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Production of guava seedlings with increasing water salinity and nitrogen-potassium fertilizations

Produção de mudas de goiaba com aumento da salinidade da água e fertilização com nitrogênio e potássio

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ABSTRACT - Salt stress affects the development of several crops, being one of the limiting factors for irrigated agriculture in the semi-arid region, where nitrogen and potassium fertilization can be an alternative for agricultural production. This study aimed to evaluate the viability of using water with different salinities associated with varying amounts of nitrogen and potassium fertilization in the production of seedlings of the guava cultivar Paluma in an experiment conducted in experimental areas of the Federal Rural University of the Semi-arid Region (UFERSA), campus of Caraúbas. The research was carried out from February to June 2021. The study was set up in a randomized block design and analyzed in a 5 × 4 factorial scheme with four replicates, and two plants per plot. Treatments were established by combining different levels of electrical conductivity of the irrigation water (ECw): 0.3, 1.1, 1.9, 2.7, and 3.5 dS m^{-1}, with Combinations (C) of nitrogen (N) and potassium (K_2O) levels of recommended fertilization: C1 = 70% N + 50% K_2O, C2 = 100% N + 75% K_2O, C3 = 130% N + 100% K_2O, and C4 = 160% N + 125% K_2O. Irrigation with electrical conductivity levels up to 2.1 dS m^{-1} favored seedling growth for the guava cv. Paluma. Fertilization combinations C1 and C2 promoted the greatest increases in growth and biomass for guava seedlings cv. Paluma 125 days after sowing. Fertilizer combinations did not mitigate the harmful effects of salt stress from irrigation water on the production of young guava cv. Paluma.

Keywords: *Psidium guajava* L. Salt stress. Fertilizer.

RESUMO - O estresse salino afeta o desenvolvimento de diversas culturas, sendo um dos fatores limitantes para a agricultura irrigada no semiárido, onde a adubação nitrogenada e potássica pode ser uma alternativa para a produção agrícola da região. Com esse trabalho objetivou-se avaliar a viabilidade do uso de água com diferentes salinidades associada a diferentes adubações nitrogenadas e potássicas na produção de mudas da goiabeira cultivar Paluma. O experimento foi conduzido em áreas experimentais da Universidade Federal Rural do Semiárido (UFERSA), Campus Caraúbas. A pesquisa foi realizada no período de fevereiro a junho de 2021. O estudo foi montado em delineamento de blocos ao acaso, com quatro repetições e duas plantas por parcela. Foi utilizado um esquema fatorial 5 × 4, que combinou cinco níveis de condutividade elétrica da água de irrigação (CEa): 0,3, 1,1, 1,9, 2,7 e 3,5 dS m^{-1}, com combinações (C) de nitrogênio (N) e níveis de potássio (K_2O) de adubação recomendada: C1 = 70% N + 50% K_2O, C2 = 100% N + 75% K_2O, C3= 130% N + 100% K_2O e C4= 160% N + 125% K_2O. Irrigação com níveis de condutividade elétrica até 2,1 dS m^{-1} favoreceu o crescimento das mudas da goiabeira cv. Paluma. As adubações C1 e C2 promoveram os maiores incrementos de crescimento e fitomassa para a goiabeira cv. Paluma aos 125 dias após a semeadura. As combinações de adubação não mitigaram os efeitos nocivos do estresse salino da água de irrigação sobre a produção de mudas de goiabeira cv. Paluma.

Palavras-chave: *Psidium guajava* L. Estresse salino. Fertilizantes.

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INTRODUCTION

Guava (*Psidium guajava* L.) has stood out in the world fruit sector due to its high nutritional value, pleasant taste and aroma, being consumed either fresh or after industrial processes, in addition to its high acceptance in the market (OMAYIO et al., 2020).

Although guava is cultivated in different areas of Brazil, the semi-arid region requires irrigation for sustainable production due to high evaporation rates, high temperatures, and irregular rainfall. Moreover, most water reservoirs in this region have low-quality water, especially with regard to salinity, given the local climatic and geological conditions (MEDEIROS et al., 2003). Although the quality of this saline water is unsatisfactory, its use has become frequent for irrigating several crops due to the large volume available and for being often the only water source at hand. In this context, in its initial development the guava plant is classified as sensitive to salinity, with a salinity threshold of 1.2 dS m^{-1} (TÁVORA; FERREIRA; HERNANDEZ, 2001).

The use of saline water in irrigation can cause severe problems for agriculture, reducing crop yield and degrading soils, especially in arid and semi-arid regions, as the application of saline water in poorly managed soils may result in adverse effects on the soil-water-plant system, leading to osmotic, toxic, and nutrient stresses in the crops (SOARES et al., 2018).

From this perspective, the wide use of low-quality water in agricultural production is associated with the development of strategies that include fertilization management aiming to reduce nutrient deficiency caused by soil and/or irrigation water salinity. According to Silva et al. (2019a), the application of appropriate N and K levels can favor low Na^+/K^+ and Cl^-/NO_3^- ratios in plant tissues, thus minimizing the deleterious effects of salt stress. Moreover, the appropriate application of fertilizer levels in guava plants during early development can reduce the negative effects of salinity on physiological and morphological plant processes (BONIFÁCIO et al., 2018; BEZERRA et al., 2018).

Such fertilizers are essential to plants since nitrogen is directly related to plant growth and metabolic activities, assisting in the formation of organic compounds, e.g., amino acids, proteins, chlorophyll, and nucleic acids (SILVA et al., 2020). In turn, potassium performs several functions in the plant that mitigate the effects of salinity, e.g., control of cell turgidity, activation of enzymes involved in respiration and photosynthesis, regulation of stomatal opening and closure, and resistance to drought and salinity, resulting in greater biomass production, carbohydrate translocation, and protein synthesis (SOUZA et al., 2023).

From this perspective, this study aimed to evaluate the viability of using water with different salinities associated with different amounts of nitrogen and potassium fertilization in the production of seedlings of the guava cv. Paluma.

MATERIAL AND METHODS

The experiment was conducted from February to June 2021 in a protected environment at the Caraúbas Multidisciplinary Center of the Federal Rural University of the Semi-Arid Region (UFERSA), Caraúbas – RN, located at 05°46’23” S and 37°34’12” W, at a mean elevation of 144 m above sea level. According to Alvares et al. (2013), the climate of the region is hot and dry, classified according to Köppen-Geiger as semi-arid BSh, with a maximum of 32 °C.

Climatological data (Figure 1) were collected during the study period from an automatic weather station located at UFERSA, Caraúbas Campus, in an area near the site where the experiment was set up.

