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Effect of Salinity and Potassium on Phytomass and Quality of Guava Rootstocks

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Abstract

Potassium fertilization is one of the main techniques that has been studied to mitigateeffects of salt stress in plants, probably because potassium reduces the toxic effect of sodium by competitive inhibition and provides greater tolerance to genotypes of plants to salinity. Hence, this study aimed to evaluate the effect of different salinities of irrigation water in the formation of phytomass and quality of rootstocks of guava cv. Paluma, fertilized with increasing doses of potassium, in an experiment conducted using eutrophic Fluvic Neosol with sandy loam texture under greenhouse conditions, in the municipality of Pombal-PB, Brazil. The experimental design was randomized blocks in 5 × 4 factorial scheme, and the treatments resulted from the combination of five levels of irrigation water electrical conductivity (ECw = 0.3; 1.1; 1.9; 2.7 and 3.5 dS m^{-1}) and four K doses (70, 100, 130 and 160% of K), in which the dose of 100% K corresponded to 726 mg of K dm^{-3} of substrate, with four replicates and two plants evaluated in each plot. Irrigation with water salinity from 0.3 dS m^{-1} compromises the total dry matter accumulation and the Dickson quality index of guava rootstocks cv. Paluma at 225 days after emergence (DAE), independent of potassium fertilization. Fertilization with different potassium doses did not promote differences in phytomasses and quality of rootstocks. There was no significant effect of interaction (salt × doses of K) on the studied variables.

Keywords: *Psidium guajava* L., salt stress, potassium

1. Introduction

Guava (*Psidium guajava* L.) is among the fruit species of highest expression in the Brazilian agribusiness, with great potential for expansion, notably in the Northeast region, due to the favorable edaphoclimatic conditions (IBGE, 2016), and the cultivar 'Paluma' stands out as the most widespread in Brazil and preferred by the most diverse consumer markets (Ramos et al., 2010).

Despite the good adaptation of this fruit crop to Northeast Brazil, this region poses limitations involving both quantitative and qualitative aspects of water resources, especially regarding the presence of salts in the irrigation water (Souto et al., 2013). However, due to the increasing demand for food, the use lower-quality water, such as saline water, becomes necessary. Nevertheless, using this waterfor irrigation increases the contents of salts in the soil solution, causing negative effects on plants through the inhibition of germination, emergence, growth and biomass accumulation, as a consequence of the osmotic and toxic effects of ions Na^+ and Cl^- and nutritional imbalance in plant metabolism (Cavalcante et al., 2010).

It should be pointed out that the effect of water salinity on crops varies among species, genotypes, saline levels, edaphoclimatic conditions, irrigation management and fertilization (Brito et al., 2014); thereby, studies have been carried out using saline water in the Northeast region, especially on the formation of guava seedlings (Cavalcante et al., 2010; Souza, et al., 2016). However, these studies are very incipient regarding the interaction between saline levels and potassium fertilization, which highlights the importance of further research on this fruit crop in this growth stage.

Potassium has several functions in the plant, such as tissue turgidity control, activation of many enzymes involved in respiration and photosynthesis, opening and closing of stomata, carbohydrate transport, transpiration, drought resistance and salt stress (Marschner, 1995). However, under conditions of salinity, the presence of excess ions from the salts, can prevent through chemical competition the absorption of essential elements for the growth of the plant, such as potassium (Tester & Davenport, 2003), which may possibly compromise the accumulation of phytomass and quality of rootstock, as in the case of guava.

Cuartero and Muñoz (1998) report that the most direct method to reestablish normal levels of K in the plant in saline conditions would be to increase the concentration of this nutrient in the root zone up to a certain level by increasing the dose of potassium, which would possibly, cause a higher absorption of K in relation to Na, presenting lower Na/K ratios in the leaves and, consequently, a nutritional balance more adequate to the plants. Schachtman and Schroeder (1994) assumed the existence of a common K and Na uptake mechanism in higher plants, which would be regulated by the concentrations of these elements in the substrate; thus suggesting that high levels of K in the substrate could modify the uptake and transport of Na and limit the toxic damages attributed to this element under salinity conditions (Blanco et al., 2008).

Therefore, it is necessary to adopt strategies of water and soil management, such as mineral fertilizationwith potassium, to reduce the deleterious effects of high saline concentrations on plants (Sá et al., 2016), since potassium is one of the most required nutrients by guava seedlings (Franco et al., 2007), besides having an osmoregulatory function (Epstein & Bloom, 2006).

In this context, it is proposed with this work, to evaluate the effect of different levels of salinityof irrigation water in the formation of phytomass and quality of rootstocks of guava cv. Paluma, fertilized with increasing doses of potassium.

2. Materials and Methods

2.1 Experiment Localization and Treatments

The experiment was conducted from March 2015 to December 2015, in a greenhouse at the Center of Sciences and Agri-food Technology of the Federal University of Campina Grande, Campus of Pombal - PB, Brazil (6º47′03″ S; 37º49′15″ W; 193 m).

The experimental design was in randomized blocks with treatments arranged in a 5 × 4 factorial scheme, relative to five levels of irrigation water salinity (ECw = 0.3; 1.1; 1.9; 2.7 and 3.5 dS m^{-1}) associated with four doses of K fertilization [(70, 100, 130 and 160% of recommended dose of K, corresponding to 508.2, 726,943.8 and 1,161.6 mg of K dm^{-3} of substrate)]. Each plot consisted of two plantswith four replicates, totaling 80 plots (5 salinity treatments × 4 fertilization treatments × 4 replicates). Potassium dose corresponding to 100% was based on itsabsorption rate in the guava seedling formation stage determined in a hydroponic system by Franco et al. (2007).

