

Growth and Gas Exchange Responses of Guava Rootstocks to Salt Stress in a Semi-arid Region

Crescimento e trocas gasosas de porta-enxertos de goiabeira ao estresse salino em região semiárida

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ABSTRACT - The limited availability of low-salinity water in the northeastern semi-arid region of Brazil is one of the main constraints to the expansion of irrigated agriculture. In this context, the objective of this study was to evaluate the effects of irrigation with saline water on the salinity tolerance of guava during the rootstock formation phase. The experimental design was a randomized complete block in a 2×5 factorial scheme, consisting of two guava genotypes (*Crioula* and *cv. Paluma*) and five levels of irrigation water electrical conductivity (ECw: 0.3, 1.2, 2.1, 3.0, and 3.9 dS m⁻¹), with six replicates. Stem diameter, plant height, fresh biomass of leaves, stems, and roots, and the accumulation of dry biomass in leaves, stems, roots, and total biomass were measured, along with Dickson quality index, transpiration rate, stomatal conductance, CO₂ assimilation rate, and the absolute and relative growth rates in plant height. Irrigation using water with electrical conductivity above 0.3 dS m⁻¹ inhibited stem diameter growth, root dry biomass, leaf transpiration, relative growth rate in height, and Dickson quality index in guava seedlings. Among the genotypes, *Crioula* showed greater growth, photosynthetic activity, and Dickson quality index under saline water irrigation, indicating its potential for use as a rootstock under semi-arid conditions.

RESUMO - A disponibilidade de águas com baixos níveis salinos no semiárido nordestino é um dos fatores limitantes para expansão da agricultura irrigada. Diante disso, objetivou-se avaliar os efeitos da irrigação com águas salobras na tolerância de goiabeira na fase de formação de porta-enxertos. O delineamento utilizado foi em blocos casualizados em esquema fatorial 2×5 , cujos tratamentos foram constituídos de dois genótipos de goiabeira (*Crioula* e *cv. Paluma*) e cinco níveis de condutividade elétrica da água de irrigação - CEa (0,3; 1,2; 2,1; 3,0 e 3,9 dS m⁻¹), com seis repetições. Foram mensurados o diâmetro do caule, altura de plantas, fitomassa fresca das folhas, de caule e de raízes, e o acúmulo de fitomassa seca de folhas, de caule, de raízes e total, o índice de qualidade de Dickson, transpiração, condução estomática, taxa assimilação de CO₂ e as taxas de crescimento absoluto e relativo em altura de plantas. A irrigação com água de condutividade elétrica superior a 0,3 dS m⁻¹ inibiu o crescimento em diâmetro de caule, a fitomassa seca de raiz, a transpiração foliar, a taxa de crescimento relativo em altura de plantas e o índice de qualidade das mudas de goiabeira. Dentre os genótipos, o *Crioula* obteve maior crescimento, atividade fotossintética e índice de qualidade de Dickson sob irrigação com água salobra, sendo indicado para formação de porta-enxerto nas condições de semiárido.

Keywords: *Psidium guajava* L.. Saline water. Cultivars. Abiotic stress.

Palavras-chave: *Psidium guajava* L.. Água salobra. Cultivares. Estresse abiótico.

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INTRODUCTION

Guava (*Psidium guajava* L.) stands out for its socioeconomic importance in northeastern Brazil, covering small to large producers, due to the various possibilities of use, being consumed fresh or processed (SILVA et al., 2024). In the 2023 harvest, guava production in Brazil was 582,832 t in an area corresponding to 22,487 hectares, and the Northeast region was responsible for 285,234 t (48.9%) with an average yield of 25,919 kg ha⁻¹ (IBGE, 2025; TORRES et al., 2025). Despite the prominence in national production, some factors, such as obtaining seedlings of high sanitary quality and physiological vigor, interfere with the quality of seedling production (SILVA et al., 2024).

The Brazilian Northeast, especially the semi-arid region, is characterized by high evapotranspiration rates and low precipitation, and the occurrence of water sources with high concentrations of dissolved salts is common, standing out as an abiotic stress factor that limits the establishment of agricultural production (SILVA et al., 2019; LACERDA et al., 2022).

High concentrations of salts cause osmotic and ionic effects, which result in damage to cell membranes, stomatal closure, reduced photosynthetic efficiency, in addition to inhibiting the biosynthesis of photosynthetic pigments and plant growth (LIMA et al., 2018; PINHEIRO et al., 2022). In this context, there is a need to adopt strategies that mitigate the effects of salt stress on plants,



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such as the identification of genotypes tolerant to water and/or soil salinity (NÓBREGA et al., 2024). This approach is considered a viable technique for successful fruit production and agricultural diversification, since salinity tolerance depends on the species, stage of development, edaphoclimatic conditions, concentration and ionic nature of the water, as well as the intensity and duration of salt stress (LAXMI et al., 2021).

Several studies have been carried out using brackish waters in guava cultivation, especially in arid and semi-arid regions, where water scarcity in terms of quality and quantity is a challenge for agricultural production (SOUZA et al., 2016, BEZERRA et al., 2018, FERREIRA et al., 2023). Fischer and Melgarejo (2021) indicate that salinity levels above 1.8 dS m⁻¹ impair germination, growth, and biomass accumulation in guava trees. Sá et al. (2016) concluded that 'Crioula' guava is more tolerant to salt stress than 'Paluma' and 'Ogawa', being indicated as a rootstock. Bezerra et al. (2018), in a study with 'Paluma' guava under irrigation with brackish water (EC_w ranging from 0.3 to 3.5 dS m⁻¹), observed that the electrical conductivity of the water from 0.3 dS m⁻¹ reduced the internal CO₂ concentration, stomatal conductance, CO₂ assimilation rate, transpiration and instantaneous water use efficiency, at 255 and 300 days after sowing.

Souza et al. (2016) concluded that irrigation with water of up to 1.75 dS m⁻¹ in the production of rootstocks of 'Crioula' guava resulted in an acceptable reduction of 10% in the growth and quality of seedlings. In another study, Ferreira

et al. (2023) concluded that guava cv. 'Paluma' is classified as sensitive to water salinity in the seedling formation phase, with a threshold level of 0.3 dS m⁻¹ and a decrease per unit increase of 11.48%. Thus, this study is based on the hypothesis that there are differences in tolerance to salt stress among the genotypes evaluated, making it possible to identify materials genetically more tolerant to salinity conditions in the semi-arid region of Northeast Brazil.

Therefore, the objective of this study was to evaluate the effects of irrigation with brackish water on growth and gas exchange during the formation of guava rootstocks in a semi-arid area.

MATERIAL AND METHODS

The experiment was carried out from May to August 2019 in a greenhouse of the Federal University of Campina Grande (UFCG), campus of Pombal, Paraíba, Brazil, located by the geographic coordinates: 6° 46' 8" South and 37° 47' 45" West, with an altitude of 184 m. According to Köppen's classification, the climate of Pombal is semi-arid (BSH' hot and semi-arid), with a rainy season that begins in November and ends in April (ÁLVARES et al., 2013). The data of maximum and minimum temperature, relative humidity and precipitation during the experimental period are presented in Figure 1. Data were obtained daily with the aid of a digital thermohygrometer (Model: Hth-241) installed inside the greenhouse.