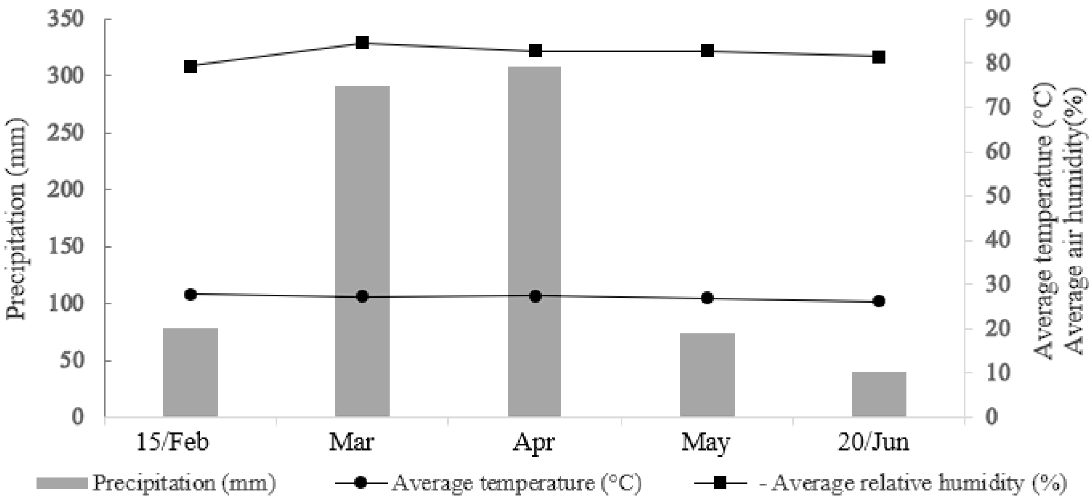


Figure 1. Precipitation, average air temperature and average air humidity data collected from February 15, 2021, to June 20, 2021.

The experimental design was completely randomized blocks arranged in a 5 × 4 factorial scheme referring to five levels of electrical conductivity of the irrigation water (ECw) (0.3, 1.1, 1.9, 2.7, and 3.5 dS m^{-1}) and four combinations (C) of nitrogen (N) and potassium (K_2O) levels (C1 = 70% N + 50% K_2O, C2 = 100% N + 75% K_2O, C3 = 130% N + 100% K_2O, and C4 = 160% N + 125% K_2O). Twenty treatment combinations were used in the experiment, with four replicates and two plants per plot. The potassium fertilization recommendation was adopted according to Bonifácio et al. (2018), with 798.6 mg of K per dm^{-3} of soil, while the nitrogen recommendation was 541.1 mg of N per dm^{-3} of soil (SOUZA et al., 2016), established as the equivalent to 100% N and K_2O. Urea was the N source used (45% N), and potassium chloride was the K_2O source used (60% K_2O).

The referred salinity levels were selected based on Bezerra et al. (2018), who indicate guava as moderately sensitive to the salinity of irrigation water, with reduced plant growth, development and production at salinities above 1.5 dS m^{-1}. In the different treatments, the irrigation water was prepared by adding NaCl, $CaCl_2.2H_2O$, and $MgCl_2.6H_2O$ until obtaining the desired electrical conductivity while maintaining a 7:2:1 ratio between the constituents, which was considered by Medeiros et al. (2003) as the ratio usually found in local water sources of the Northeast region of Brazil. The ECw was calculated based on the relationship between the ECw and the concentration of salts (mmol-$_c$ L^{-1} = ECw × 10), as proposed by Richards (1954).

Before sowing, 1,150-mL plastic bags were filled with a substrate composed of soil (collected from the 0-30 cm layer in the municipality of Caraúbas – RN), cattle manure, crushed carnauba straw, and charcoal powder at a 2:2:2:1 ratio. The bags had holes at their bottom to allow free drainage and were placed on wooden planks at 0.3 m from the soil.

Sowing was performed with three seeds per bag at a depth of 1.0 cm. The seedlings were thinned to one plant per bag when showing two pairs of true leaves, and the seedling with the best growth was selected.

The physical and chemical characteristics of the substrate were analyzed at the beginning of the experiment according to the methodologies proposed by Teixeira et al. (2017) (Table 1).

Table 1. Physical and chemical characteristics of the substrate used to sow the guava cv. Paluma.

Sand		Silt	Clay		Textural classification		ECse dS m^{-1}	pHse H_2O		OM	
--------------------%--------------------										g kg^{-1}	
44.7		41.1	14.3		Loam		0.68	6.03		37	

P	K^+	Na^+	Ca^{2+}	Mg^{2+}	Al^{3+}	(H +Al)	SB	t	CEC	V	m	ESP
mg dm^{-3}	---cmol$_c$ dm^{-3}---									--------%--------		
134.2	0.87	0.15	17.11	1.14	0.0	0.58	19.27	19.27	19.27	97	0	0.78

Available phosphorus (P) – EMBRAPA methodology; OM – Organic matter: Walkley-Black Wet Digestion; Ca^{2+} and Mg^{2+} - Extracted with 1 mol L^{-1} KCl at pH 7.0; Na^+ and K^+ - Extracted with 1 mol L^{-1} NH_4OAc at pH 7.0; Al^{3+} and (H^+ + Al^{3+}) - Extracted with 1 mol L^{-1} CaOAc at pH 7.0; ECse – Electrical conductivity of the substrate saturation extract at 25 °C; pHse – pH of the substrate saturation extract; SB – Sum of bases; t – Effective CEC; CEC – Cation exchange capacity; V – base saturation; m – Aluminum saturation ; ESP – Exchangeable sodium percentage.

Substrate moisture was maintained close to field capacity during the experimental period. The plants were irrigated with local supply water (ECw of 0.3 dS m^{-1}) until 30 days after sowing (DAS), after which irrigation was performed with the respective treatments. The water volume applied at each irrigation was determined by weighing one bag sample for each treatment, with weekly evaluations to observe plant development. Moreover, the evapotranspiration volume for each treatment was supplied daily to maintain the soil close to field capacity.

The combinations of N and K levels were applied at weekly intervals from 30 DAS. The crop management practices consisted of aphid and cochineal control using a specific insecticide. The experimental area was kept free of weeds through manual hoeing to eliminate invasive plants.

Growth evaluations were performed at 125 DAS to analyze the effect of the treatments by determining the number of leaves (NL), plant height (PH), stem diameter (SD), and leaf area (LA). NL was counted considering only those with a fully opened blade. SD was determined using a digital caliper at 3 cm from the ground, and PH was measured as the distance between the base of the plant and the insertion of the youngest leaf.