Irrigation solutions were prepared through the addition of NaCl, $CaCl_2 \cdot 2H_2O$ and $MgCl_2 \cdot 6H_2O$ in water from the local supply system (Pombal-PB), which had electrical conductivity of 0.3 dS m^{-1}, maintaining equivalent proportions of 7:2:1 for Na:Ca:Mg, whose quantity (Q) was determined based on Richards (1954), according to Equation 1, calibrated using a portable conductivity meter. Subsequently, the solutions were stored in 200-L plastic containers to avoid evaporation and/or contamination by external agents.

$$Q \text{ (mg L}^{-1}\text{)} = 640 \times ECw \tag{1}$$

Where, Q = quantity of salts to be applied (mg L^{-1}) and ECw = desired level of water electrical conductivity (dS m^{-1}).

2.2 Plant Material and Management of the Experiment

Rootstocks were produced using as containers polyethylene plastic bags, with capacity for 1.23 dm^{-3}, perforated at the bottom to allow free drainage. The substrate was composed of soil classified as eutrophic Fluvic Neosol with sandy loam texture (EMBRAPA, 2013), fine sand and aged bovine manure at proportion of 82, 15 and 3% respectively, according to studies previously conducted by Silva et al. (2017). Its physical-chemical characteristics (Table 1) were determined according to Claessen (1997).

Table 1. Physical and chemical characteristics of the substrate used in the experiment

Textural Class	Apparent (Bulk) density	Total porosity	Organic matter	P	Exchangeable cation			
					Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}
	---- g cm^{-3} ----	------- % ------	---- g kg^{-1} ----	mg dm^{-3}	------------------ cmol$_c$ dm^{-3} --------------------			
Sandy loam	1.38	47.00	32	17	5.4	4.1	2.21	0.28

Saturation extract										
pH_{PS}	ECse	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	Cl^{-}	SO_4^{2-}	CO_3^{2-}	HCO_3^{-}	Saturation
	-- dS m^{-1} --	-- mmol$_c$ dm^{-3} --								------ % ------
7.41	1.20	2.50	3.75	4.74	3.02	7.50	3.10	0.00	5.63	27.00

Note. Ca^{2+} and Mg^{2+} extracted with KCl 1 M at pH 7.0; Na^{+} and K^{+} extracted with NH_4OAc 1 M at pH 7.0; Organic matter: determined by wet digestion Walkley-Black method; pH_{PS}: pH of saturated paste of thesubstrate; ECse: Electrical conductivity of the saturation extract of thesubstrate at 25 °C.

As the bags were filled, phosphorus (P) was incorporated to the substrate (100 mg dm^{-3}) using ground single superphosphate as P source, according to Dias et al. (2012), for the production of guava seedlings, cv. 'Paluma'.

The cultivar 'Paluma' was used in the experiment because it is a genetic material adapted to the edaphoclimatic conditions of the Brazilian Northeast region and one of the most cultivated in Brazil (Dias et al., 2012), due to the easy access to it, high yield, vigor, suitability for fresh and industrial consumption, tolerance to pests and diseases, especially rust (*Puccinia psidii* Wint.) (Oliveira et al., 2012).

'Paluma' guava seeds used for rootstock formation in the experiment were obtained from a commercial plantation in the municipality of Aparecida/PB. Plants were standardized according to the criterion of vigor, lack of pests, and sanitary health. Healthy, physiologically mature fruits with homogeneous size were harvested and washed in running water after removal of pulp and dried in the shade on paper towel for 3 days. Four seeds were equidistantly planted in polyethylene bag at 1.0 cm depth and, when plants showed on average two pairs of true leaves, thinning was performed to leave onlyonemost vigorous plant per bag.

Soil moisture was maintained close to field capacity through water balance in the substrate, irrigated using low-ECw water (0.3 dS m^{-1}), until the beginning of treatment application (40 days after seedling emergence - DAE). Irrigation wasmanually performed in the early morning (8 h) and late afternoon (17 h), and the applied water volume was determined by the drainage lysimetry method, obtained by the difference between the applied volume and the volume drained in the previous irrigation, plus a leaching fraction of 0.15 (Bernardo et al., 2006), to reduce the salinity level of the substrate saturation extract. ECw readings were taken after each irrigation event, according to the pre-established treatments, using a portable conductivity meter.

The bags had two holes at the bottom to allow drainage and plastic bottles were placed below to monitor the drained water volume and estimate water consumption by plants.

Potassium fertilization started at 40 DAE and was divided into 24 equal applications, weekly performed. Potassium nitrate - KNO_3 (14% N and 48% K) was used as K source, manually applied using a Beaker, to simulate a fertigation with ECw of 0.3 dS m^{-1}, individually in each plot, according to the treatments.

In addition, 24 nitrogen (N) fertilizations were weekly applied using urea (45% N) as source, as recommended by Dias et al. (2012) for guava rootstocks propagated by herbaceous cuttings, at dose of 773 mg of N dm^{-3} of substrate considering the N percentage of 14% supplied by the potassium nitrate.