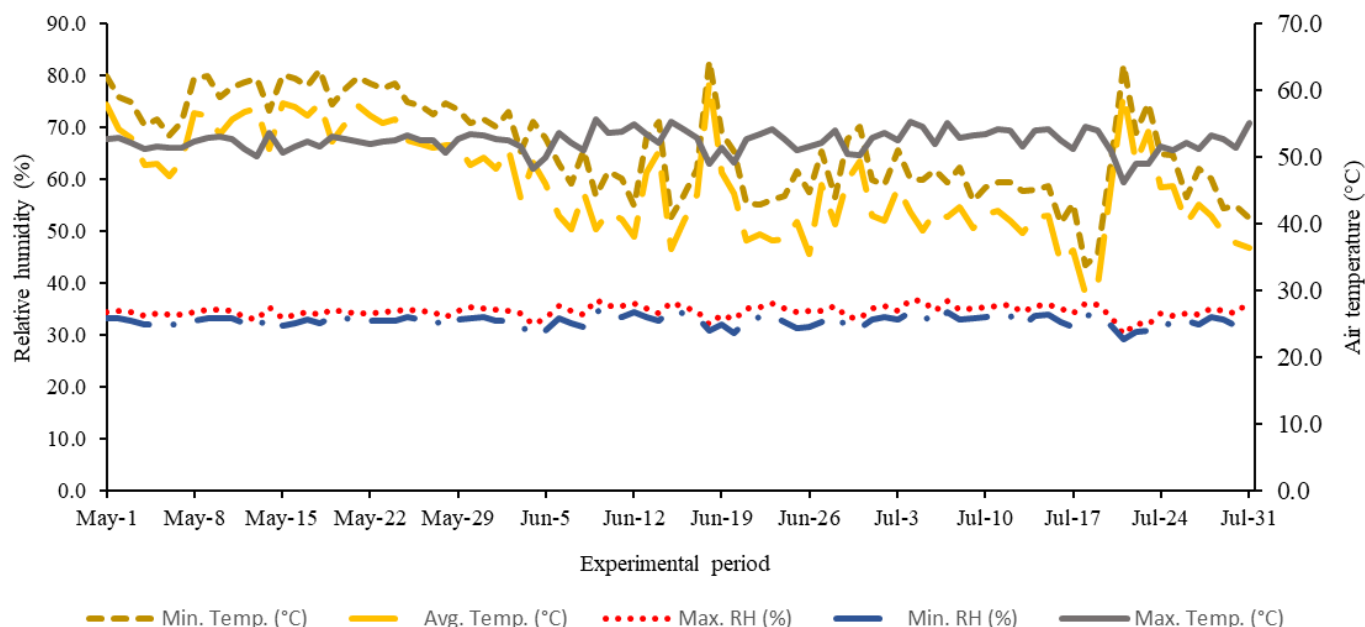


Figure 1. Data on maximum and minimum air temperature, and relative humidity during the period from May to July 2019.

The experimental design was randomized blocks in a 2 × 5 factorial scheme, whose treatments consisted of two guava genotypes ('Crioula' and cv. 'Paluma') and five electrical conductivities of irrigation water – EC_w (0.3, 1.2, 2.1, 3.0 and 3.9 dS m⁻¹), with six replicates, whose plot

consisted of one plant, totaling 60 experimental units. The EC_w levels were defined based on the study conducted by Bezerra et al. (2018), who classified guava as moderately sensitive to irrigation water salinity, with reductions of growth, development, and production in plants at salinity

levels above 1.5 dS m⁻¹.

Seeds for the formation of guava (*P. guajava* L.) rootstocks were acquired in commercial orchards in the municipality of Pombal, Paraíba State, Brazil. The fruits were harvested when they reached their physiological maturity, and after harvest, they were transported to the post-harvest laboratory of UFCG, washed in running water, dried, manually pulped, washed and packed in trays placed to dry in the shade. Five seeds were sown per tube (Citropote) at a

depth of 0.5 cm. At 30 days after sowing (DAS), the first thinning was carried out, leaving three plants per tube, and after 35 DAS the last thinning was performed, leaving only one plant per tube.

The tubes had dimensions of 325 × 149 × 149 mm, with a volume of 3.5 L, and were filled with a mixture of soil, sand and manure in a ratio of 3:2:1 (on a volume basis). The soil was classified as *Neossolo Regolítico* (Psamment), whose physical and chemical characteristics are shown in Table 1.

Table 1. Physical-hydraulic and chemical attributes of the substrate used in the experiment.

Chemical characteristics								
pH	OM	P	K ⁺	Na ⁺	Ca ²⁺	Mg ²⁺	Al ³⁺	H ⁺
1:2.5	g kg ⁻¹	mg kg ⁻¹				cmol.kg ⁻¹		
5.58	2.93	39.2	0.23	1.64	9.07	2.78	0.0	8.61
Chemical characteristics				Physical characteristics				
EC _{se}	CEC	SAR	ESP	Particle-size fraction (g kg ⁻¹)			Moisture (dag kg ⁻¹)	
(dS m ⁻¹)	cmol.kg ⁻¹	(mmol L ⁻¹) ^{0.5}	%	Sand	Silt	Clay	33.42	1519.5
2.15	22.33	0.67	7.34	572.7	100.7	326.6	25.91	12.96

pH – Hydrogen potential, OM – Organic matter: Walkley-Black wet digestion; Ca²⁺ and Mg²⁺ extracted with 1 M KCl at pH 7.0; Na⁺ and K⁺ extracted with 1 M NH₄OAc at pH 7.0; Al³⁺+H⁺ extracted with 0.5 M CaOAc at pH 7.0; EC_{se} - Electrical conductivity of the saturation extract; CEC - Cation exchange capacity; SAR - Sodium adsorption ratio of the saturation extract; ESP - Exchangeable sodium percentage; ^{1,2} Referring to field capacity and permanent wilting point, respectively.

The tubes were placed on metal benches, at a height of 0.8 m from the ground. Fertilization with nitrogen, phosphorus and potassium was performed in the substrate of the tube containing the guava rootstocks, following the recommendation of Novais, Neves and Barros (1991). Doses equivalent to 100 mg of N, 300 mg of P₂O₅ and 150 mg of K₂O per kg of substrate were applied. The sources used were urea (45% N), monoammonium phosphate (52% P₂O₅) and potassium chloride (60% K₂O). Fertilization was divided into three portions, applied via fertigation, with fifteen-day intervals between applications. The irrigation waters were prepared using local-supply water (ECw = 0.30 dS m⁻¹) as a control, and the other levels were prepared from the dissolution of sodium chloride (NaCl) in water with ECw of 0.3 dS m⁻¹, and its amount was determined considering the relationship between ECw and salt concentration (RICHARDS, 1954), according to Equation 1:

$$C = 640 \times ECw \quad (1)$$

Where:

C = Concentration of salts to be added (mg L⁻¹); and
ECw = Desired electrical conductivity of water (dS m⁻¹).