Leaf area was measured according to Lima et al. (2012), using Equation 1:

$$LA = 0.3205 \times L^{2.0412} \quad (1)$$

where: LA = leaf area (cm^2); L = length of the leaf midrib (cm).

The leaf area data were used to calculate the absolute (AGR) and relative (RGR) growth rates in the interval from 85 to 125 DAS according to Benincasa (2003), as described below in Equations 2 and 3:

$$AGR_{LA} = \frac{(LA_2 - LA_1)}{(t_2 - t_1)} \quad (2)$$

where:
AGR - Absolute growth rate of leaf area (cm^2 per day);
LA_1 - Leaf area (cm^2) at time t_1; and,
LA_2 - Leaf area (cm^2) at time t_2.

$$RGR_{LA} = \frac{(\ln LA_2 - \ln LA_1)}{(t_2 - t_1)} \quad (3)$$

where:
RGR - Relative growth rate of leaf area (cm^2 cm^{-2} per day); and,
ln - natural logarithm.

The dry mass of leaves (DML), stem (DMS), root (DMR), total dry mass (TDM), and the Dickson quality index (DQI) were determined at 125 DAS. Biomass accumulation was determined by weighing the leaves, stem, and root on a precision balance accurate to 0.001g, with the dry mass obtained after weighing this material in a forced-air oven at 65 °C until reaching constant weight.

Seedling quality was determined using the Dickson quality index (DQI), proposed by Dickson, Leaf and Hosner (1960) and described by Equation 4:

$$\mathrm{DQI} = \frac{(\mathrm{TDM})}{\mathrm{PH/SD} + (\mathrm{DMSh/DMR})} \qquad (4)$$

where: TDM = total dry mass (g per plant); PH = plant height (cm); SD = stem diameter (cm); DMSh = dry mass of shoots (g per plant); DMR = dry mass of roots (g per plant).

The variables were subjected to analysis of variance by the F test (1 and 5% probability levels). In cases of significant effects, regression analysis was performed for the salinity levels, whereas the combinations of nitrogen and potassium fertilization were compared by the Tukey test (1 and 5% probability levels) using the statistical software SISVAR/ UFLA (FERREIRA, 2019).

RESULTS AND DISCUSSION

According to the analysis of variance (Table 2), there was no significant effect of the interaction between water salinity levels and nitrogen and potassium fertilization on the variables analyzed. The number of leaves (NL), stem diameter (SD), and leaf area (LA) at 125 DAS and the absolute (AGR_{LA}) and relative (RGR_{LA}) growth rates of leaf area from 85 to 125 DAS showed a significant individual effect as a function of irrigation water salinity and NK combination. Plant height (PH) was not significantly affected by any of the studied sources of variation.

Table 2. Summary of the analysis of variance for the number of leaves (NL), plant height (PH), stem diameter (SD), and leaf area (LA) at 125 DAS, and absolute (AGR_{LA}) and relative (RGR_{LA})growth rates of leaf area from 85 to 125 DAS as a function of different levels of irrigation water salinity and the combination of nitrogen and potassium fertilization.

Source of variation	Mean squares					
	NL	PH	SD	LA	AGR_{LA}	RGR_{LA}
Salinity levels (SL)	35.125^{**}	59.101^{ns}	1.004^{**}	21613.269^{*}	17.633^{**}	0.0001^{**}
Linear regression	126.025^{**}	139.129^{ns}	3.378^{**}	78594.431^{**}	62.575^{**}	0.0003^{**}
Quadratic regression	0.071^{ns}	33.325^{ns}	0.437^{ns}	992.886^{ns}	3.698^{ns}	0.00007^{*}
NK combination	22.817^{**}	73.427^{ns}	1.070^{**}	33087.144^{*}	6.705^{**}	0.00007^{*}
Interaction (SL × NK)	4.608^{ns}	57.186^{ns}	0.122^{ns}	4023.606^{ns}	1.741^{ns}	0.00002^{ns}
Blocks	15.250^{*}	237.622^{**}	0.437^{*}	47258.423^{**}	2.609^{ns}	0.00013^{**}
Residual	5.273	35.736	0.1333	6035.59	2.1903	$1.904e^{-5}$
Mean	21.125	48.743	4.26	541.01	6.103	0.0159
CV (%)	10.87	12.26	8.57	14.36	24.25	27.44

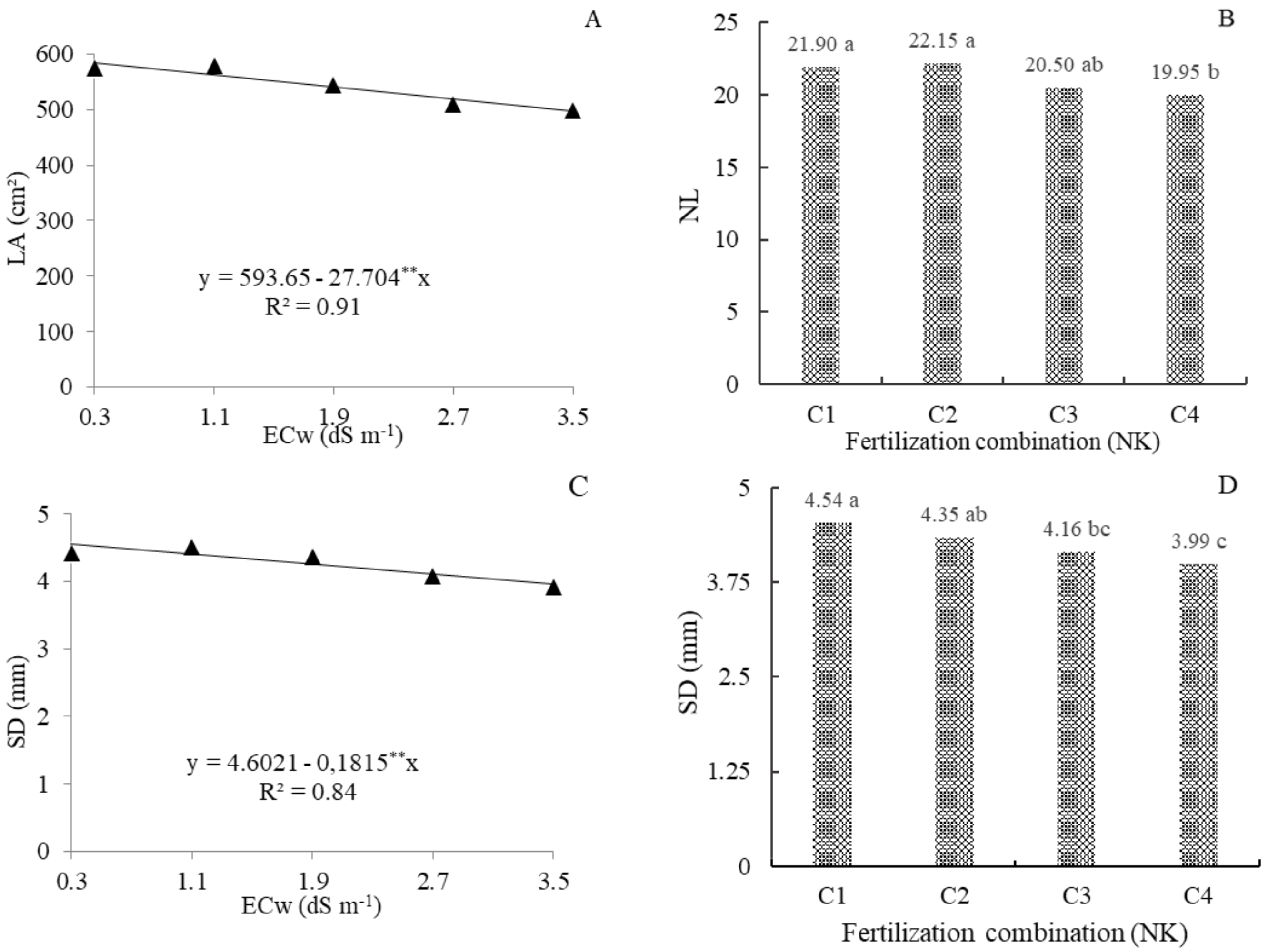
ns, **,* respectively non-significant, significant at $p < 0.01$, and significant at $p < 0.05$; CV= coefficient of variation.