Cultivation practices consisted of manual weeding, superficial scarification of the substrate to remove compacted layers and pruning of lateral branches, since there was no incidence of pests and/or diseases.

2.3 Variables Measured

To analyze treatment effects on the phytomass production of guava rootstocks at 225 DAE, when the plants presented a diameter suitable for grafting (above 4 mm) (Bastos & Ribeiro, 2011), plants were collected, roots were washed to remove the adhered soil and each plant was separated into leaves, stem and roots. This material was placed in previously identified paper bags and taken to the laboratory for the determination of leaf area according to Lima et al. (2012), using Equation 2. Subsequently, the material was dried in a forced-air oven at 65 ºC for 72 hours and weighed on analytical scale to determine stem dry phytomass (StDP), leaf dry phytomass (LDP), root dry phytomass (RDP) and shoot dry phytomass (ShDP) (stem + leaves), which were summed to provide the value of total dry phytomass (TDP: stem + leaves+root).

$$LA = 0.3205 \times L2.0412 \quad (2)$$

Where, LA = leaf area (cm^2) and L = leaf midrib length (cm).

In addition, root/shoot ratio (R/S) ($g\ g^{-1}$), obtained through the quotient between root dry phytomass and shoot dry phytomass, and leaf area ratio (LAR) ($cm^2\ g^{-1}$) (Benincasa, 2003), obtained through the ratio between leaf area and total dry phytomass (Equation 3), were evaluated.

$$LAR = LA/TDP \quad (3)$$

Where, LAR = leaf area ratio ($cm^2\ g^{-1}$), LA = leaf area (cm^2) and TDP = total dry phytomass (g).

Rootstock quality was measured using the Dickson quality index (DQI) for seedlings, through the formula of Dickson et al. (1960), described in Equation 4.

$$DQI = TDP/[(PH/SD) + (ShDP/RDP)] \quad (4)$$

Where, DQI = Dickson quality index, TDP = total dry phytomass (g), PH = plant height (cm), SD = stem diameter (cm), $ShDP$ = shoot dry phytomass (g) and RDP = root dry phytomass (g).

2.4 Statistical Analysis

The variables were subjected to analysis of variance by F test (0.01 and 0.05 probability levels) and, in cases of significant effect, linear and quadratic regression analyses were applied using the statistical software SISVAR-Version 5.3 (Ferreira, 2011). The regression model was selected through the best fit based on coefficient of determination (R^2) and considering a probable biological explanation for the treatments. Due to the data heterogeneity evidenced by the coefficients of variation (Tables 2 and 3), an exploratory analysis became necessary and the data were transformed to $\sqrt{x}$ for the variables leaf dry phytomass, root dry phytomass, shoot dry phytomass, total dry phytomass, root/shoot ratio, leaf area ratio and Dickson quality index.

3. Results and Discussion

According to the analysis of variance summary (Table 2), the levels of irrigation water salinity had significant effect ($p \leq 0.01$) on the dry phytomass of stem (StDP), leaves (LDP), shoots (ShDP) and roots (RDP) at 225 DAE. For K doses, significant effect ($p \leq 0.05$) occurred only on stem dry phytomass. There was no significant interaction between the factors salinity levels and K doses (S × KD) for any of the studied variables.

Various authors report that K^+ is the main nutrient related to osmotic functions of plants and have observed a better performance of some genotypes under conditions of salt stress, associated with adequate potassium nutrition (Blanco et al., 2008; Gurgel et al., 2010; Parveen et al., 2016). However, Gurgel et al. (2010) argue that increasing the proportion of K^+ in saline medium does not always result in beneficial effects for plants; and may offer a non-significant effect with increased K doses, as verified in the present study. Such phenomena may be related to the use of low doses that do not contribute to the decrease of the Na^+/K^+ ratio in the leaves.

Table 2. Analysis of variance summary for dry phytomass of stem (StDP), leaves (LDP), shoots (ShDP) and roots (RDP) of guava rootstocks, cv. 'Paluma', at 225 DAE under irrigation with waters of different saline levels and potassium fertilization

Source of variation	FD	Mean Square			
		StDP	LDP	ShDP	RDP
Salinitylevels (S)	4	6.78^{**}	7.26^{**}	26.41^{**}	1.66^{**}
Linear regression	1	23.39^{**}	16.76^{**}	80.27^{**}	6.24^{**}
Quadratic regression	1	1.74^{ns}	9.19^{*}	19.17^{*}	0.03^{ns}
Potassium doses (KD)	3	1.45^{*}	0.84^{ns}	4.27^{ns}	0.39^{ns}
Linear regression	1	3.60^{*}	1.44^{ns}	9.77^{ns}	0.16^{ns}
Quadratic regression	1	0.48^{ns}	0.00^{ns}	0.60^{ns}	0.00^{ns}
Interaction (S*KD)	12	0.67^{ns}	0.83^{ns}	1.82^{ns}	0.15^{ns}
Blocks	3	1.77^{*}	4.99^{*}	9.35^{*}	0.57^{*}
CV (%)		20.16	28.96	14.53	16.15

Note. ns = non-significant; ** and * = significant at 0.01 and 0.05 probability levels ($p \leq 0.01$ and $p \leq 0.05$); FD = Freedom degree; CV = coefficient of variation.

Increasing levels of irrigation water salinity negatively affected stem dry phytomass and, according to the regression equation (Figure 1A), the data fitted best to a linear model, with StDP reductions of 9.17% per unit increase of ECw. At 225 DAE, plants irrigated using 3.5 dS m^{-1} water showed reduction of 29.35% in StDP (1.50 g per plant) in comparison to those under irrigation with 0.3 dS m^{-1} water.