After preparation, the water was stored in 200 L plastic containers, which were properly protected to avoid evaporation, entry of rainwater and contamination with materials that could compromise its quality. Prior to sowing, the soil moisture content was raised to the level corresponding to the maximum water retention capacity. The volume of water applied was determined based on the water balance,

obtained by the difference between the volume applied (Va) and the volume drained (Vd), according to Equation 2:

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

Where:

VI = volume of water to be used in the irrigation event (mL);
Va = volume applied in the previous irrigation event (mL);
Vd = volume of water drained (mL); and
LF = leaching fraction of 0.15.

Growth variables of guava rootstocks were evaluated at 30 and 60 days after sowing (DAS), with stem diameter (SD, cm) measured at 5 cm from the plant collar and plant height (PH, cm), measured from the soil surface to the stem apex. The absolute growth rate in plant height (AGR_{PH}) and the relative growth rate in plant height (RGR_{PH}) were determined according to Benincasa (2003), using Equation 3:

$$AGR_{PH} = \frac{PH_2 - PH_1}{t_2 - t_1} \quad (3)$$

AGR_{PH} = absolute growth rate in plant height (cm day⁻¹),

PH₁ = plant height (cm) at time t₁,

PH₂ = plant height (cm) at time t₂.

RGR_{PH} expresses plant growth within a given time interval, relative to plant height at the beginning of this

interval, and measured following the methodology described by Benincasa (2003), according to Equation 4:

$$RGR_{PH} = \frac{\ln PH_2 - \ln PH_1}{t_2 - t_1} \quad (4)$$

RGR_{PH} = Relative growth rate in plant height ($\text{cm cm}^{-1} \text{ day}^{-1}$);
 PH_1 = plant height (cm) at time t_1 ;
 PH_2 = plant height (cm) at time t_2 ;
 $\ln$ = natural logarithm.

At 60 DAS, the plants were collected and divided into leaves, stem and root, and weighed to obtain leaf fresh mass (LFM, g per plant), stem fresh mass (STFM, g per plant), root fresh mass (RFM, g per plant), and subsequently subjected to drying in a forced circulation oven at a temperature of 65 °C. After drying, the following parameters were determined: leaf dry mass (LDM, g per plant) and stem dry mass (STDm, g per plant), the sum of which resulted in shoot dry mass (SHDM, g per plant), and root dry mass (FSR, g per plant) and total dry mass (TDM, g per plant), obtained by the sum of SHDM and FSR.

The quality of the seedlings was evaluated by the Dickson quality index (DQI), considering plant height (PH), stem diameter (SD), total dry mass (TDM), shoot dry mass (SHDM) and root dry mass (FSR), according to Dickson et al. (1960) and calculated using Equation 5:

$$DQI = \frac{(TDM)}{\left(\frac{PH}{SD}\right) + \left(\frac{SHDM}{RDM}\right)} \quad (5)$$

Gas exchange was determined at 60 DAS from the measurement of stomatal conductance (g_s , $\text{mol H}_2\text{O m}^{-2} \text{ s}^{-1}$), transpiration (E , $\text{mmol H}_2\text{O m}^{-2} \text{ s}^{-1}$), and CO_2 assimilation rate (A , $\mu\text{mol CO}_2 \text{ m}^{-2} \text{ s}^{-1}$), using an infrared gas analyzer - IRGA (Infra-Red Gas Analyser, model LCpro - SD, from ADC Bioscientific, UK). Readings were carried out from 7 a.m. to 10 a.m., using the third fully expanded leaf, counted from the apical bud. Measurements were carried out under natural conditions of air temperature and CO_2 concentration, employing an artificial source of photosynthetically active radiation with an intensity of $1200 \mu\text{mol m}^{-2} \text{ s}^{-1}$.

The data obtained were subjected to analysis of variance by the F test and, when significant, subjected to the Tukey means comparison test ($p \leq 0.05$) for the genotype factor, whereas the water salinity levels were analyzed by polynomial regression, using the statistical software Sisvar version 5.7 (FERREIRA, 2019).

RESULTS AND DISCUSSION

There was a significant effect of the interaction between the factors electrical conductivity levels of irrigation water and genotypes on the root fresh mass (RFM) and root dry mass (FSR) of guava seedlings. The electrical conductivity levels of irrigation water significantly affected the variables stem diameter (SD), plant height (PH), leaf fresh mass (LFM), stem fresh mass (STFM), leaf dry mass (LDM), and stem dry mass (STDm). The genotypes showed a significant effect on plant height (PH), and leaf dry mass (LDM) (Table 2).

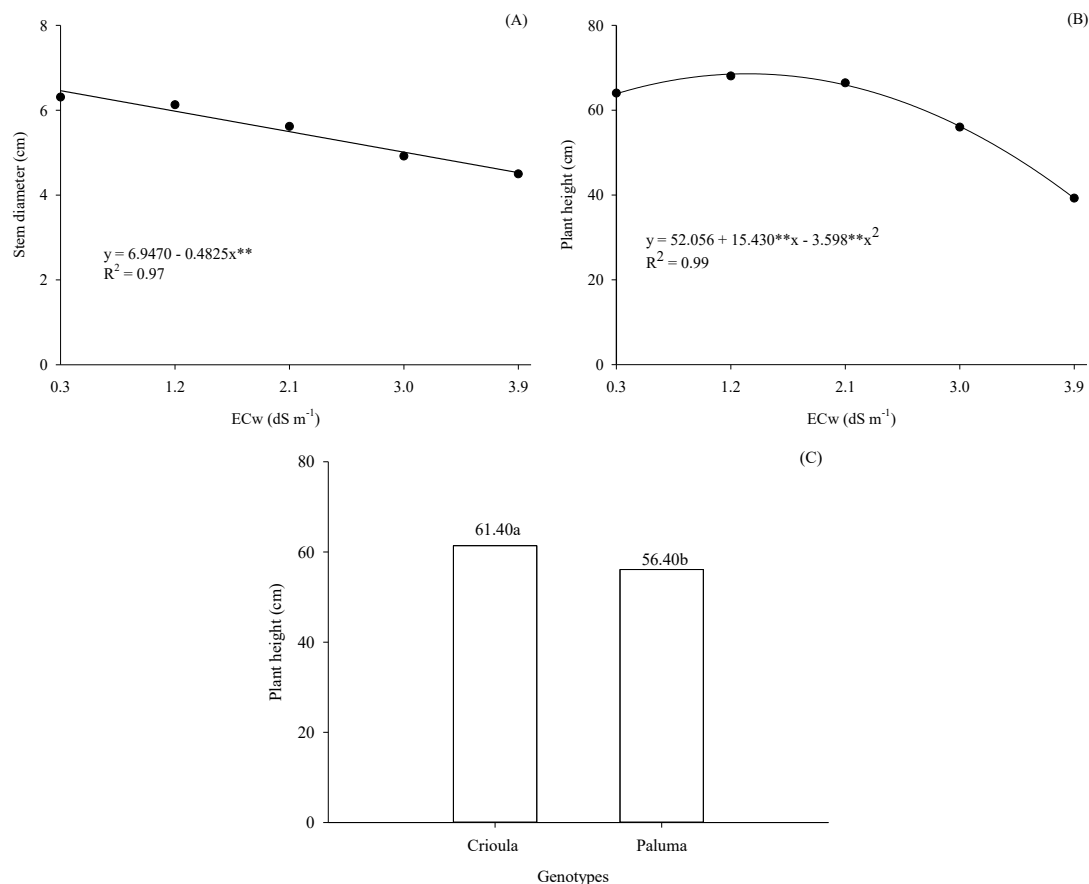
Table 2. Summary of analysis of variance for stem diameter (SD), plant height (PH), leaf fresh mass (LFM), stem fresh mass (STFM), root fresh mass (RFM), leaf dry mass (LDM), stem dry mass (STDm) and root dry mass (FSR) of guava (*P. guajava* L.) genotypes grown under different electrical conductivities of irrigation water (ECw), at 60 days after sowing.