According to the regression equation (Figure 2A), the increase in water salinity linearly decreased leaf production in the guava cv. Paluma at 125 DAS by 4.77% (approximately 3 leaves) per unit increase in ECw. The seedlings irrigated with the highest water salinity (3.5 dS m^{-1}) showed a 16.7% reduction in LA compared to those irrigated with 0.3 dS m^{-1}. This reduction could be a response of crop tolerance mechanisms to minimize water loss through transpiration and maintain a high cell water potential, reducing the uptake of water and sodium chloride, which could avoid or decrease the toxicity of specific ions (SÁ et al., 2019).

With regard to NK fertilization (Figure 2B), the C1 (70% N + 50% K_2O) and C2 (100% N + 75% K_2O) combinations promoted the highest number of leaves at 125 DAS, highlighting that N application at higher levels than the recommended, as well as K levels above 75% of the recommended, does not favor leaf production in guava seedlings cv. Paluma at 125 DAS. This condition was also observed by Silva et al. (2017), in whose study the increase in the recommended N levels for guava caused NL losses of 6.95% and 11.22% for each 30% increase in N at 130 and 190 days after emergence (DAE). Moreover, the amount of urea applied during longer exposures may have intensified the adverse effects of salt stress.

According to the regression equation referring to stem diameter (Figure 2C), there was a linear decrease of 3.98% per unit increase in ECw and a 12.75% decrease (0.5 mm) between the treatment with the lowest salinity level (0.3 dS m^{-1}) and the treatment with the highest salinity (3.5 dS m^{-1}). This decrease is possibly due to the high exposure of plants to salinity since, under salt stress conditions, Ca^{2+} may be displaced from cell wall binding sites due to the sodium increase, especially in stem meristem tissues, hindering the function of pectin and thus affecting cell elongation and division (BYRT et al., 2018).

Abrantes et al. (2017) also observed a decrease in the SD of guava rootstocks with the increase in irrigation water salinity, with a 2.6% decrease per unit increase in ECw, suggesting that osmotic and toxic problems due to salinity affect plant growth.



C1 = 70% N + 50% K_2O; C2 = 100% N + 75% K_2O; C3 = 130% N + 100% K_2O; C4 = 160% N + 125% K_2O. Means followed by different letters indicate a significant difference between treatments by the Tukey test ($p < 0.05$ probability level)

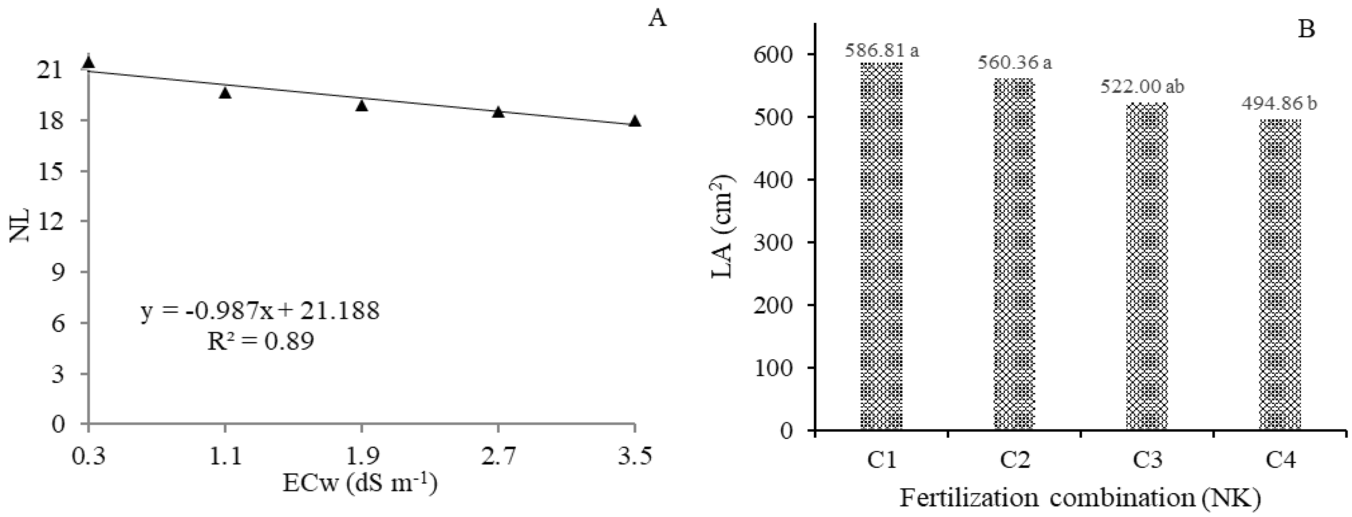
Figure 2. Leaf area – LA (A) and number of leaves – NL (B) and B) and stem diameter - SD (C and D) of guava seedlings as a function of irrigation water salinity and nitrogen and potassium fertilization combinations at 125 days after sowing.