Reductions in guava StDP caused by salt stress were found by Souza et al. (2016), who evaluated the formation of 'Crioula' guava rootstock under irrigation with saline water (ECw from 0.3 and 3.5 dS m^{-1}) and nitrogen fertilization (ND = 541, 773, 1005 and 1237 mg of N dm^{-3} of substrate), and observed reduction of 7.6% per unit increase in irrigation water electrical conductivity.

Dry phytomass of leaf showed a quadratic response as water salinity increased, considering mean values, plants irrigated using water with ECw of 1.3 dS m^{-1}, attained highest value, corresponding to 2.96 g $plant^{-1}$ (Figure 1B). It assumes that the plants acquired adaptation to salinity up to this level of electrical conductivity of to avoid greater loss of water by transpiration, creating mechanisms of acclimatization such as wax accumulation on the leaf surface and increase in the number of layers of paliçadic and spongy cells in leaf mesophyll, thus increasing leaf biomass, as reported by Silva et al. (2017), in a study evaluating the effect of salinity on Paluma guava rootstocks under nitrogen fertilization.

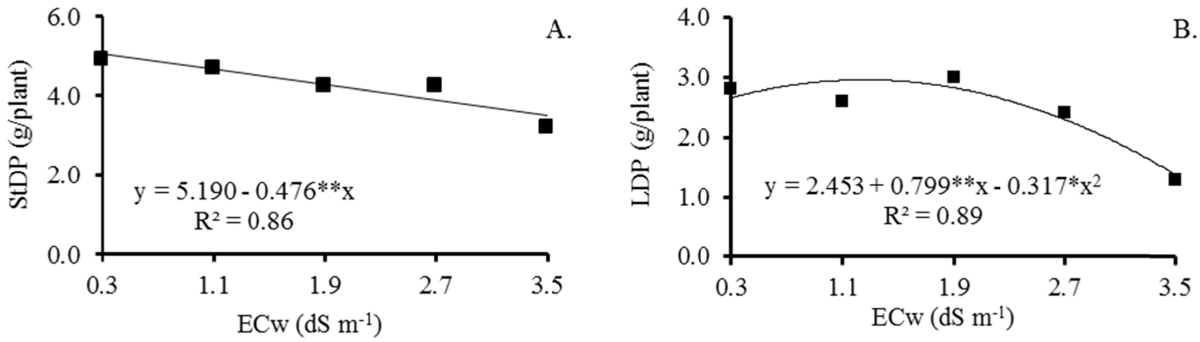

Figure 1. Stem dry phytomass - StDP (A) and leaf dry phytomass - LDP (B) of guava rootstocks, cv. 'Paluma', as a function of irrigation water electrical conductivity - ECw at 225 DAE

Note. **, and * = significant at 0.01 and 0.05 probability levels ($p \leq 0.01$ and $p \leq 0.05$).

According to the regression equation (Figure 2A), ShDP exhibited a quadratic effect due to the increment in irrigation water salinity. Its values increased up to the ECw of 0.9 dS m^{-1} (7.72 g), similar to LDP (Figure 1B), which may be the main cause of this effect, above ECw of 0.9 dS m^{-1} a decrease was observed (Figure 2A). This reduction in ShDP can be attributed to the lower number of leaves, leaf area and lower stem biomass of the plants, being such salinity effects reported by Souza et al. (2016) in guava rootstocks of the Crioula genotype.

The mean value of dry phytomass of roots decreased with the increase of water salinity levels, and reduction with per unit increase of ECw was 12.51%, representing a decrease of 40.04% (0.76 g per plant) in plants irrigated using 3.5 dS m^{-1} water in comparison to those under ECw of 0.3 dS m^{-1} (Figure 2B). This reduction in guava RDP, as water salinity increased was similar to that reported by Gurgel et al. (2007), being attributed to the osmotic and ionic effects caused by salinity.

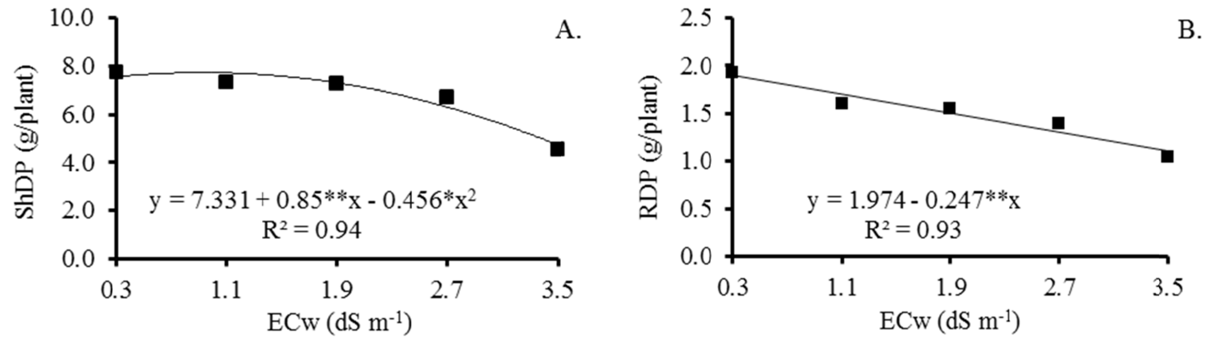

Figure 2. Shoot dry phytomass - ShDP (A) and root dry phytomass - RDP (B) of guava rootstocks, cv. 'Paluma', as a function of irrigation water electrical conductivity - ECw at 225 DAE

Note. **, and * = significant at 0.01 and 0.05 probability levels ($p \leq 0.01$ and $p \leq 0.05$).

