves emitted per plant, absolute growth rates of stem diameter, dry phytomass of the aerial part, and root/aerial part ratio (Souza et al., 2017a, 2017b; Bezerra et al., 2018a, 2018b; Sena et al., 2018; Veloso et al., 2018), affecting seedling quality (Souza et al., 2017a; Bonifacio et al., 2018). Guava tree is a crop sensitive to salinity, since reductions in its productive capacity occur when the electrical conductivity of irrigation water exceeds 3.0 dS $m^{-1}$ (Cavalcante et al., 2005). However, sensitivity to salinity can vary according to the genetic material used and the growing conditions.

To mitigate the deleterious effects of salts on plants, the use of some strategies is necessary, one of these being salicylic acid. This acid is a phenolic phytohormone, distributed in a wide range of plant species (Taiz et al., 2017), playing an important role in the regulation of glycolysis, plant growth and development, germination, flowering, and fruit production (Bagherifard et al., 2015). Salicylic acid is involved in several plant processes, including defense responses to biotic and abiotic stresses, such as saline stress (Jayakannan et al., 2015; Silva et al., 2018a).

Therefore, knowing the lack of studies on salicylic acid, it is necessary to study the vegetative behavior as well as the quality of guava 'Paluma' seedlings under saline stress and salicylic acid conditions in the Northeast region.

## Materials and Methods

The experiment was conducted in a protected environment (6° 47' 20" S, 37° 48' 01" W, and 144 m of altitude) of the Center of Agroalimentary Sciences and Technology (Centro de Ciências e Tecnologia Agroalimentar - CCTA), at the Universidade Federal de Campina Grande (UFCG), municipality of Pombal, PB, Brazil.

The treatments were obtained from the combination of electrical conductivity of irrigation water (0.3, 0.8, 1.9, 3.0, and 3.5 dS $m^{-1}$) and salicylic acid (0.0, 0.3, 1.0, 1.7, and 2.0 mol $L^{-1}$), in the $2^2 + 2 \times 2 + 1$ scheme, according to box central composite matrix (Montgomery, 2013) and detailed in Table 1. A randomized block design with four repetitions and five seedlings per plot was used.

The seedlings were grown in plastic bags with a capacity of 2 $dm^3$. The substrate used in the experiment was prepared from the mixture of material collected from the 0.0-0.2 m deep layer of a 'Neossolo Flúvico', sand, and bovine manure in the ratio of 2:1:1, respectively. The fertility attributes of the substrate were analyzed at CCTA/UFCG (Table 2).

The irrigation was done based on lysimetric drainage according to Equation 1, and the bags were wrapped in plastic containers that allowed the collection of the drained water.

$$\mathrm{Va} = \frac{\mathrm{Vta} - \mathrm{Vd}}{\mathrm{n} \times (1 - \mathrm{LF})} \quad (1)$$

where: Va - volume to be applied, mL; Vta - volume applied in the previous irrigation, mL; Vd - volume drained, mL; n - number of containers in the plot; and, LF - leaching fraction of 10%.

Irrigations with saline water started 50 days after the beginning of seedling production, being prepared from the

**Table 1.** Scheme between the levels of the factors (ECiw - electrical conductivity of irrigation water and SA - salicylic acid) used in the experiment.

| Treatments[1] | Levels[2] | | Concentrations | |
|---|---|---|---|---|
| | ECiw | SA | ECiw (dS $m^{-1}$) | SA (mol $L^{-1}$) |
| 1 (Control) | - | - | 0.3 | 0.0 |
| 2 | $-\alpha^3$ (-1.41) | 0 | 0.3 | 1.0 |
| 3 | -1 | -1 | 0.8 | 0.3 |
| 4 | -1 | 1 | 0.8 | 1.7 |
| 5 | 0 | -α (-1.41) | 1.9 | 0.0 |
| 6 | 0 | 0 | 1.9 | 1.0 |
| 7 | 0 | α (1.41) | 1.9 | 2.0 |
| 8 | 1 | -1 | 3.0 | 0.3 |
| 9 | 1 | 1 | 3.0 | 1.7 |
| 10 | α (1.41) | 0 | 3.5 | 1.0 |

[1] Number of treatments = $2^k + 2k + 1$ (k = 2, n. of factors) ∴ $2^2 + 2 \times 2 + 1 = 9$ (Montgomery, 2013). [2] Levels established according to the box central composite matrix. [3] $\alpha = \sqrt{k}$ ∴ $\sqrt{2} = 1.41$.