With regard to the fertilization combinations (Figure 2D), plants under fertilization management C1 showed the highest SD values, although not differing significantly from plants under the C2 combination. Both for SD and for NL (Figure 2B), fertilization with the C3 and C4 combinations resulted in the lowest values of these variables, indicating that the application of high nitrogen and potassium levels can result in nutritional imbalance and excessive NO_3^- and K^+ accumulation in the cell vacuole of leaves and branches, decreasing leaf production and stem diameter.

Salinity had a similar effect on the leaf area of guava seedlings as each unit increase in ECw decreased LA by 4.73% (22.2 cm^2), i.e., plants grown under ECw of 3.5 dS m^{-1} showed a 15.14% reduction in LA compared to those irrigated with 0.3 dS m^{-1}. For the number of leaves (Figure 3A), there was a linear decrease of 4.77% per unit increase in ECw and a decrease of 14.90% between the highest and lowest levels of salinity. This change in the plant photosynthetic apparatus, i.e., the decrease in the transpiration surface, could be considered, according to Taiz et al. (2017), as adaptative morphological and anatomical changes in response to salt stress.

As a 10% relative reduction is considered acceptable for plants grown under saline conditions (AYERS; WESTCOT, 1999), it should be noted that the growth variables, e.g., NL, SD, and LA, were affected by the increase in ECw. However, based on the equations (Figures 2A, 2C, and 3A), an acceptable relative reduction of up to 10% is estimated when the seedlings are irrigated with a mean ECw of 3.1 dS m^{-1}, denoting a certain tolerance of the guava cv. Paluma to salts with regard to plant growth.

When evaluating the LA as a function of the different NK combinations (Figure 3B), plants under the C1 and C2 combinations showed the highest LA values, whereas plants under the C4 combination showed the lowest LA, suggesting that the excess N and K levels cause osmotic and/or toxic stress in plants (HASANUZZAMAN et al., 2018).



C1 = 70% N + 50% K_2O; C2 = 100% N + 75% K_2O; C3 = 130% N + 100% K_2O; C4 = 160% N + 125% K_2O. Means followed by different letters indicate a significant difference between treatments by the Tukey test ($p < 0.05$ probability level)

Figure 3. Number of leaves – NL (A) and leaf area - LA (B) of guava seedlings as a function of irrigation water salinity (A) and combinations of nitrogen and potassium fertilization (B) at 125 days after sowing.

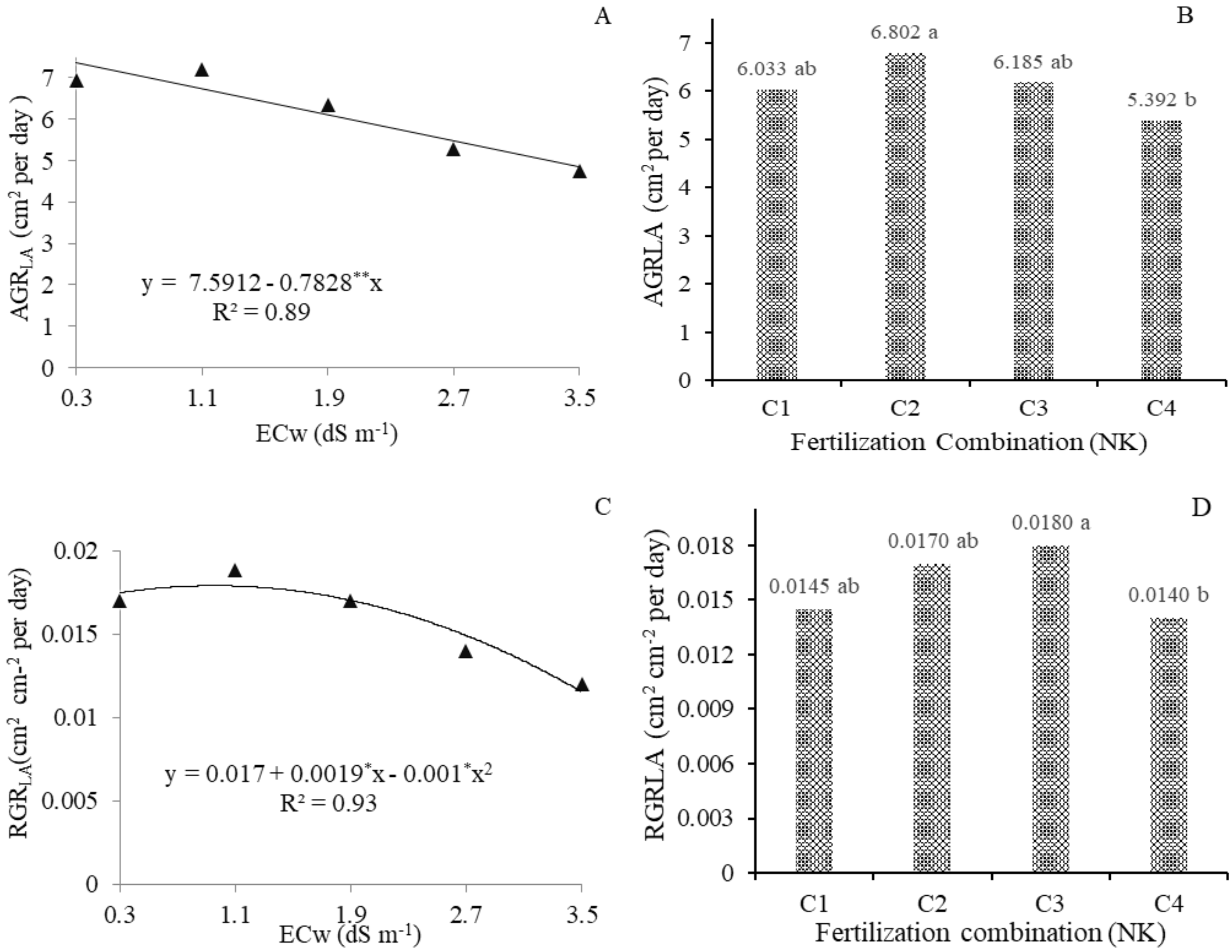
According to the regression equation in Figure 4A, the increase in irrigation water salinity linearly decreased the AGR_{LA} by 10.64% (0.6 cm^2 per day) per unit increase in ECw. Comparatively, seedlings irrigated with 3.5 dS m^{-1} showed a 34.05% decrease in AGR_{LA} compared to lower salinity treatments. Zhao et al. (2021) stated that salt stress interferes with the leaf area of plants due to cell turgor pressure, which occurs due to the lower water content in the tissues where cell wall expansion is decreased, resulting in less plant growth.