Increments in K doses negatively affected StDP at 225 DAE and the data fitted best to a linear regression equation (Figure 3), showing reductions of 3.59% for every 30% increase in K dose, which resulted in losses of 10.77% (0.5 g per plant) in plants fertilized with the 160% K dose compared with those fertilized with 70% K. Although studies have reported that adequate potassium fertilization may mitigate the effects of salt stress on plant genotypes (Blanco et al., 2008; Parveen et al., 2016), the results of the present study (Figure 3) show that under saline stress , an increase in the dose of potassium affects the accumulation of phytomass in guava plants, and can be attributed to the intensification of soil salinity by the use of potassium fertilizer.Gurgel et al. (2010) state that in a medium containing NaCl, salinity provoked by high K^+ concentrations may be even more damaging to plant growth than that caused by high Na^+ concentrations.

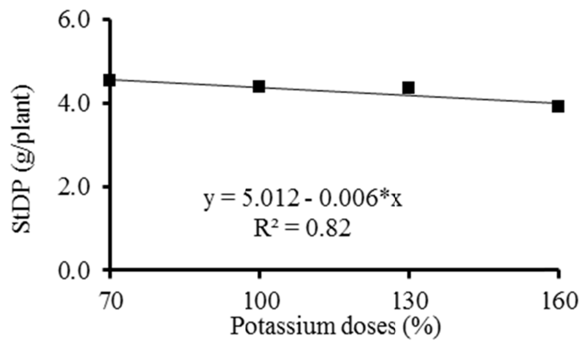

Figure 3. Stem dry phytomass - StDP of guava rootstocks, cv. 'Paluma', as a function of potassium doses at 225 DAE

Note. * = significant at 0.05 probability levels ($p \leq 0.05$).

According to the analysis of variance summary (Table 3), the levels of irrigation water salinity had significant effect on total dry phytomass ($p \leq 0.01$), root/shoot ratio ($p < 0.05$), leaf area ratio ($p \leq 0.05$) and Dickson quality index ($p \leq 0.01$). However, K doses and the interaction between factors (S × KD) had no significant influence on any of the studied variables, and may be explained on the same explanation attributed to Table 1.

Table 3. Analysis of variance summary for total dry phytomass (TDP), root/shoot ratio (R/S), leaf area ratio (LAR) and Dickson quality index (DQI) of guava rootstocks, cv. 'Paluma', at 225 DAE as a function of different levels of irrigation water salinity and potassium doses

Source of variation	FD	Mean Square			
		TDP	R/S	LAR	DQI
Salinitylevels (S)	4	40.19^{**}	0.004^{*}	955.33^{*}	0.14^{**}
Linear regression	1	130.64^{**}	0.01^{*}	102.30^{ns}	0.54^{**}
Quadratic regression	1	20.58^{*}	0.00^{ns}	3333.03^{**}	0.00^{ns}
Potassium doses (KD)	3	6.48^{ns}	0.01^{ns}	43.23^{ns}	0.01^{ns}
Linear regression	1	12.32^{ns}	0.01^{ns}	126.41^{ns}	0.02^{ns}
Quadratic regression	1	0.57^{ns}	0.00^{ns}	1.65^{ns}	0.00^{ns}
Interaction (S*KD)	12	2.09^{ns}	0.01^{ns}	271.36^{ns}	0.00^{ns}
Blocks	3	10.47^{*}	0.02^{**}	642.90^{ns}	0.03^{ns}
CV (%)		13.58	15.34	23.55	14.63

Note. ns = non-significant; ** and * = significant at 0.01 and 0.05 probability levels ($p \leq 0.01$ and $p \leq 0.05$); FD = Freedom degree; CV = coefficient of variation.

Irrigation water salinity negatively affected the total dry phytomass of the 'Paluma' guava rootstocks at 225 DAE. The linear model (Figure 4A) evidenced reductions of 10.88% per unit increase in irrigation water salinity, i.e., TDP reduction of 34.81% (3.5 g per plant) in plants irrigated with 3.5 dS m^{-1} water, in comparison to those subjected to irrigation with the lowest salinity level (ECw = 0.3 dS m^{-1}). Similar effects on the TDP of guava rootstocks, cv. Ogawa, irrigated using water of different salinity levels (ECw: 0.5, 1.5, 2.5, 3.5 and 4.5 dS m^{-1}) at 80 days after emergence, were observed by Gurgel et al. (2007).

The reduction of TDP accumulation results from decreases in phytomass of root and part of plants, being related to several effects of salinity, such as reduction in water availability for the plant, which decreases rate of cell elongation and division, and excessive accumulation of (Na^+ and Cl^-), leading to physiological disturbances, such as stomatal opening, rate of assimilation of CO_2 and transpiration, as well as causing nutritional imbalance in the plants (Apse & Blumwald, 2007; Willadino & Camara, 2010). Similar effects were reported by Gurgel et al. (2007), Silva et al. (2015, 2017), and Sá et al. (2016) in the production of guava rootstocks Ogawa and Paluma.