**Table 2.** Fertility attributes of the substrate used in the experiment.

| pH | ECse (dS $m^{-1}$) | P (mg $dm^3$) | $K^+$ | $Na^+$ | $Ca^{2+}$ | $Mg^{2+}$ | SB | $Al^{3+}$ | $Al^{3+} + H^+$ | CEC | PES | V | OM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | ($cmol_c$ $dm^3$) | | | | | | | | | (%) | |
| 7.41 | 1.41 | 19 | 0.75 | 0.28 | 3.91 | 3.31 | 8.25 | 0.00 | 0.00 | 8.25 | 3.4 | 100 | 1.08 |

pH (hydrogen potential) in water at a 1:2.5 ratio of air dried fine earth and distilled water, respectively; ECse - Electrical conductivity of the saturation extract; P (phosphorus), $K^+$ (potassium), and $Na^{2+}$ (sodium), extrator Mehlich I; $Ca^{2+}$ (calcium), $Mg^{2+}$ (magnesium), and $Al^{3+}$ (aluminum), extractor KCl 1 M; $H^+ + Al^{3+}$ (hydrogen + aluminum) with 0.5 M calcium acetate extractant at pH 7.0; SB (sum of bases) = $K^+ + Na^+ + Ca^{2+} + Mg^{2+}$; CEC (cation exchange capacity) = SB + $H^+$ + $Al^{3+}$; V (base saturation) = (SB/CEC) × 100; PES (percentage of exchangeable sodium) = ($Na^+$/CEC) × 100; OM (organic matter) = organic carbon × 1.724, Walkley-Black method.

dilution of NaCl, $CaCl_2.2H_2O$, and $MgCl_2.6H_2O$ salts, in order to obtain a ratio of 7:2:1 of the respective cations Na:Ca:Mg. To this end, in preparing the irrigation water, the relationship between ECw and salt concentration was considered (10 meq $L^{-1}$ = 1 dS $m^{-1}$ of ECw), extracted from Rhoades et al. (1992), valid for ECw from 0.1 to 5.0 dS $m^{-1}$ in which the tested values fit, based on the local water supply, and the values were checked with a portable conductivity meter.

The applications of salicylic acid (SA) started 47 days after the start of seedling production, and five sprays were made at 30 day intervals, applying 10 mL $plant^{-1}$.

Nutritional management followed the recommendations proposed by Novais et al. (1991), using urea (45% N), monoamophosphate (MAP - 48% $P_2O_5$, 11% N), and potassium chloride (KCl - 60% $K_2O$), with the foundation fertilizer being applied in installments until the end of the experiment.

At 170 days after the start of seedling production, 120 days irrigating with saline water, they were measured: stem diameter at substrate level (DSL, mm), using a digital pachymeter; plant height (PH, cm), measuring the distance between the surface of the substrate and the apical meristem with a ruler; number of leaves (NL); leaf size (LS); leaf area (LA), from the length of the main vein corrected by the correction factor according to Equation 2 (Lima et al., 2012); masses of root dry matter (MRDM), of stem (MSDM), of leaves (MLDM), of aerial part (MAPDM = MSDM + MLDM), and total (MTDM = MAPDM + MRDM); ratio between aerial part and root dry biomass (RB); and, Dickson quality index (DQI), according to Dickson et al. (1960) and described in Equation 3.

$$\mathrm{LA} = 0.3205 \times \mathrm{L}^{2.0412} \quad (2)$$

where: LA - leaf area ($cm^2$); and, L - main leaf vein length (cm).

$$\mathrm{DQI} = \frac{(\mathrm{MTDM})}{\left(\frac{\mathrm{PH}}{\mathrm{DSL}}\right) + \left(\frac{\mathrm{MAPDM}}{\mathrm{MRDM}}\right)} \quad (3)$$

where: DQI - Dickson quality index; MTDM - mass of total dry matter (g); PH - plant height (cm); DSL - stem diameter at substrate level (mm); MAPDM - mass of aerial part dry matter (g); and, MRDM - mass of root dry matter (g).

The data were submitted to variance and polynomial regression analysis using the F test ($p \leq 0.05$). The analyses were performed in the SAS® University Edition software.

## Results and Discussion

According to the analysis of variance, there was a significant interaction effect between the electrical conductivity of irrigation water and doses of salicylic acid for all variables evaluated (Table 3).

The stem diameter of guava seedlings reduced by 1.02 (-13%) and 0.13 mm (-2%) with each unit increase in