With regard to the fertilization combinations (Figure 4B), C2 (100% N + 75% K_2O) promoted the highest mean values of AGR_{LA}, not differing statistically from the C1 and C3 combinations, whereas the C4 combination led to the lowest values and the C2 combination was superior to C4 by 20.7%. The treatment with the highest N and K levels resulted in the lowest values for this variable, which may indicate an increase in substrate salinity due to the increase in urea and K_2O combined with salt accumulation resulting from the application of irrigation water. Excess salt leads to greater energy use for osmotic adjustment, decreasing the amount of energy substrate applied for plant growth (SILVA et al., 2021).

There was a significant effect ($p<0.01$) of irrigation water salinity on the RGR_{LA} from 85 to 125 DAS, with a quadratic response according to the regression equation (Figure 4C), whose highest (0.018 cm^2 cm^{-2} per day) and lowest (0.012 cm^2 cm^{-2} per day) values were obtained, respectively, with the ECw levels of 1.1 and 3.5 dS m^{-1}. The inhibition in the relative growth rate of leaf area in guava seedlings could be associated with the decrease in the number of leaves and leaf area (Figures 2A and 3A), as the reduction of the transpiration surface is a plant adaptation mechanism to reduce transpiration rates and mitigate the stress caused by excess salts (XAVIER et al., 2022). Abrantes et al. (2017) observed a decreasing linear effect on the RGR_{LA} with the increase in ECw from 50 to 100 days after emergence, causing a 6.85% decrease per unit increase in ECw.

With regard to the NK combination (Figure 4D), plants under the C3 fertilization condition showed the highest RGR_{LA} values, which were statistically different only from those of plants under the C4 combination, denoting that the 30% increase in the recommended N level had a positive effect, possibly because N assists in shoot growth and participates in the composition of chlorophyll molecules, which capture light energy (TAIZ et al., 2017). However, high N and K levels may have salinized the substrate over the successive applications of saline water, causing a decrease in RGR_{LA}.

According to the analysis of variance (Table 3), there was a significant effect of the interaction between irrigation water salinity levels and nitrogen and potassium combinations on dry mass of roots (DMR) and Dickson quality index (DQI) at 125 DAS. In contrast, the variables dry mass of stem (DMS) and total dry mass (TDM) showed significant individual effects of irrigation water salinity and N and K fertilization. Dry mass of leaves (DML) was significantly affected only by irrigation water salinity at 125 DAS.



C1 = 70% N + 50% K_2O; C2 = 100% N + 75% K_2O; C3 = 130% N + 100% K_2O; C4 = 160% N + 125% K_2O. Means followed by different letters indicate a significant difference between treatments by the Tukey test ($p < 0.05$ probability level)

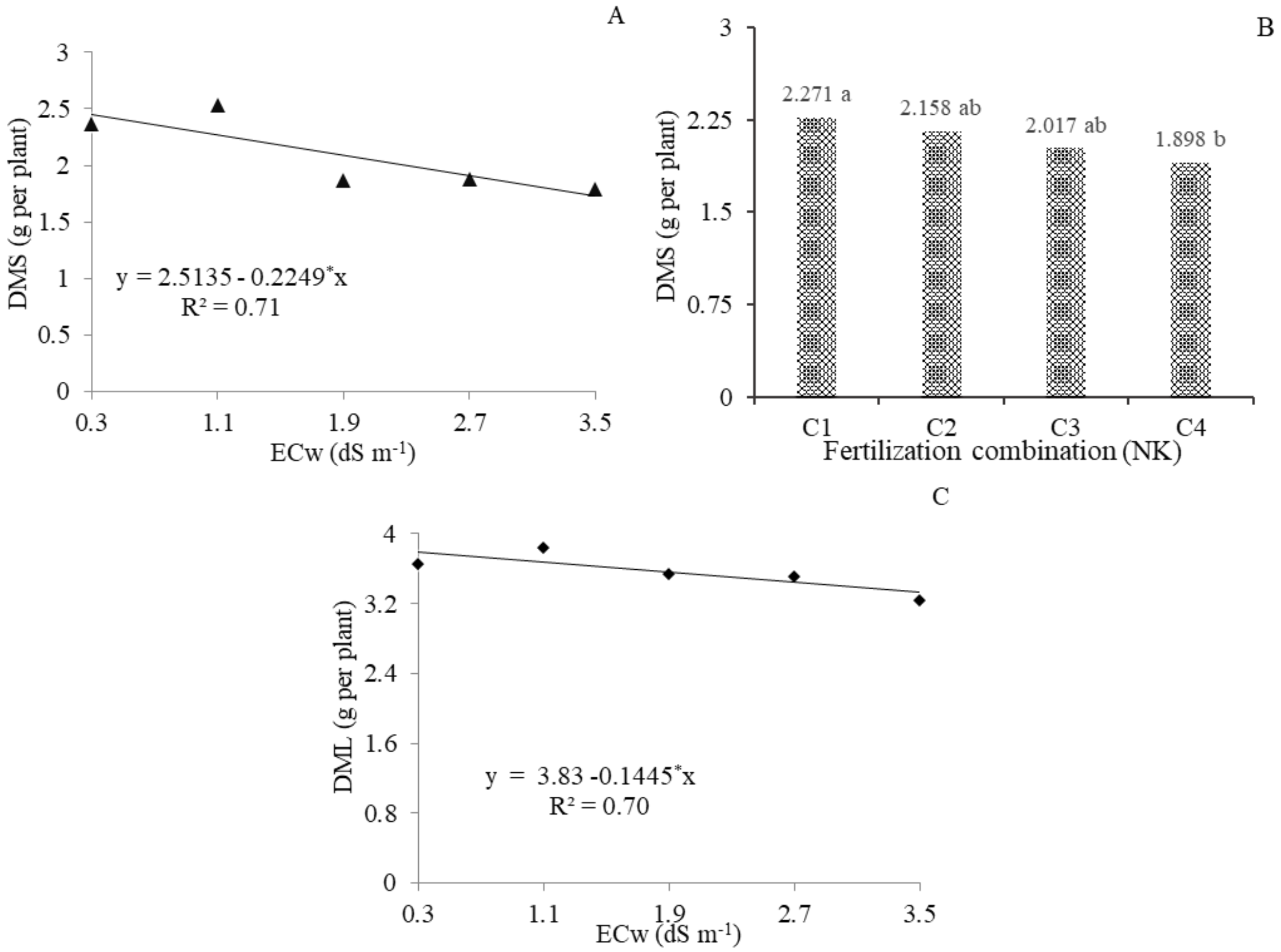
Figure 4. Absolute growth rate of leaf area – AGR_{LA} (A and B) and relative growth rate of leaf area – RGR_{LA} (C and D) of guava seedlings irrigated with different water salinities and combinations of nitrogen and potassium fertilization from 85 to 125 days after sowing.