Sources of variation	DF	Mean squares							
		SD	PH	LFM	STFM	RFM	LDM	STDm	FSR
ECw	4	7.198**	1683.30**	263.06**	207.86**	108.53**	29.19**	22.40**	3.994**
Linear regression	1	27.93**	4552.24**	552.29**	740.18**	430.69**	94.12**	67.02**	15.58**
Quadratic regression	1	0.375 ^{ns}	2175.12**	487.83**	69.107**	0.6968 ^{ns}	19.51**	12.10**	0.0014 ^{ns}
Genotypes (GN)	1	0.021 ^{ns}	417.120*	40.31 ^{ns}	6.363 ^{ns}	0.011 ^{ns}	3.567*	0.840 ^{ns}	0.044 ^{ns}
Interaction (ECw × GN)	4	0.803 ^{ns}	98.911 ^{ns}	10.42 ^{ns}	1.542 ^{ns}	12.44**	1.200 ^{ns}	0.839 ^{ns}	0.486**
Blocks	5	0.540 ^{ns}	282.441 ^{ns}	11.23 ^{ns}	8.370 ^{ns}	4.30 ^{ns}	1.137 ^{ns}	0.434 ^{ns}	0.257 ^{ns}
Residual	45	0.492	60.5285	11.04	2.745	2.54	0.776	0.362	0.143
C.V		12.76	13.24	21.62	18.87	28.67	21.02	19.68	26.60

ECw - Electrical conductivity of water; DF - Degrees of freedom; CV - Coefficient of variation; ^{ns}, *, ** not significant, significant at $p \leq 0.05$ and $p \leq 0.01$, respectively

The stem diameter of the seedlings was reduced by the electrical conductivity of irrigation water (Figure 2A), with a decrease of 6.94% per unit increase in ECw, i.e., plants irrigated with water of 3.9 dS m^{-1} showed a reduction of 25.53% compared to those that received the lowest ECw

(0.3 dS m^{-1}). Growth inhibition by salt stress occurs due to the specific effects of ions and osmotic effects that restrict the absorption of water and nutrients by plants, consequently affecting cell expansion and division (BEZERRA et al., 2018; NÓBREGA et al., 2024).



Means followed by the same letter do not differ from each other by Tukey test $p \leq 0.05$.
Values followed by ** indicate significance at $p \leq 0.01$ by the F test.

Figure 2. Stem diameter (A) and plant height (B) of guava (*P. guajava* L.), as a function of the electrical conductivity of irrigation water - ECw and plant height (C) as a function of the genotypes, at 60 days after sowing.

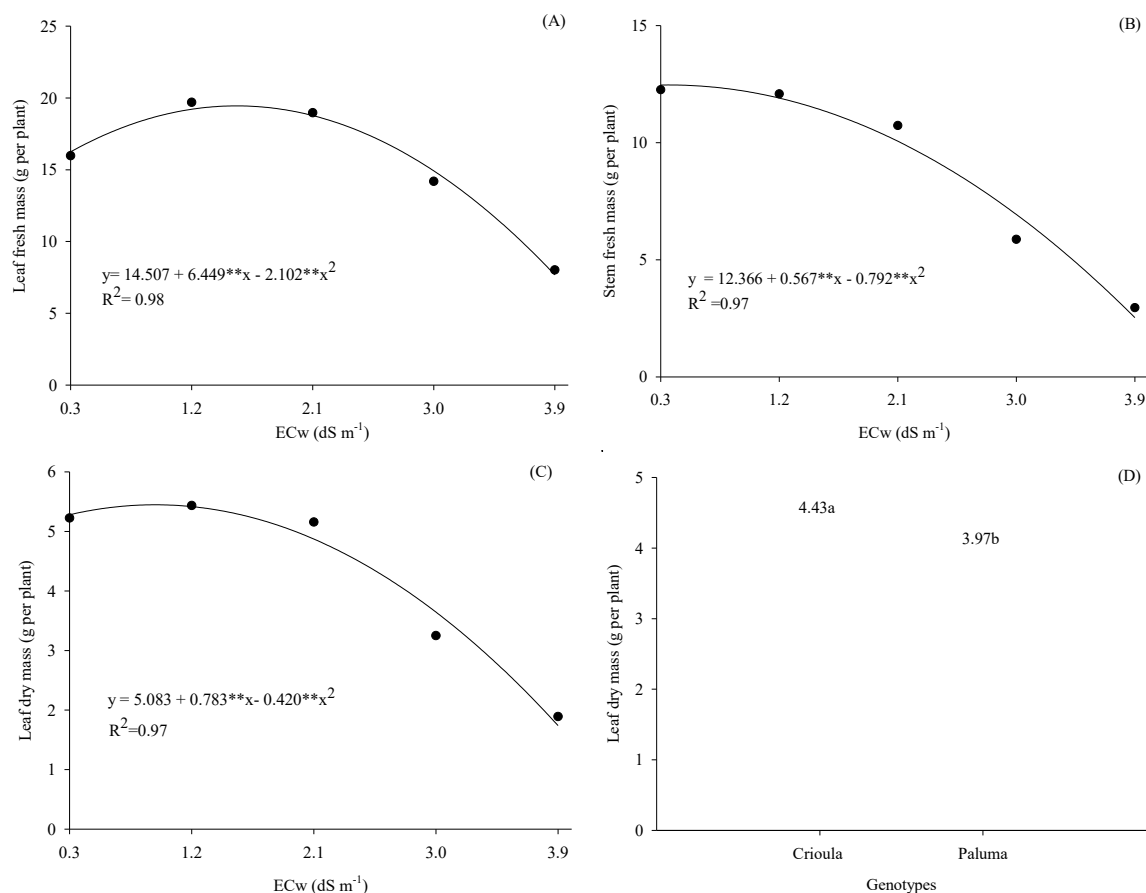
Plant height was also influenced by brackish water irrigation (Figure 2B). It was observed that the estimated ECw of 2.1 dS m⁻¹ resulted in greater growth in PH, which decreased from this ECw, reaching a minimum value of 57.50 cm under irrigation with water of 3.9 dS m⁻¹. The increase in ECw in the substrate possibly restricts the absorption of water and nutrients, due to the reduction of osmotic potential and competition between specific ions, leading to cell membrane disorganization, reduced cell division and expansion, and consequently causing plant growth disorders (WANI et al., 2020; FERREIRA et al., 2023).