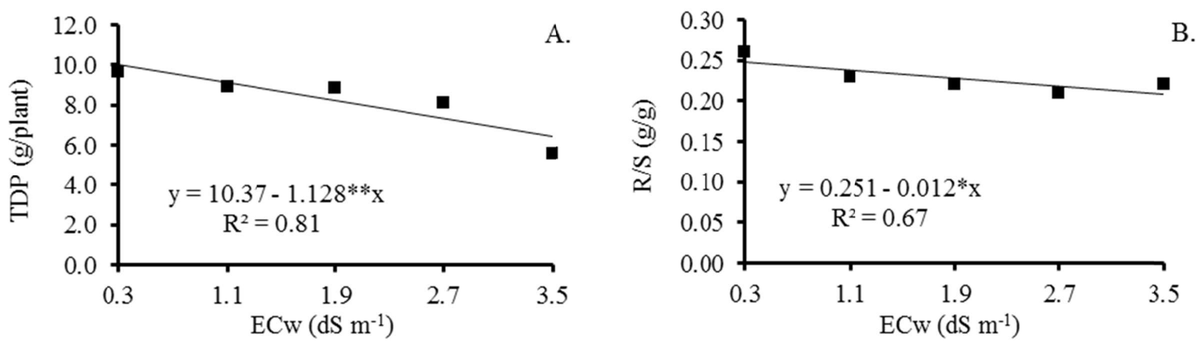

Figure 4. Total dry phytomass - TDP (A) and root/shoot ratio - R/S (B) of guava rootstocks, cv. 'Paluma', as a function of irrigation water electrical conductivity - ECw at 225 DAE

Note. **, and * = significant at 0.01 and 0.05 probability levels ($p \leq 0.01$ and $p \leq 0.05$).

Regarding leaf area ratio (Figure 5A), the data fitted to a quadratic model and the 'Paluma' guava rootstocks showed increasing values at 225 DAE up to the ECw level of 2.0 dS m^{-1}, reaching maximum LAR of 50.08 cm^2 g^{-1}. Leaf area ratio represents the leaf area per unit of mass produced in the plant (Magalhães et al., 2007). This result shows that from the ECw of 2.0 dS m^{-1}, there was a decrease in leaf area in order to reduce water losses due to transpiration, in relation to the phytomass accumulation in the plant. In addition, it is possible that there was a higher accumulation of organic compounds to achieve the osmotic adjustment, resulting in a greater accumulation of phytomass in the plant in relation to the leaf area from this salinity level, culminating in decreases in LAR (Figure 5A). Normally, these phenomena occur under saline conditions, being known as mechanisms of acclimatization of plants to saline stress (Willadino & Camara, 2010).

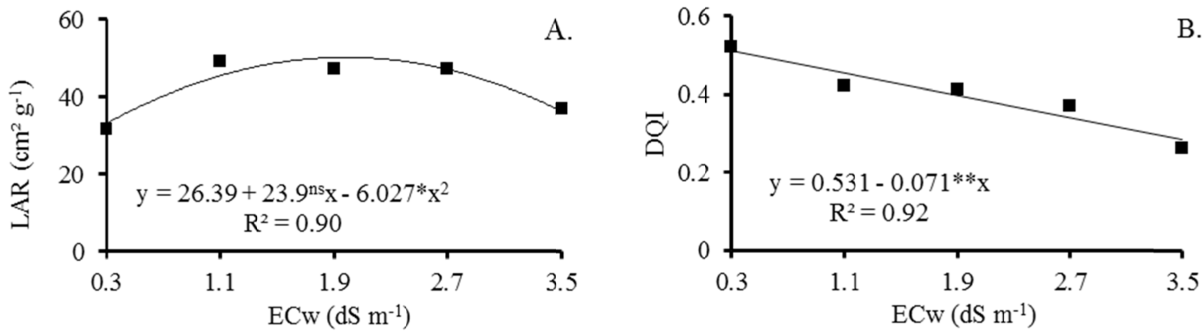

Figure 5. Leaf area ratio - LAR (A) and Dickson quality index - DQI (B) of guava rootstocks, cv. 'Paluma', as a function of irrigation water electrical conductivity - ECw at 225 DAE

Note. ns, **, and * = non-significant, significant at 0.01 and 0.05 probability levels ($p \leq 0.01$ and $p \leq 0.05$).

The Dickson quality index (DQI) of the 'Paluma' guava rootstocks at 225 DAE (Figure 5B) decreased with the increment in water salinity, showing reductions of 13.37% per unit increase in ECw and 34.81% (0.17) in plants irrigated with 3.5 dS m^{-1} water in comparison to those subjected to ECw = 0.3 dS m^{-1}. Similar results were obtained by Souza et al. (2016), who studied the effects of water salinity on the quality of 'Crioula' guava rootstocks and observed reductions of 12.24% per unit increase in ECw and 39.16% in plants irrigated with 3.5 dS m^{-1} water, compared with those subjected to ECw = 0.3 dS m^{-1}.