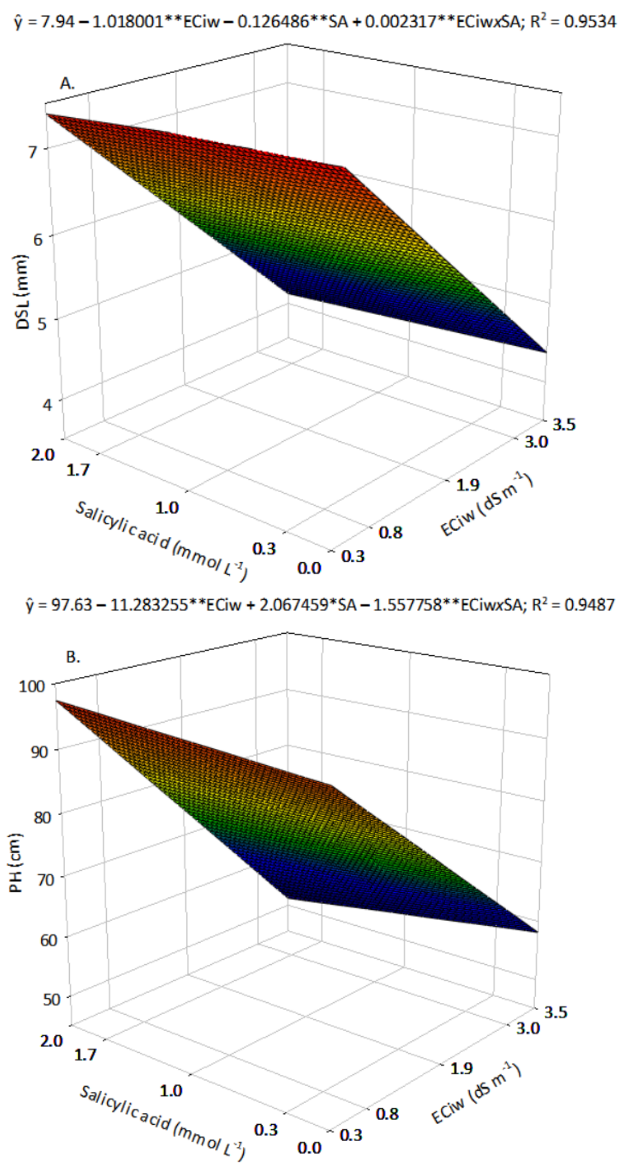
**Table 3.** Summary of analysis of variance for growth in stem diameter at substrate level (DSL), plant height (PH), number of leaves (NL), leaf size (LS), leaf area (LA), mass of roots dry matter (MRDM), stem (MSDM), leaves (MLDM), aerial part (MAPDM), and total (MTDM), ratio between aerial part and root dry biomass (RB), and Dickson quality index (DQI) in guava 'Paluma' seedlings as a function of electrical conductivity of irrigation water (ECiw) and sprayed with salicylic acid (SA).

| SV | DF | Mean square DSL (mm) | PH (cm) | NL | LS ($cm^2$) | LA ($cm^2$) | MRDM (g) |
|---|---|---|---|---|---|---|---|
| Block | 3 | 0.3473$^{ns}$ | 309.2018** | 10.6896$^{ns}$ | 14.5526$^{ns}$ | 42,187.896$^{ns}$ | 0.0194$^{ns}$ |
| Treatments | (9) | 6.1035** | 924.8718** | 71.9340** | 159.6115** | 413,649.94** | 6.6568** |
| ECwi – L | 1 | 52.0894** | 7,853.9502** | 573.2894** | 1,328.7529** | 3,450,128.06** | 52.664** |
| ECwi – Q | 1 | 0.3278$^{ns}$ | 139.3212$^{ns}$ | 14.3056$^{ns}$ | 9.8501$^{ns}$ | 18,868.753$^{ns}$ | 0.1258$^{ns}$ |
| SA – L | 1 | 3.4901** | 348.7384* | 25.0104$^{ns}$ | 52.6255$^{ns}$ | 141,356.080* | 3.4019** |
| SA – Q | 1 | 1.0490$^{ns}$ | 175.9809$^{ns}$ | 1.6414$^{ns}$ | 73.0408$^{ns}$ | 46,048.506$^{ns}$ | 0.3973* |
| ECwi × SA | 1 | 0.000021** | 9.5880** | 1.6792** | 0.6424** | 277.4966** | 0.0119** |
| Residue | 27 | 0.270962 | 60.35301 | 7.087731 | 19.138642 | 28,835.492 | 0.08375 |
| CV (%) | | 8.59 | 10.06 | 9.75 | 11.24 | 15.58 | 11.17 |
| Mean | | 6.06 | 77.20 | 27.31 | 38.91 | 1,089.82 | 2.59 |

| SV | DF | MSDM (g) | MLDM (g) | MAPDM (g) | MTDM (g) | RB | DQI |
|---|---|---|---|---|---|---|---|
| Block | 3 | 0.4487$^{ns}$ | 0.5609$^{ns}$ | 1.2145$^{ns}$ | 1.3343$^{ns}$ | 0.1827$^{ns}$ | 0.0257* |
| Treatments | (9) | 224.0838** | 23.9928** | 96.6944** | 153.5850** | 1.3353* | 0.5968** |
| ECwi – L | 1 | 198.9798** | 196.2772** | 790.5048** | 1,251.2410** | 6.2325** | 4.8418** |
| ECwi – Q | 1 | 0.8876** | 0.0165$^{ns}$ | 0.6616$^{ns}$ | 1.3645$^{ns}$ | 0.6487$^{ns}$ | 0.0102$^{ns}$ |
| SA – L | 1 | 6.7454** | 13.1461** | 38.7252** | 65.0827** | 1.8101$^{ns}$ | 0.3265** |
| SA – Q | 1 | 0.3974* | 0.1171$^{ns}$ | 0.9460$^{ns}$ | 0.1172$^{ns}$ | 0.5776$^{ns}$ | 0.0008$^{ns}$ |
| ECwi × SA | 1 | 1.4406** | 0.0539** | 0.5201** | 0.3848** | 0.6406** | 0.0014** |
| Residue | 27 | 0.0937 | 0.2393 | 0.5451 | 0.6541 | 0.4990 | 0.0076 |
| CV (%) | | 5.58 | 8.61 | 6.61 | 5.88 | 15.18 | 10.82 |
| Mean | | 5.48 | 5.68 | 11.16 | 13.75 | 4.65 | 0.81 |