Table 3. Summary of the analysis of variance referring to *dry* mass of *leaves* (DML), dry mass of stem (DMS), dry mass of roots (DMR), total dry mass (TDM), and Dickson quality index (DQI) performed at 125 DAS as a function of different salinity levels of the irrigation water and nitrogen and potassium fertilization combinations.

Source of variation	Mean squares				
	DML	DMS	DMR	TDM	DQI
Salinity levels (SL)	0.7694^{*}	1.824^{**}	0.448^{**}	7.839^{**}	0.045^{**}
Linear regression	2.137^{*}	5.177^{**}	1.402^{**}	24.235^{**}	0.155^{**}
Quadratic regression	0.465^{ns}	0.030^{ns}	0.149^{ns}	0.793^{ns}	0.009^{ns}
NK combination	0.684^{ns}	0.529^{*}	0.132^{ns}	3.426^{**}	0.025^{**}
Interaction (SL × NK)	0.254^{ns}	0.138^{ns}	0.162^{**}	0.758^{ns}	0.007^{*}
Blocks	0.233^{ns}	0.342^{ns}	0.164^{*}	1.562^{ns}	0.009^{*}
Residual	0.330	0.148	0.045	0.767	0.003
Mean	3.555	2.086	1.487	7.123	0.468
CV (%)	16.16	18.43	14.23	12.29	11.97

ns, **,* respectively non-significant, significant at $p < 0.01$, and significant at $p < 0.05$; CV= coefficient of variation.

According to the regression equation (Figure 5A), the increase in irrigation water salinity resulted in a linear reduction of 9.20% in dry mass of stem per unit increase in ECw, with a loss of 0.57 g per unit increase in ECw. Seedlings irrigated with 3.5 dS m^{-1} showed a 29.44% reduction in DMS compared to those irrigated with the lowest salinity level. The high NaCl concentrations in the root zone possibly increased the uptake of these salts in the mesophyll, decreasing the uptake of other ions, causing toxicity by specific ions, leading to the appearance of physiological and nutritional damage in the crops (XAVIER et al., 2022), and, consequently, affecting biomass production. For the same cultivar, Silva et al. (2015) observed the highest DMS of 1.25 g per plant at the salinity level of 1.3 dS m^{-1} at 190 DAE, maintaining tolerance up to the ECw of 2.2 dS m^{-1}.



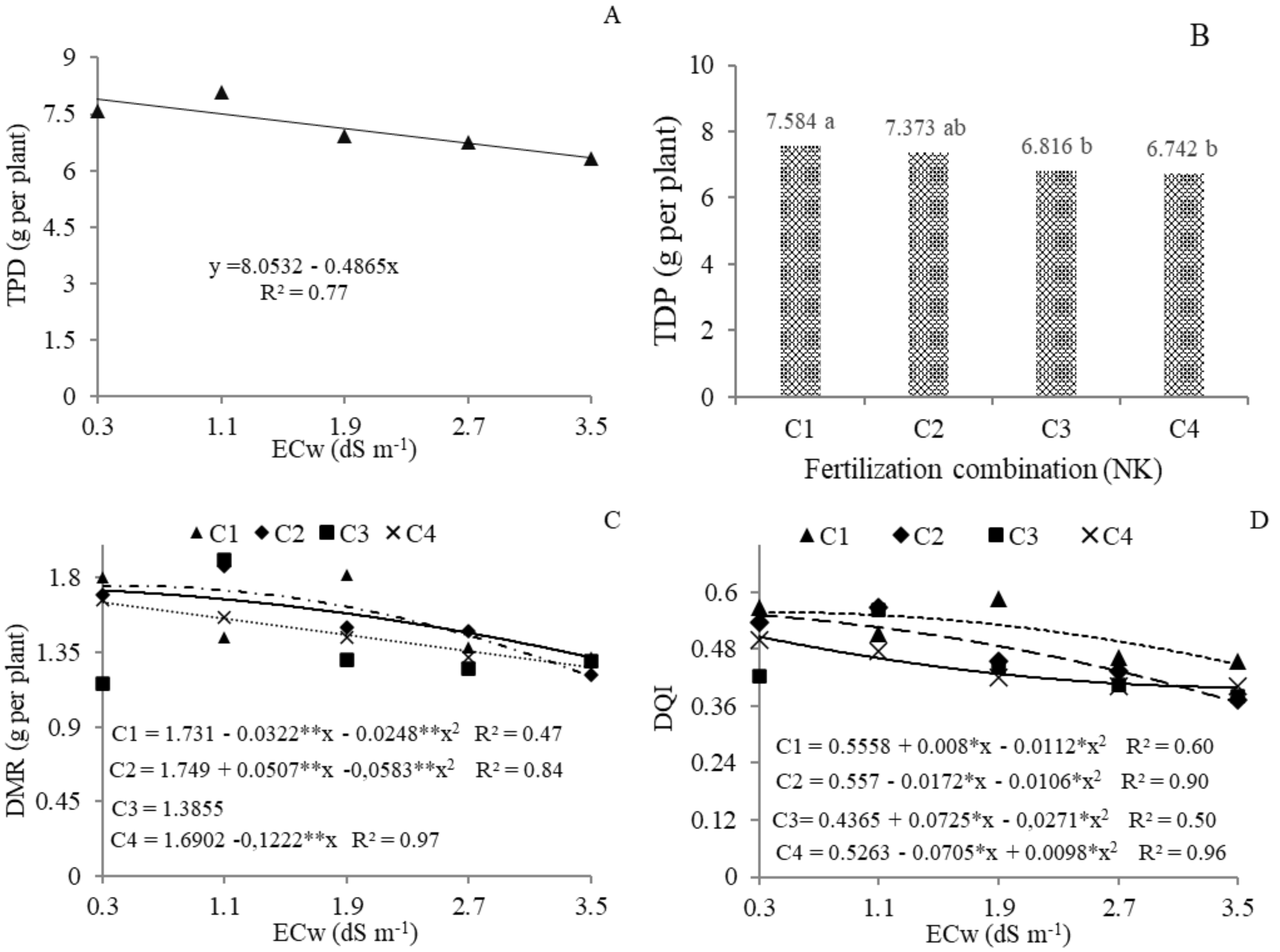
C1 = 70% N + 50% K_2O; C2 = 100% N + 75% K_2O; C3 = 130% N + 100% K_2O; C4 = 160% N + 125% K_2O. Means followed by different letters indicate a significant difference between treatments by the Tukey test ($p < 0.05$ probability level)

Figure 5. Dry mass of stem – DMS (A and B) and *dry* mass of *leaves* – DML (C) of guava seedlings irrigated with water with different salinities and nitrogen and potassium combinations at 125 days after sowing.