Regarding the effect of the genotypes, it was found that ‘Crioula’ guava was superior to cv. ‘Paluma’ (Figure 2C). This effect may be related to a tolerance mechanism, in which the plant expands its root system in search of nutrients, minimizing the effects of salt stress. This favors acclimatization and is reflected on agronomic characteristics considered ideal for a rootstock that must be rustic, fast-growing, and adapted to the cultivation conditions in the semi-arid Northeast (SA et al., 2016).

The inhibition of plant height and stem diameter growth resulted in lower amount of biomass in guava plants (Figures 2B and 2C). For leaf fresh mass (Figure 3A), the maximum estimated value of 19.45 g per plant was obtained

under irrigation with ECw of 1.53 dS m⁻¹. On the other hand, plants subjected to ECw of 3.9 dS m⁻¹ obtained the lowest LFM value (7.68 g per plant). For stem fresh mass (Figure 3B), the highest estimated value of 12.46 g per plant was reached under irrigation with water of 1.0 dS m⁻¹ and the minimum of 2.53 g per plant was observed when using ECw of 3.9 dS m⁻¹. Irrigation using water with increasing levels of electrical conductivity significantly reduces the photosynthetic activity of plants, which leads to reduced growth, due to changes in water potential caused by the high concentration of dissolved salts that restricts the absorption of water and nutrients (REIS et al., 2016).

Regarding leaf dry mass (Figure 3C), irrigation with water of 0.9 dS m⁻¹ resulted in higher LDM accumulation (5.44 g per plant). On the other hand, ECw of 3.9 dS m⁻¹ led to the lowest LDM accumulation (1.74 g per plant). Inhibition in biomass accumulation is a consequence of alterations in the partition of photoassimilates, as there is a diversion of energy, which is directed to growth for activation and maintenance of metabolic activities associated with salinity tolerance mechanisms, such as membrane integrity and regulation of ion transport and distribution in various organs (QUEIROGA et al., 2023).



Means followed by the same letter do not differ from each other by Tukey test $p \leq 0.05$.
Values followed by ** indicate significance at $p \leq 0.01$ by the F test.

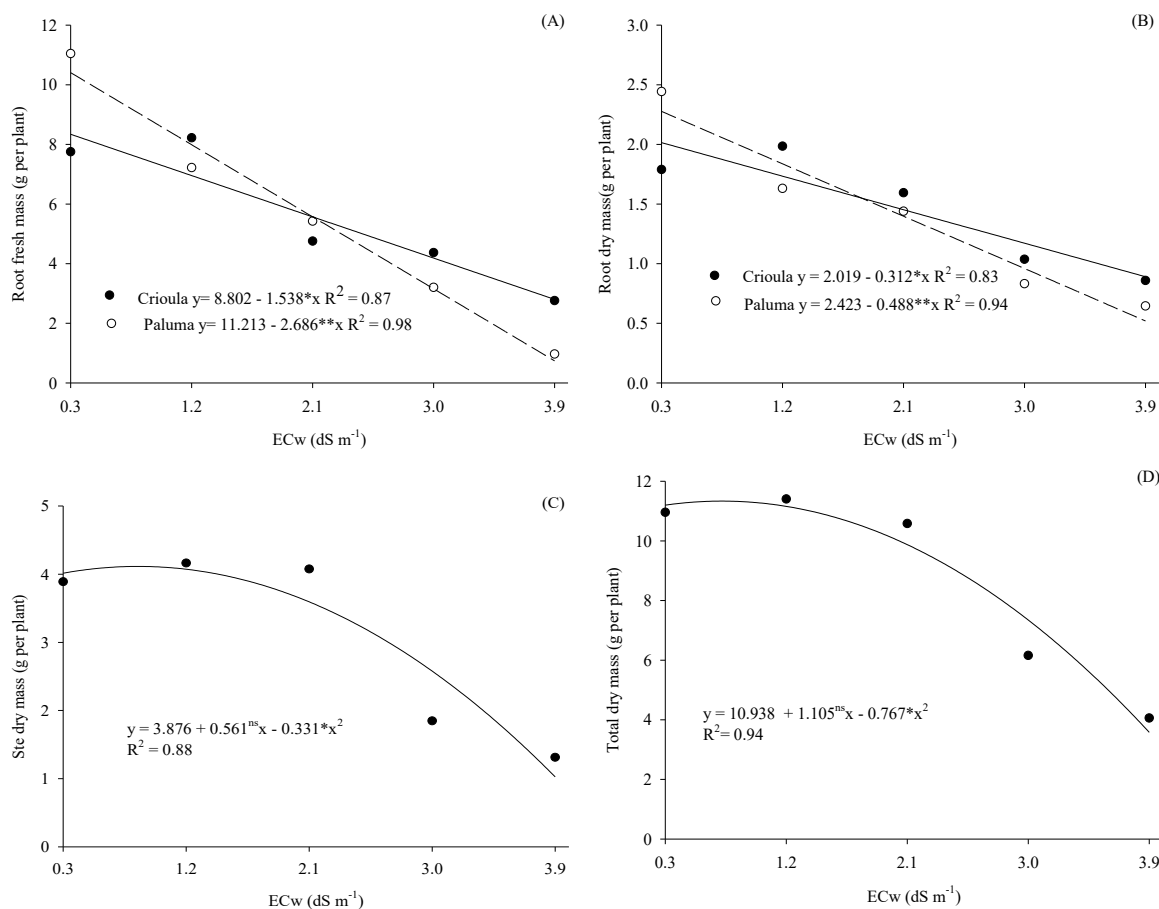
Figure 3. Leaf fresh mass (A), stem fresh mass (B), and leaf dry mass (C) of guava seedlings (*P. guajava* L.), as a function of electrical conductivities of irrigation water - ECw and leaf dry mass (D), as a function of genotypes, at 60 days after sowing.

In relation to the effects of the genotypes (Figure 3D), it was observed that ‘Crioula’ guava had higher values of leaf dry mass (4.43 g per plant), which was 1.12 g per plant higher than that observed in the cv. ‘Paluma’. This may be related to the tolerance mechanism of ‘Crioula’ guava, which develops its root system in the search for nutrients, thereby increasing its absorption capacity, mitigating the deleterious effects of salt stress, which will later bring benefits to the growth and development of plants (SÁ et al., 2016). Under conditions of salt stress, plants increase the demand for energy, for compartmentalization of toxic ions and production of compatible solutes for the maintenance of metabolic activities. Thus, the increase in energy consumption reduces the resources available for growth, resulting in less accumulation of plant biomass (MUNNS; TESTER, 2008).