SV - Sources of variation; DG - Degrees of freedom; CV - Coefficient of variation; $^{ns}$, *, and ** - Not significant and significant at 5 and 1% probability by the F test, respectively.

electrical conductivity of irrigation water and salicylic acid concentration, respectively (Figure 1A). It is also noteworthy that the inhibition in stem growth promoted by increasing the electrical conductivity of irrigation water was intensified up to 3% per mmol $L^{-1}$ of salicylic acid. The highest average (7.63 mm) observed was when irrigating with water of 0.3 dS $m^{-1}$ without the application of acid, while the lowest (4.14 mm) was recorded in the combination between water of 3.5 dS $m^{-1}$ with 2 mmol $L^{-1}$ of salicylic acid. Plant height growth was also inhibited by salinity, with a reduction of 11.3 cm (-12%) for each unit of electrical conductivity of irrigation water (Figure 1B). However, spraying salicylic acid stimulated growth, that is, with each 1 mmol $L^{-1}$ the seedling increased in height by an average of 2.1 cm (3%). It was observed that the inhibition promoted by salinity was enhanced when salicylic acid was




* and ** - Significant at 5 and 1% probability by the F test, respectively.

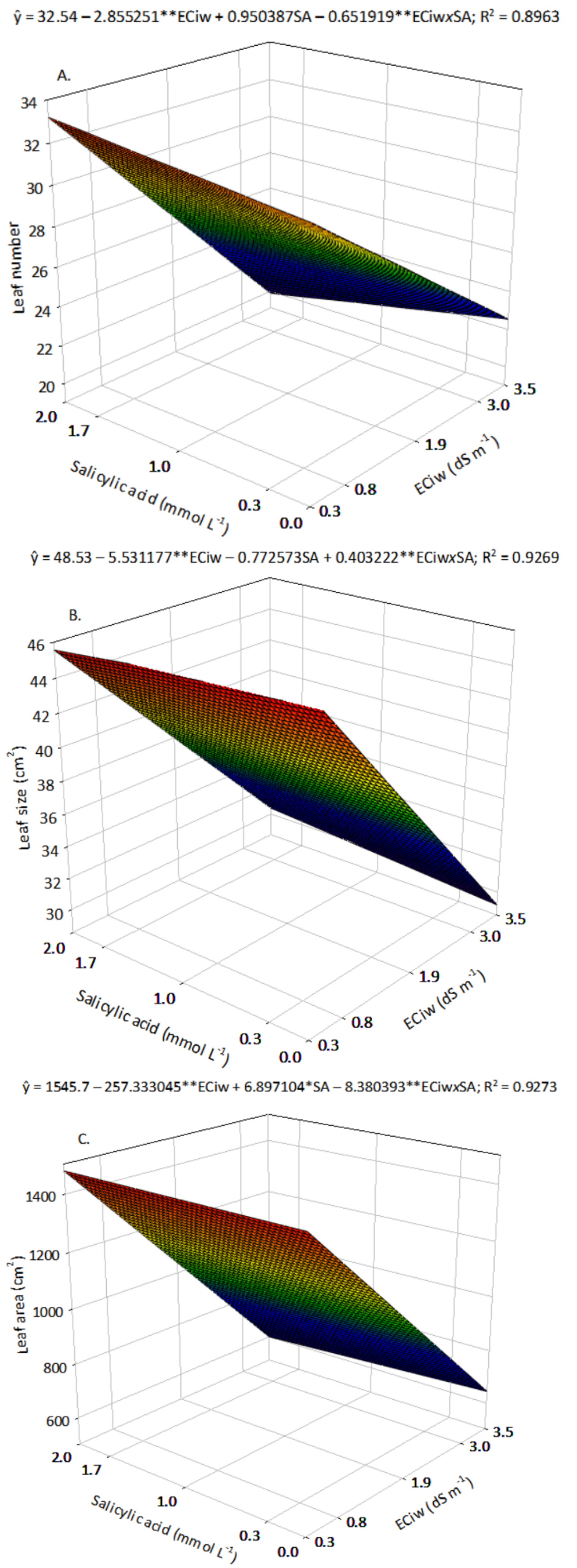
**Figure 1.** Stem diameter at substrate level - DSL (A) and plant height - PH (B) of guava 'Paluma' seedlings as a function of electrical conductivity of irrigation water (ECiw) and doses of salicylic acid (SA).

applied with a reduction of up to 3.4 cm (-6%) per mmol $L^{-1}$. Under the application of 2 mmol $L^{-1}$ of salicylic acid associated with irrigation with water of 0.3 and 3.5 dS $m^{-1}$ we obtained seedlings with the highest (97.4 cm) and lowest (51.4 cm) height, respectively.