Figure 5B shows that the DMS was lower in plants fertilized with the C4 combination, whereas the C1 combination resulted in a higher DMS increase. The increase in the NK levels decreased the DMS, with a response that can be attributed to the sources of N fertilization used in the experiment since urea releases H^+ and may result in increased salinity in the soil saturation extract, affecting the osmotic potential close to the rhizosphere and inhibiting the uptake of water and essential nutrients (SILVA et al., 2019a).

The increase in irrigation water salinity also led to a decrease in dry mass of leaves (Figure 5C), with a linear decrease of 3.82% per unit increase in ECw, resulting in a 12.23% reduction in plants grown under the salinity of 3.5 dS m^{-1} compared to those irrigated with the lowest water salinity level (0.3 dS m^{-1}). The variation in dry mass production caused by the increase in salinity occurs because the salts inhibited biomass production and changed the partition of photoassimilates among plant parts, which is considered a response to osmotic, toxic, and nutrient effects, and the greater the potential for biomass accumulation, the greater the efficiency of the plant in transforming light energy into photoassimilates (ROQUE et al., 2022).

The increase in irrigation water salinity decreased the total dry mass. According to the regression equation (Figure 6A), there was a 6.15% decrease (0.39 g per plant) per unit increase in ECw. Seedlings irrigated with water with 3.5 dS m^{-1} showed a 19.69% decrease in TDM compared to those irrigated with the lowest salinity.



C1 = 70% N + 50% K_2O; C2 = 100% N + 75% K_2O; C3 = 130% N + 100% K_2O; C4 = 160% N + 125% K_2O. Means followed by different letters indicate a significant difference between treatments by the Tukey test ($p < 0.05$ probability level)

Figure 6. Total dry mass – TDM (A), (B) Dickson quality index –DQI (C), and dry mass of roots - DMR (D) of guava seedlings irrigated with different water salinities and combinations of nitrogen and potassium fertilization at 125 days after sowing.

Figure 5B shows that plants grown under the C1 combination (70% N + 50% K_2O) had greater total dry mass production and did not differ statistically from those subjected to C2, whereas treatments C3 and C4 led to lower values for this variable, indicating that the increase in the levels of these fertilizers may have increased the salinity index of the soil and, consequently, reduced biomass production. Silva et al. (2015) also observed that the increase in N fertilization negatively affected TDM accumulation in guava seedlings, causing a linear reduction of 15.27% per 30% increase in the N levels.

Figure 6C shows the effect of irrigation water salinity at each NK combination; the ECw increment promoted a quadratic effect on DMR when using the C1 (70% N + 50% K_2O) and C2 (100% N + 75% K_2O) combinations. In contrast, there was a linear effect for the C4 combination (160% N + 125% K_2O). The increase in salinity did not influence the DMR of plants fertilized with 130% N + 100% K_2O (C3), with a mean of 1.38 g per plant. In contrast, the DMR values of plants fertilized with the C1 combination were negatively affected by the increase in water salinity, achieving the highest value of 1.74 g per plant at the ECw of 0.3 dS m^{-1}. On the other hand, the irrigation water salinity of 3.5 dS m^{-1} decreased the DMR to the lowest value of 1.37 g per plant.

Plants fertilized with 100% N + 75% K_2O (Figure 6C) behaved similarly to those under C1, and the highest and lowest DMR values were 1.75 and 1.20 g for the salinity levels of 0.3 and 3.5 dS m^{-1}, respectively. The salinity levels obtained for an acceptable reduction of up to 10% were 2.0 dS m^{-1} for C1 and 2.2 dS m^{-1} for C2. For C4, there was a linear reduction with the increase in irrigation water salinity, decreasing by 7.39% per unit increase in ECw, with a difference of 23.64% between the DMR values of seedlings irrigated with the highest and lowest salinity levels, indicating that C4 fertilization did not sufficiently reduce salt stress in the crop. The change in the osmotic potential of the soil solution possibly contributed to reducing DMR due to the increase in irrigation water salinity, because the restriction in root growth is considered a tolerance mechanism to reduce water uptake and, consequently, salt accumulation, decreasing toxicity (DINIZ et al., 2020).

For the Dickson quality index (DQI), the effect of irrigation water salinity at each NK fertilization combination caused a quadratic behavior in all studied treatments (Figure 6D). The lowest DQI values found for the salinity of 3.5 dS m^{-1} were 0.447, 0.367, 0.358, and 0.399 for C1, C2, C3, and C4, respectively. On the other hand, the highest values were 0.557, 0.557, 0.485, and 0.526 for C1, C2, C3, and C4 at the ECw levels of 0.4, 0.3, 1.3, and 0.3, respectively. The DQI values found in the seedlings of the present study are within those considered acceptable for seedling production. Even under conditions of high ECw and regardless of the NK fertilization management applied, the seedlings obtained values above 0.2, so they are considered to be of good final quality for field establishment.

Souza et al. (2016) and Bonifácio et al. (2018) evaluated the Dickson quality index of seedlings of the guava cultivars Crioula and Paluma and observed that each unit increase in ECw decreased the DQI by 12.24 and 13.37%, respectively, while seedlings irrigated with 3.5 dS m^{-1} achieved values 0.14 (Crioula) and 0.17 (Paluma), lower than those of seedlings irrigated with the ECw of 0.3 dS m^{-1}. Even though it is an important parameter to assess the quality of seedlings, the DQI must be evaluated in conjunction with other factors, such as plant health and uniformity (SILVA et al., 2019b).

CONCLUSIONS

Nitrogen and potassium fertilizations of 70% N + 50% K_2O (C1) and 100% N + 75% K_2O (C2) promote greater growth and biomass in seedlings of the guava cv. Paluma.

Seedlings of the guava cv. Paluma can be produced with ECw of 2.1 dS m^{-1}, given the acceptable losses of up to 10% in growth, biomass, and seedling quality.

The deleterious effect of salinity is more pronounced on biomass accumulation and seedling quality for seedlings of the guava cv. Paluma.

Different combinations of nitrogen and potassium levels do not mitigate the harmful effects of salt stress due to the irrigation water on seedlings of the guava cv. Paluma.

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