Root fresh mass of guava seedlings was affected by the interaction between the factors (Figure 4A). For ‘Crioula’ genotype and cv. ‘Paluma’, it was observed that the salinity of irrigation water caused a linear decrease in RFM accumulation, with reductions of 17.47% and 23.95% per unit increase in ECw, respectively. When comparing the RFM of ‘Crioula’ plants irrigated with ECw of 3.9 to the value of those that received 0.3 dS m⁻¹, a reduction of 5.53 g per plant was observed. For cv. ‘Paluma’ (Figure 4A), there was a reduction in RFM accumulation of 2.68g per unit increment in

ECw. In relative terms, there was a decline in RFM of 9.66 g per plant between plants irrigated with ECw of 3.9 and 0.3 dS m⁻¹. The reduction in the accumulation of root fresh mass reflects the inhibition in the growth of the root system caused by the high concentrations of salts in the irrigation water, as previously highlighted by Nóbrega et al. (2024).

Root dry mass was also affected by the ECw × GN interaction (Figure 4B), in which the ‘Crioula’ genotype had the maximum estimated value (1.92 g per plant) under irrigation with ECw of 0.3 dS m⁻¹. The minimum estimated value of 0.80 g per plant was reached under water salinity of 3.9 dS m⁻¹. For cv. ‘Paluma’ (Figure 4C), there were linear decreases as a function of the increase in ECw levels, with a reduction of 20.14% per unit increase in the electrical conductivity of the water. Stem dry mass (Figure 4C) was also affected by the salinity of irrigation water, with the maximum estimated value of 4.01 g per plant obtained under irrigation with water of 0.8 dS m⁻¹. It can be observed that the minimum estimated value of 1.02 g per plant was reached in plants grown under ECw of 3.9 dS m⁻¹. The reduction of biomass is associated with a reduction in soil water potential and difficulty in water uptake by the roots, in addition to the toxicity of ions such as Na⁺ and Cl⁻, which negatively affect cell integrity, root metabolism and cell division (MUNNS; TESTER, 2008).



Values followed by ** and * indicate statistical significance with $p \leq 0.01$ and $p \leq 0.05$, respectively, while 'ns' indicates no significance, according to the F test.

Figure 4. Root fresh mass - RFM (A) and root dry mass - FSR (B) as a function of the interaction between electrical conductivities of irrigation water (ECw) and guava (*P. guajava* L.) genotypes, stem dry mass - STDM (C) and total dry mass - TDM (D) as a function of ECw, at 60 days after sowing.

For total dry mass (Figure 4D), irrigation with ECw of 0.7 dS m⁻¹ resulted in the maximum estimated value of 11.33 g per plant. On the other hand, irrigation with ECw of 3.9 dS m⁻¹ led to a minimum value of 3.58 g per plant. The decreases in biomass accumulation of guava can be related to the effects of salts dissolved in irrigation water. The exposure of roots to salts causes osmotic and ionic disturbances in plants, which interfere with photosynthetic efficiency through energy expenditure to maintain membrane integrity, synthesis of organic solutes for osmoregulation and/or protection of macromolecules and regulation of ion transport and distribution, reduction in the synthesis and transport of photoassimilates and, consequently, in the growth and development of plants (QUEIROGA et al., 2023).

There was a significant effect of the interaction between the factors (ECw $\times$ GN), only for the CO₂ assimilation rate (*A*) and Dickson quality index (DQI) of guava seedlings (Table 3). ECw levels affected all the variables analyzed, except stomatal conductance (*gs*). The genotypes significantly interfered with transpiration (*E*), stomatal conductance (*gs*), CO₂ assimilation rate (*A*), absolute

growth rate in plant height (AGR_{PH}), and relative growth rate in plant height (RGR_{PH}).

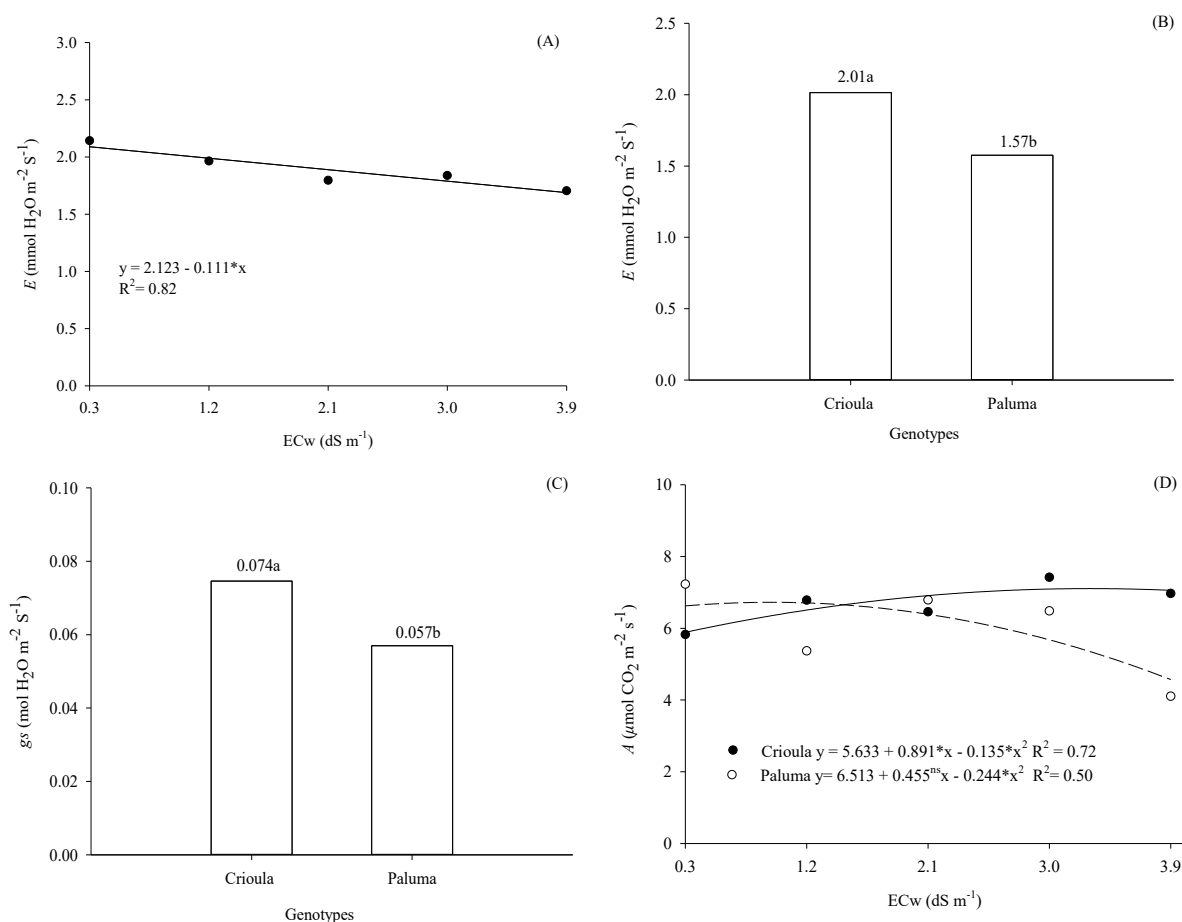
The transpiration of guava seedlings decreased by 5.22% per unit increase in ECw (Figure 5). When comparing plants irrigated with ECw of 3.9 dS m⁻¹ to those cultivated under water salinity of 0.3 dS m⁻¹, a decrease of 0.34 mmol H₂O m⁻² s⁻¹ was observed. The decrease in transpiration may be a consequence of the partial closure of the stomata caused by the reduction in water absorption under salinity conditions and can be considered a strategy to minimize the loss of water vapor to the atmosphere. However, the closure of the stomata restricts the entry of CO₂ into the cell and limits the photosynthetic activity of plants (LACERDA et al., 2022).