The negative effect of salinity on the growth of guava plants was also recorded by Cavalcante et al. (2010), Sena et al. (2018), and Silva et al. (2017a), with losses of 7, 3, and 3% for stem diameter and 10, 4, and 3% for height with each unit increase in the electrical conductivity of irrigation water, respectively. Saline stress causes both physiological changes, such as reductions in stomatal conductance and consequently in transpiration and net carbon dioxide assimilation (Bezerra et al., 2018b; Veloso et al., 2018), as well as biochemical (Viudes & Santos, 2014), resulting not only in lower growth as exposed in this research, caused by lower cytokinesis and cell expansion (Taiz et al., 2017), but also morpho-physiological changes in seedlings (Bezerra et al., 2019; Nascimento Neto et al., 2020). While salicylic acid, an endogenous regulator of plant growth and productivity (Taiz et al., 2017), when applied at high dose and/or frequency can have detrimental effects (Silva et al., 2018a), and the exogenously applied dose capable of causing detrimental effects can vary depending on some factors, such as the species itself (El-Esawi et al., 2017).

The number of guava leaves was reduced by an average of 2.9 (-9%) with a unit increase in the electrical conductivity of irrigation water (Figure 2A). Unlike the application of salicylic acid, which showed an average increase of 0.95 (2%) leaf at each dose, irrigation with water of 0.3 and 3.5 dS $m^{-1}$ provided the highest (33.2 cm) and lowest (19.9 cm) in the number of leaves, respectively, with the application of 2 mmol $L^{-1}$ of salicylic acid. For leaf size we observed average reductions of 5.5 (-12%) and 0.8 $cm^2$ (-1%) with each 1 dS $m^{-1}$ of water and 1 mmol $L^{-1}$ of salicylic acid, respectively (Figure 2B). The highest dose of salicylic acid decreased the effect of saline stress on seedlings irrigated with 3.5 dS $m^{-1}$ water, representing a gain of 4.0% (1.3 $cm^2$) when compared to plants without acid application. However, the highest (46.9 $cm^2$) and lowest average (29.2 $cm^2$) were recorded under the irrigations with 0.3 and 3.5 dS $m^{-1}$ water without salicylic acid. The unit increase in irrigation water conductivity reduced leaf area by 257.3 $cm^2$ (-18%), while salicylic acid stimulated leaf area by 6.9 $cm^2$ with the unit increase of this input (Figure 2C). It is noteworthy that salicylic acid, under saline conditions, intensified the saline stress, reducing the leaf area by 7% (44.9 $cm^2$) between the absence and the application of 2 mmol $L^{-1}$ of salicylic acid. The largest (1,477.3 $cm^2$) and smallest (600.2 $cm^2$) leaf area were recorded under irrigation with water of 0.3 and 3.5 dS $m^{-1}$, respectively, under 2 mmol $L^{-1}$ salicylic acid.

One of the adaptation mechanisms of plants to saline stress is reduced leaf expansion and leaf abscission (Taiz et al., 2017). In this regard, Sena et al. (2018) observed reductions of 4 and 6% in the number of leaves and leaf area, respectively of guava plants with each unit increase in electrical conductivity of irrigation water, trends also observed by Bezerra et al. (2018a). Therefore, the reduction of leaf area by salinity may




* and ** Significant at 5 and 1% probability by the F test, respectively.