The quality index of Dickson becomes an important factor in the determination of the quality of seedlings, since it weighs the results of several morphological parameters used for quality evaluation, such as aerial parts, root and total dry mass, besides height of plant and diameter of the colon (Gomes et al., 2003). Dias et al. (2012) state that the higher the value of this index, the greater the seedling robustness and the biomass distribution, assigning greater seedling resistance to transplanting and the ability to survive in the field. In this case, it can be stated in practical terms that the increase in salinity of irrigation water decreases the quality of guava rootstocks (Figure 5B) and, consequently, may compromise the grafting of grafted seedlings after transplanting to the field. Fact related to the osmotic, toxic and nutritional effects of the irrigation water salts on the accumulation and distribution of phytomass between root and shoot in the plant during the formation of the rootstock.

4. Conclusions

Irrigation with water from 0.3 dS m^{-1}salinity compromises the total dry matter accumulation and the Dickson quality index of guava rootstocks cv. Paluma at 225 days after emergence, independent of potassium fertilization.

Fertilization with potassium doses did not promote differences in phytomass and quality of rootstocks, except dry stem phytomass, which was negatively affected by the increase of the potassium dose from 508.2 mg K dm^{-3} of substrate.

There was no significant interaction (water salinity × doses of K) on the studied variables, possibly due to the increase of the potassium doses were not enough to cause decreases in the Na/K ratio in the leaves.

References

Apse, M. P., & Blumwald, E. (2007). Na^+ transport in plants. *FEBS Letters, 581*(12), 2247-54. https://doi.org/10.1016/j.febslet.2007.04.014

Bastos, D. C., & Ribeiro, J. M. (2011). *Produção de mudas de goiabeira* (Technical Communication, 148). Petrolina: EMBRAPA. Retrieved from https://ainfo.cnptia.embrapa.br/digital/bitstream/item/54791/1/COT148.pdf

Benincasa, M. M. P. (2003). *Análise de crescimento de plantas, noções básicas* (2nd ed.). Jaboticabal: Funep.

Bernardo, S., Soares, A. A., & Mantovani, E. C. (2006). *Manual de irrigação* (8th ed.). Viçosa, MG: UFV.

Blanco, F. F., Folegatti, M. V., & Henriques Neto, D. (2008). Doses de N e K no tomateiro sob estresse salino: I. Concentração de nutrientes no solo e na planta. *Revista Brasileira de Engenharia Agrícola e Ambiental, 12*(1), 26-33. https://doi.org/10.1590/S1415-43662008000100004

Brito, M. E. B., Fernandes, P. D., Gheyi, H. R., Melo, A. S., Soares Filho, W. S., & Santos, R. T. (2014). Sensibilidade à salinidade de híbridos trifoliados e outros porta-enxertos de citros. *Revista Caatinga, 27*(1), 17-27. Retrieved from https://periodicos.ufersa.edu.br/index.php/caatinga/article/view/2610/pdf_82

Cavalcante, L. F., Vieira, M. S., Santos, A. F., Oliveira, W. M., & Nascimento, J. A. M. (2010). Água salina e esterco bovino líquido na formação de mudas de goiabeira cultivar Paluma. *Revista Brasileira de Fruticultura, 32*(1), 251-261. https://doi.org/10.1590/S0100-29452010005000037

Claessen, M. E. C. (1997). *Manual de métodos de análise de solo* (2nd ed.). Rio de Janeiro, RJ: Embrapa CNPS.

Cuartero, J., & Muñoz, R. F. (1998). Tomato and salinity. *Scientia Horticulturae, 78*(1/4), 83-125. https://doi.org/10.1016/S0304-4238(98)00191-5

Dias, M. J. T., Sousa, H. A., Natale, W., Modesto. V. C., & Rozane, D. E. (2012). Adubação com nitrogênio e potássio em mudas de goiabeira em viveiro comercial. *Semina: Ciências Agrárias, 33*(S1), 2837-2848. https://doi.org/10.5433/1679-0359.2012v33Supl1p2837

Dickson, A., Leaf, A. L., & Hosner, J. F. (1960). Quality appraisal of white spruce and white pine seedling stock in nurseries. *The Forest Chronicle, 36*(1), 10-13. https://doi.org/10.5558/tfc36010-1

EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária). (2013). *Sistema brasileiro de classificação de solos* (3rd ed.). Rio de Janeiro, RJ: Embrapa-SPI.

Epstein, E., & Bloom, A. J. (2006). *Nutrição mineral de plantas: Princípios e perspectivas* (2nd ed.). Londrina, PR: Editora Planta.

Ferreira, D. F. (2011). Sisvar: A computer statistical analysis system. *Ciência e Agrotecnologia, 35*(6), 1039-1042. https://doi.org/10.1590/S1413-70542011000600001

Franco, F. C., Prado, R. M., Brachirolli, L. F., & Rozane, D. E. (2007). Curva de crescimento e marcha de absorção de macronutrientes em mudas de goiabeira. *Revista Brasileira de Ciência do Solo, 31*(6), 1429-1437. https://doi.org/10.1590/S0100-06832007000600020

Gomes, J. M., Couto, L., Leite, H. G., Xavier, A., & Garcia, S. L. R. (2003). Crescimento de mudas de *Eucalyptus grandis* em diferentes tamanhos de tubetes e fertilização N-P-K. *Revista Árvore, 27*(2), 113-127. https://doi.org/10.1590/S0100-67622003000200001

Gurgel, M. T., Gheyi, H. R., Fernandes, P. D., Santos, F. J. S., & Nobre, R. G. (2007). Crescimento inicial de porta-enxertos de goiabeira irrigados com águas salinas. *Revista Caatinga, 20*(2), 24-31. https://doi.org/10.1590/S1415-43662010000100001