The seedlings of the 'Crioula' genotype showed the highest transpiration (*E*) of 2.01 mmol of H₂O m⁻² s⁻¹, representing an increase of 21.89% compared to cv. 'Paluma', which had transpiration (*E*) of 1.57 mmol of H₂O m⁻² s⁻¹ (Figure 5B). The higher value of *E* in the 'Crioula' genotype may be associated with the characteristics of rusticity, which allows greater transpiration flow and, consequently, absorption of water and nutrients.

Table 3. Summary of the analysis of variance for transpiration (E), stomatal conductance (g_s), CO_2 assimilation rate (A), absolute growth rate in plant height (AGR_{PH}), relative growth rate in plant height (RGR_{PH}), total dry mass (TDM), and Dickson quality index (DQI) of guava (*P. guajava* L.) seedlings subjected to different electrical conductivities of irrigation water (ECw) at 60 days after sowing.

Sources of variation	DF	Mean squares						
		E	g_s	A	AGR_{PH}	RGR_{PH}	TDM	DQI
ECw	4	1.14**	0.0016 ^{ns}	3.618**	1.69**	0.651**	131.91**	0.672**
Linear regression	1	1.20*	0.00052 ^{ns}	1.467 ^{ns}	4.80**	1.70**	435.63**	2.640**
Quadratic regression	1	1.32*	0.00081 ^{ns}	3.965*	1.90**	0.89**	64.877**	0.0023**
Genotypes (GN)	1	2.88**	0.0045*	7.280**	0.63**	0.177**	2.211 ^{ns}	0.0159 ^{ns}
Interaction ($\text{ECw} \times \text{GN}$)	4	0.46 ^{ns}	0.00046 ^{ns}	8.062**	0.085 ^{ns}	0.0353 ^{ns}	0.661 ^{ns}	0.0296*
Blocks	5	0.60 ^{ns}	0.00019 ^{ns}	0.999 ^{ns}	0.320**	0.0879**	4.247 ^{ns}	0.010 ^{ns}
Residual	45	0.23	0.00064	0.709	0.077	0.0218	2.949	0.0079
CV		27.02	38.57	13.27	16.47	3.72	19.89	16.32

ECw - Electrical conductivity of water; DF - Degrees of freedom; CV - Coefficient of variation; ^{ns}, *, ** not significant, significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.



Means followed by the same letter do not differ from each other by Tukey test $p \leq 0.05$. Values followed by ** and * indicate statistical significance with $p \leq 0.01$ and $p \leq 0.05$, respectively, while 'ns' indicates no significance, according to the F test.

Figure 5. Transpiration - E (A) as a function of the electrical conductivities of the water - ECw , transpiration - E (B), stomatal conductance - g_s (C), as a function of the genotypes, and CO_2 assimilation rate - A (D) as a function of the interaction between ECw and genotypes, at 60 days after sowing.

Stomatal conductance (Figure 5C) had a behavior similar to that of transpiration (Figure 5B), and the 'Crioula' genotype had the highest g_s of $0.078 \text{ mol m}^{-2} \text{s}^{-1}$, representing an increase of 25.64% in the g_s compared to cv. 'Paluma',

which obtained the lowest conductance of $0.058 \text{ mol m}^{-2} \text{s}^{-1}$ (Figure 5C). These results of transpiration (E) and stomatal conductance (g_s) may be related to the greater resilience of the 'Crioula' genotype to adverse conditions, such as the semi

-arid conditions, which may include the maintenance of stomatal conductance and transpiration at levels that do not compromise the photosynthetic activity and growth of plants.

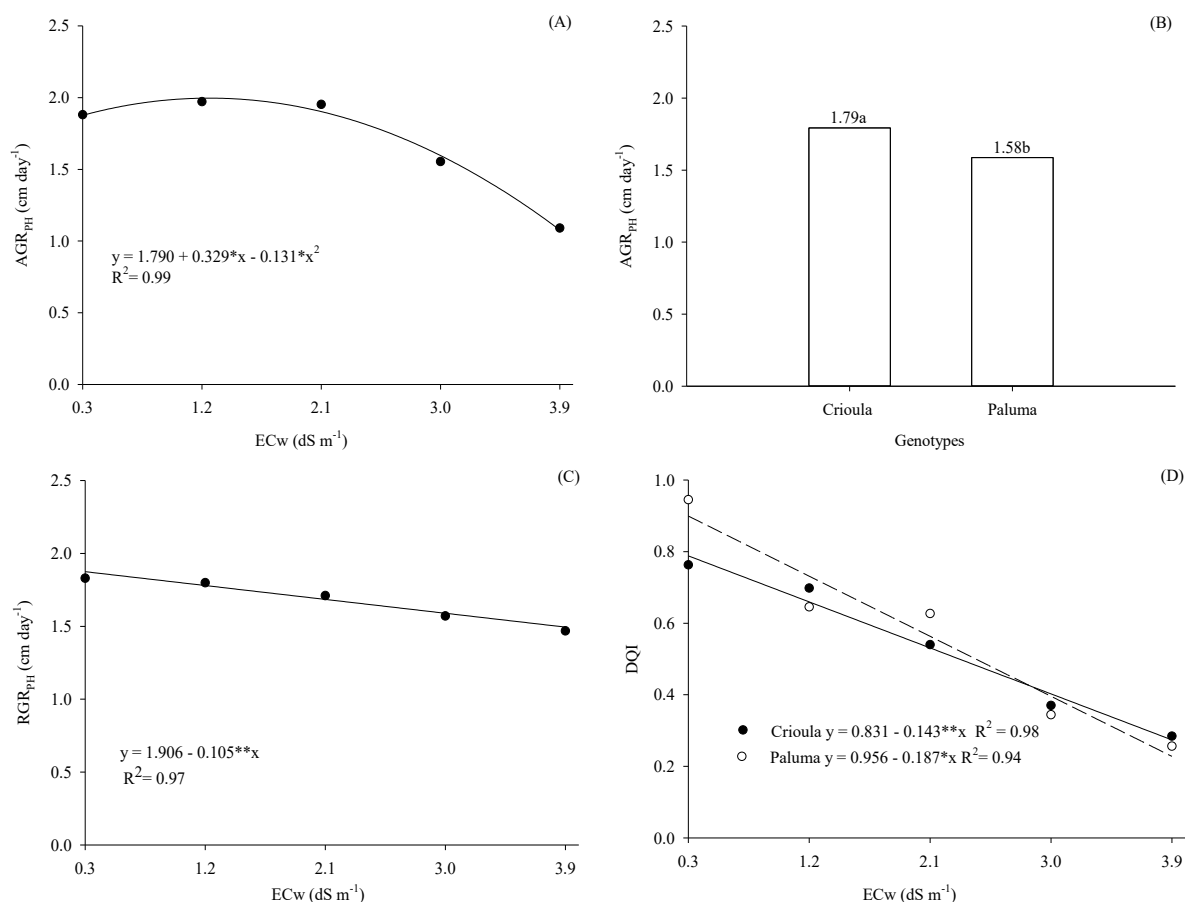
CO₂ assimilation rate (*A*) was also significantly affected by the interaction between the factors (Figure 5D), and the Crioula genotype obtained the maximum estimated value (7.11 μmol CO₂ m⁻² s⁻¹) under irrigation with EC_w of 3.3 dS m⁻¹. The minimum estimated value (5.88 μmol CO₂ m⁻² s⁻¹) was observed under water salinity of 0.3 dS m⁻¹. For cv. 'Paluma', the maximum estimated value of 6.72 μmol CO₂ m⁻² s⁻¹ was obtained under irrigation with EC_w of 1.0 dS m⁻¹. The minimum estimated value of 4.57 μmol CO₂ m⁻² s⁻¹ was observed under water salinity of 3.9 dS m⁻¹, representing a reduction of 28%.