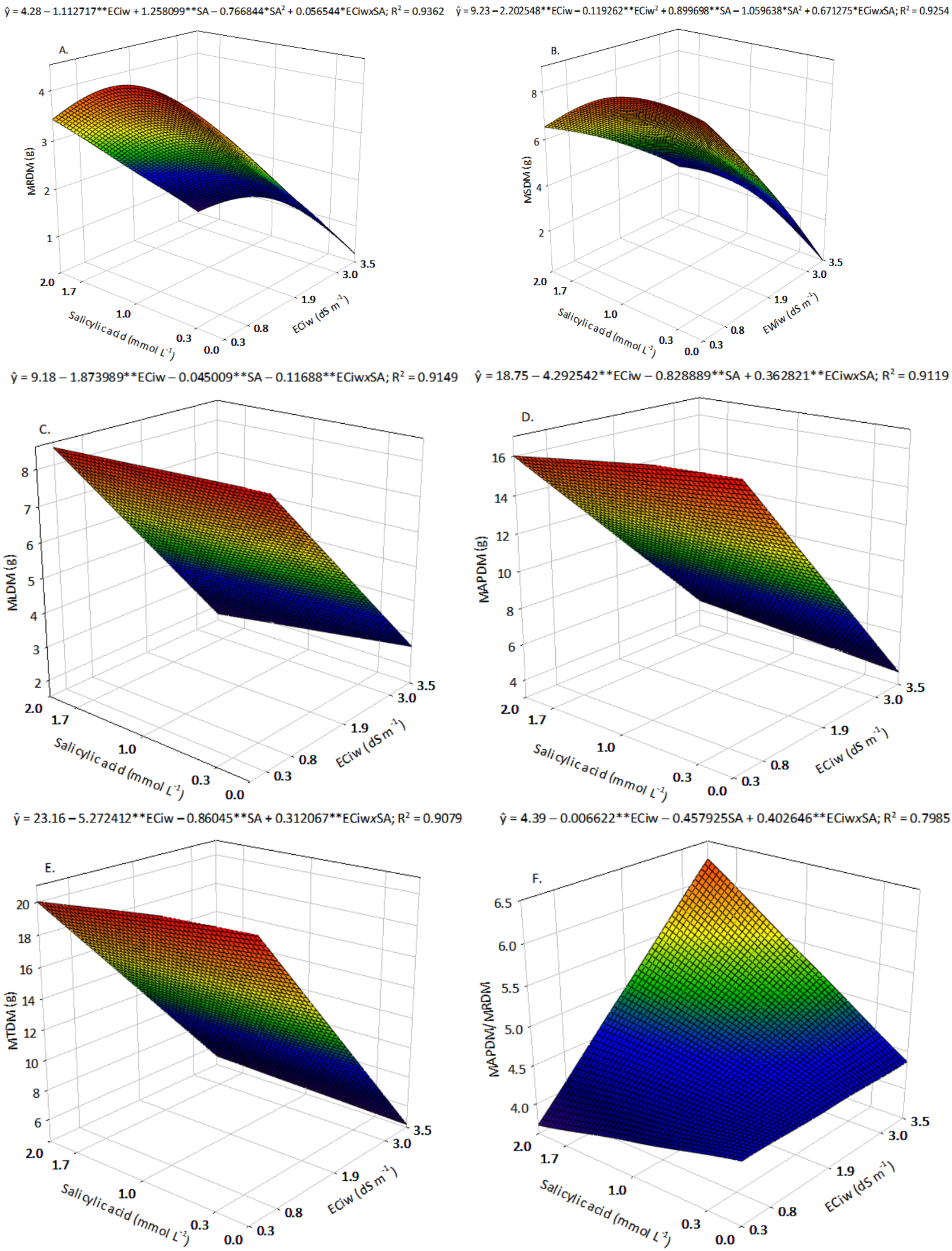
**Figure 2.** Leaf number (A), leaf size (B) and leaf area (C) in guava 'Paluma' seedlings as a function of electrical conductivity of irrigation water (ECiw) and doses of salicylic acid (SA).

be more intense on leaf expansion (leaf size) than on emission and/or abscission as also occurred in the present study (Figure 2), and structural changes may also occur in leaves (Bezerra et al., 2019; Nascimento Neto et al., 2020). However, there are cases where leaf number was more sensitive to saline stress than leaf area (Silva et al., 2017a). Salicylic acid may have a beneficial action on leaf area, because this hormone increases carbon assimilation and metabolite synthesis (Khan et al., 2003), increasing the photosynthetic capacity of the plant and, consequently, tissue expansion. As observed in the results of this study, exogenous salicylic acid provided an increase in the number of leaves of guava seedlings when under low salinity conditions. Mazzuchelli et al. (2014) observed that the number of leaves of eucalyptus seedlings under water stress condition was maintained with the application of 100 and 200 mg $L^{-1}$ salicylic acid. However, when irrigated with high salinity water the effect was reversed for both leaf size and leaf area. The reduction in area with acid application under saline stress condition may have occurred due to high concentrations of this acid, causing reverse action on plant physiology and metabolism, inhibiting the production of photoassimilates in the leaves (Bezerra et al., 2018b).

The application of salicylic acid, under non-saline and saline conditions, stimulated the accumulation of dry biomass in the roots of guava seedlings (Figure 3A). The highest mass of root dry matter (4.48 g) was obtained under the 0.8 mmol $L^{-1}$ dose of salicylic acid associated with irrigation with water of 0.3 dS $m^{-1}$, being reduced by 1.07 g at each 1.0 dS $m^{-1}$. Under the highest electrical conductivity of irrigation water (ECiw - 3.5 dS $m^{-1}$) the application of 0.9 mmol $L^{-1}$ of salicylic acid was the one that best mitigated the stress, stimulating by 182% the accumulation of biomass, that is, an increase from 0.38 to 1.07 g without and under the best dose of the acid, respectively.