Gurgel, M. T., Uyeda, C. A., Gheyi, H. R., Oliveira, F. H. T., Fernandes, P. D., & Silva, F. V. (2010). Crescimento de meloeiro sob estresse salino e doses de potássio. *Revista Brasileira de Engenharia Agrícola e Ambiental, 14*(1), 3-10. Retrieved from http://www.scielo.br/pdf/rbeaa/v14n1/v14n01a01.pdf

IBGE (Instituto Brasileiro de Geografia e Estatística). (2016). *Sidra - Produção Agrícola Municipal*. Retrieved December 30, 2016, from http://www.sidra.ibge.gov.br

Lima, L. G. S., Andrade, A. C., Silva, R. T. L., Fronza, D., & Nishijima, T. (2012). Modelos matemáticos para estimativa de área foliar de goiabeira (*Psidium guajava* L.). *64ª Reunião Anual da SBPC*. São Luiz, Maranhão: UFMA. Retrieved from http://www.sbpcnet.org.br/livro/64ra/resumos/resumos/3478.htm

Magalhães, P. C., Durães F. O. M., & Rodrigues, J. A. S. (2007). Ecofisiologia. In J. A. S. Rodrigues (Ed.), *Cultivo do sorgo* (5th ed., p. 30). Sete Lagoas, MG: Embrapa Milho e Sorgo.

Marschener, H. (1995). *Mineral nutition of higher plants* (2nd ed.). London: Academic Press. https://doi.org/10.1016/B978-012473542-2/50016-X

Oliveira, I. P., Oliveira, L. C., Moura, C. S. F. T., Lima Junior, A. F., & Rosa, S. R. A. (2012). Cultivo da goiabeira: Do plantio ao manejo. *Revista Faculdade Montes Belos, 5*(4), 137-156. Retrieved from http://revista.fmb.edu.br/index.php/fmb/article/download/92/88

Parveen, Anwar-ul-Haq, M., Akhtar, J., & Basra, S. M. A. (2016). Interactive effect of salinity and potassium on growth, biochemical parameters, protein and oil quality of soybean genotypes. *Pakistan Journal of Agricultural Sciences, 53*(1), 69-78. https://doi.org/10.21162/PAKJAS/16.4755

Ramos, D. P., Silva, A. C., Leonel, S., Costa, S. M., & Damatto Júnior, E. R. (2010). Produção e qualidade de frutos da goiabeira 'Paluma', submetida à diferentes épocas de poda em clima subtropical. *Revista Ceres, Viçosa, 57*(5), 659-664. https://doi.org/10.1590/S0034-737X2010000500015

Richards, L. A. (1954). *Diagnosis and improvement of saline and alkali soils*. Washington, USA: Salinity Laboratory.

Sá, F. V. S., Nobre, R. G., Silva, L. A., Moreira, C. L., Paiva, E. P., & Oliveira, F. A. (2016). Tolerância de porta-enxertos de goiabeira ao estresse salino. *Revista Brasileira de Engenharia Agrícola e Ambiental, 20*(12), 1072-1077. https://doi.org/10.1590/1807-1929/agriambi.v20n12p1072-1077

Schachtman, D. P., & Schroeder, J. I. (1994). Structure and transport mechanism of a high-affinity potassium uptake transporter from higher plants. *Nature, 370*(6491), 655-658. https://doi.org/10.1038/370655a0

Silva, E. M., Nobre, R. G., Lima, G. S., Gheyi, H. R., Sousa, L. P., Barbosa, J. L., … Pimenta, T. A. (2017). Biomass and rootstock quality of guava (*Psidium guajava* L.) saline water irrigated under nitrogen fertilization. *Journal of Agricultural Science, 9*(11), 162-171. https://doi.org/10.5539/jas.v9n11p162

Silva, E. M., Nobre, R. G., Souza, L. P., Abrantes, D. S., &Andrade, A. B. A. (2015). Efeito da adubação nitrogenada na formação de mudas de goiabeira irrigadas com águas salinizadas. *Revista Verde de Agroecologia e Desenvolvimento Sustentável, 10*(4), 42-48. https://doi.org/10.18378/rvads.v10i4.3735

Souto, A. G. L., Cavalcante, L. F., Nascimento, J. A. M., Mesquita, F. O., & Lima Neto, A. J. (2013). Comportamento do noni à salinidade da água de irrigação em solo com biofertilizante bovino. *Irriga, 18*(3), 442-453. https://doi.org/10.15809/irriga.2013v18n3p442

Souza, L. P., Nobre, R. G., Silva, E. M., Lima, G. S., Pinheiro, F. W. A., & Almeida, L. L. S. (2016). Formation of 'Crioula' guava rootstock under saline water irrigation and nitrogen doses. *Revista Brasileira de Engenharia Agrícola e Ambiental, 20*(8), 739-745. https://doi.org/10.1590/1807-1929/agriambi.v20n8p739-745

Tester, M., & Davenport, R. (2003). Na^+ tolerance and Na^+ transport in higher plants. *Annals of Botany, 91*(5), 503-27. https://doi.org/10.1093/aob/mcg058

Willadino, L., & Camara, T. R. (2010). Tolerância das plantas à salinidade: Aspectos fisológicos e bioquímicos. *Enciclopédia Biosfera, 6*(11), 1-23. Retrieved from http://www.conhecer.org.br/enciclop/2010c/tolerancia%20das%20plantas.pdf