The reduction in *A* may be related to the partial closure of the stomata, restricting the entry of CO₂ into the substomatal chamber, probably due to phytotoxic damage resulting from the accumulation of salts in the plant (SILVA et al., 2024). According to Pan et al. (2021), salt stress can inhibit RuBisCO activity and reduce ribulose-1,5-bisphosphate (RuBP) regeneration, negatively impacting carbon consumption and plant photosynthetic efficiency. Therefore, the reduction in *A* can be explained by a combination of stomatal and non-stomatal factors, involving both the limitation of CO₂ input and the biochemical

inhibition of Calvin cycle reactions (LAWLOR; CORNIC 2002).

It is worth pointing out that the *g_s*, *E*, CO₂ assimilation rate (*A*), plant height, leaf dry mass and absolute growth rate in plant height of guava seedlings of the 'Crioula' genotype were higher than those obtained by cv. 'Paluma', which may be an indication that the plants adapted better to the salt stress conditions studied. Cavalcante et al. (2005) characterize the 'Crioula' as a rustic plant material, adapted to the climate and soil conditions of the northeastern semi-arid region. Sá et al. (2016) reported that the 'Crioula' genotype showed superior salinity tolerance capacity compared to cv. 'Paluma', thus indicating that 'Crioula' is considered the most recommended to be used as a rootstock in the production of guava seedlings.

The absolute growth rate in plant height (AGR_{PH}) of guava seedlings showed a quadratic behavior (Figure 6A), whose maximum estimated value of 1.99 cm⁻¹day⁻¹ was obtained in plants irrigated with EC_w of 1.3 dS m⁻¹. On the other hand, irrigation with water of 3.9 dS m⁻¹ resulted in the lowest AGR_{PH} value (1.08 cm⁻¹day⁻¹). Regarding the effects of genetic materials (Figure 6B), 'Crioula' obtained the highest value of absolute growth rate, 1.79 cm⁻¹day⁻¹, which is 11.73% higher than that observed for cv. 'Paluma', 1.59 cm⁻¹day⁻¹.



Means followed by the same letter do not differ from each other by Tukey test $p \leq 0.05$. Values followed by ** and * indicate statistical significance with $p \leq 0.01$ and $p \leq 0.05$, respectively, according to the F test.

Figure 6. Absolute growth rate in plant height - AGR_{PH} (A) as a function of the levels of electrical conductivity of water - EC_w, absolute growth rate in plant height - AGR_{PH} (B) as a function of genotypes in guava (*P. guajava* L.), relative growth rate in plant height - RGR_{PH} (C), as a function of EC_w, and Dickson quality index - DQI (D), as a function of the interaction between EC_w and genotypes, at 60 days after sowing.

Regarding the relative growth rate in plant height (RGR_{PH}), a decreasing linear behavior was observed (Figure 6C), with a reduction of 5.50% per unit increment in EC_w . Plants under irrigation with water of 3.9 dS m^{-1} showed an inhibition in RGR_{PH} of 20.16%, compared to those cultivated under EC_w of 0.3 dS m^{-1} . The inhibition in the growth of guava seedlings results from the reduction of water potential caused by the excess of salts in the substrate. Under these conditions, plants have higher energy expenditure to maintain metabolic activities and consequently there is a decline in meristematic activity and cell elongation, as well as functional and metabolic disorders (SILVA et al., 2024).

Dickson quality index (DQI) was significantly affected by the interaction between salinity levels and genotypes (Figure 6D), showing a decreasing linear behavior for the genotypes studied; for 'Crioula', the decrease was 17.20% per unit increase in EC_w . When comparing seedlings of the 'Crioula' genotype irrigated with water of 3.9 dS m^{-1} to those subjected to the lowest EC_w level (0.3 dS m^{-1}), a decrease of 65.32% was observed. For cv. 'Paluma', there was also a decrease in DQI, equal to 19.56% per unit increase in EC_w . In relative terms, seedlings of cv. 'Paluma' irrigated with EC_w of 3.9 dS m^{-1} had a decrease in IDQ of 74.80% compared to those cultivated under water salinity of 0.3 dS m^{-1} .

The reductions in DQI values as a function of the increases in salinity levels occurred mainly due to decreases in plant height, stem diameter, root dry mass, shoot dry mass and total dry mass, which are used to obtain the Dickson Quality Index. The highest values of DQI observed in the 'Crioula' genotype, compared to cv. 'Paluma', suggest a better performance under salt stress, which may represent an advantage in its use as a rootstock in regions with high salinity. Despite the reduction in DQI, the two genotypes studied subjected to EC_w of 3.9 dS m^{-1} showed characteristics to be transplanted to the field, as they had DQI higher than 0.20, so the seedlings were considered to be of acceptable quality for transplantation to the field (DICKSON et al., 1960; QUEIROGA et al., 2023).

CONCLUSIONS

Irrigation using water with electrical conductivity higher than 0.3 dS m^{-1} inhibited the growth in stem diameter, root dry mass, leaf transpiration, relative growth rate in plant height and Dickson quality index of guava. Among the genotypes, 'Crioula' obtained the highest growth, photosynthetic activity and seedling quality index under irrigation with brackish water, hence being recommended for rootstock formation under semi-arid conditions.

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