In the plant stem, the highest mass of dry matter (8.84 g) was obtained at a dose of 0.4 mmol $L^{-1}$ of salicylic acid associated with irrigation with water of 0.3 dS $m^{-1}$, reducing with increasing saline condition (Figure 3B). Under the highest electrical conductivity of irrigation water (ECiw - 3.5 dS $m^{-1}$), the most efficient dose was 1.5 mmol $L^{-1}$ of salicylic acid providing a dry biomass of 2.60 g, a stimulus of 4,233% in relation to the absence of the acid, where the average was 0.06 g. The mass of leaf dry matter of guava plants decreased by 1.87 g (-22%) and 0.08 g (-1%) with the unit increase in the electrical conductivity of irrigation water and salicylic acid, respectively (Figure 3C). Salicylic acid intensified the reduction in leaf dry biomass when associated with saline stress, with a maximum value (8.62 g) recorded in plants irrigated with non-saline water (0.3 dS $m^{-1}$) without salicylic acid. The lowest average (1.72 g) was determined under the highest electrical conductivity of irrigation water (3.5 dS $m^{-1}$) associated with 2 mmol $L^{-1}$ of salicylic acid, a reduction of 80% compared to the highest result.

The mass of aerial part of dry matter of plant was inhibited by 4.29 g (-25%) and 0.72 g (-4%) per unit increase in the electrical conductivity of irrigation water and salicylic acid




* and ** Significant at 5 and 1% probability by the F test, respectively.

**Figure 3.** Masses of root dry matter - MRDM (A), of stem - MSDM (B), of leaves - MLDM (C), of aerial part - MAPDM (D), and total - MTDM (E), and ratio between mass of aerial part and root dry matter - MAPDM/MRDM (F) in guava 'Paluma' seedlings as a function of electrical conductivity of irrigation water (ECiw) and doses of salicylic acid (SA).

(Figure 3D). However, salicylic acid mitigated saline stress by stimulating the accumulation of biomass in the aerial part. Under the highest electrical conductivity of irrigation water (ECiw - 3.5 dS $m^{-1}$), the increase was from 3.73 to 4.61 g (24%) without and under the 2.0 mmol $L^{-1}$ dose of salicylic acid, respectively. The highest (17.46 g) and lowest (3.86 g) aerial part of dry biomass was recorded without the application of salicylic acid when the seedlings were irrigated with water of 0.3 and 3.5 dS $m^{-1}$, respectively.

The total dry matter accumulation of guava ‘Paluma’ seedlings was inhibited by both unit increase in salinity and salicylic acid by 5.27 (24%) and 0.77 g (4%), respectively (Figure 3E). However, the application of salicylic acid to plants under saline stress (3.5 dS $m^{-1}$) attenuated the damaging effect, stimulating biomass production by 10%, i.e., an increase from 4.71 to 5.17 g under the respective conditions without and with 2.0 mmol $L^{-1}$ of the acid. The highest (21.58 g) and lowest (4.71 g) average plant dry biomass were recorded without acid application under the 0.3 and 3.5 dS $m^{-1}$ water irrigations, respectively.

The ratio between the dry biomass of the stem and root systems reflects the sensitivity to the factors studied, with reductions being observed in both the root system (Figure 3A) and the stem (Figure 3D) with increasing salinity and salicylic acid. Even with higher biomass input in the aerial part, 4.4 to 1.0 g in the aerial part and root system under non-saline condition and without salicylic acid, respectively, it was observed that it was more sensitive to the damaging effect of salinity and salicylic acid for guava seedlings (Figure 3F). However, under high saline stress (ECiw - 3.5 dS $m^{-1}$) salicylic acid stimulated greater biomass accumulation in the aerial part relative to the roots.

Saline stress directly affects the synthesis, accumulation and allocation of biomass in seedlings (Bezerra et al., 2018b, 2018c; Nascimento Neto et al., 2020). In guava rootstocks Souza et al. (2017b) observed reductions in biomass allocation in roots, aerial part and total, with greater intensity on roots, while Souza et al. (2017a) observed greater sensitivity to salinity in the aerial part. Dry biomass accumulation in guava plants is reduced in both the stem and leaves as observed by Sena et al. (2018). The variation in dry biomass allocation between the aerial part and roots reflects plant adaptation to adverse environmental conditions (Silva et al., 2018b). A similar result was found by Souza et al. (2017a), where the root/aerial part ratio of guava plants reduced by 28% as a function of increasing of electrical conductivity of irrigation water.

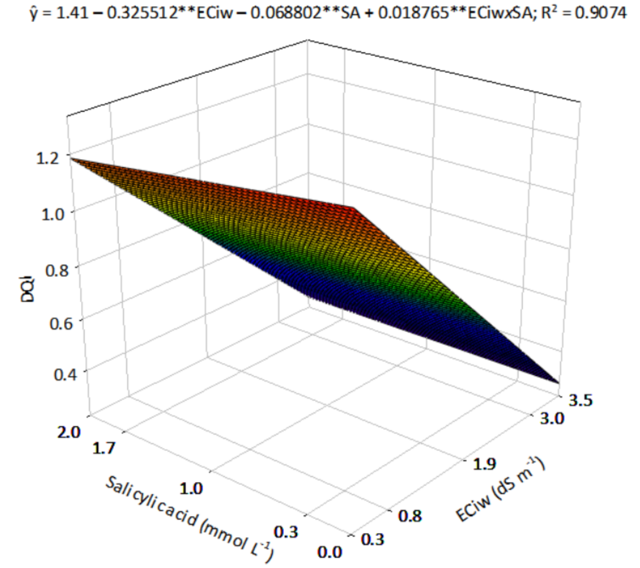
The reduction in production and accumulation of dry mass under a given electrical conductivity of irrigation water, related to a non-saline environment, can be used as a criterion for assessing tolerance to saline stress, and the use of mitigants, such as salicylic acid, is important to increase the tolerance of these plants. In this sense, it was observed that the accumulation of biomass in the aerial part was favored under the application of salicylic acid under saline stress condition. According to Jayakannan et al. (2015), salicylic acid controls $Na^+$ uptake in the roots and its transport to the aerial part, thus decreasing the toxicity, contributing to the increase of the aerial part under saline stress condition.

Silva et al. (2018a) found that 1.0 mM salicylic acid increased basil root length when subjected to saline stress, indicating acting directly on root growth.

The quality of the seedlings, evaluated by Dickson quality index (DQI), reduced by 0.33 (-24%) and 0.07 (5%) with the unitary increment of the electrical conductivity of irrigation water and salicylic acid, respectively, intensifying the reduction with the association of these factors (Figure 4), being the highest (1.31) and lowest (0, 26) value of the DQI, representing the seedlings of best and worst quality, respectively, obtained under the respective combinations between irrigation with non-saline water (0.3 dS $m^{-1}$) without spraying with salicylic acid and between saline water (3.5 dS $m^{-1}$) associated with a dose of 2.0 mmol $L^{-1}$ of salicylic acid.

Dickson quality index is a global attribute used to express the quality and robustness of seedlings. Being based on the biometrics of aerial part and roots, resulting from the physiological relations of these structures, which are reflected in the architecture (Bezerra et al., 2019) and also in the allometric and morphosiological relations (Nascimento Neto et al., 2020) of the seedlings. According to Hunt (1990), Dickson quality index values above 0.20 indicate quality seedlings suitable for transplanting to the field. This value was exceeded even under the highest electrical conductivity of irrigation water (ECiw - 3.5 dS $m^{-1}$). In this same sense, Souza et al. (2017a, 2017b) obtained guava seedlings with Dickson quality index above 0.20, corroborating the feasibility of using saline water, even with the sensitivity to salinity by this crop in the seedling stage. However, seedlings with higher Dickson quality index are more tolerant to adverse conditions.

$\hat{y} = 1.41 - 0.325512^{**}ECiw - 0.068802^{**}SA + 0.018765^{**}ECiwxSA; R^2 = 0.9074$




** Significant at 1% probability by the F test.

**Figure 4.** Dickson quality index in guava ‘Paluma’ seedlings as a function of electrical conductivity of irrigation water (ECiw) and doses of salicylic acid (SA).

## Conclusions

The guava 'Paluma' seedling is sensitive to salinity, and can be produced with water up to 0.8 dS $m^{-1}$, reducing on average 10% in growth and quality with the application of the highest electrical conductivity of irrigation water (3.5 dS $m^{-1}$).

Salicylic acid sprays favor height growth, leaf production, and leaf area up to a dose of 2 mmol $L^{-1}$, and mass of root dry matter accumulation up to 0.8 mmol $L^{-1}$, and reduce stem diameter, leaf size, leaf, part area, and total dry biomass, and seedling quality.

The effect of saline stress on leaf size and biomass accumulation in guava 'Paluma' seedlings is attenuated with salicylic acid applications, but is intensified for diameter, height, leaf yield, and Dickson quality index.

The use of salicylic acid in the production of guava 'Paluma' seedlings is not recommended.

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## Compliance with Ethical Standards

**Author contributions:** Conceptualization: CJAO, WEP, FTCB; Data curation: CJAO, WEP, RCLM, FTCB; Formal analysis: WEP e FTCB; Funding acquisition: CJAO, WEP; Investigation: CJAO, MAFB, WAOS; Metodology: CJAO, WEP, WAOS, AGLS, ENM; Project administration: CJAO, WEP; Resources: CJAO, WEP, FTCB; Software: WEP, FTCB; Supervision: WEP, FTCB, AGLS; Validation: WEP, FTCB, MAFB; Visualization: CJAO, WEP, WAOS, ENM; Writing - original draft: CJAO, WAOS, ENM; Writing - review and editing: WEP, FTCB, AGLS, MAFB.

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