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Formation of 'Crioula' guava rootstock under saline water irrigation and nitrogen doses

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Key words:
Psidium guajava L.
water electrical conductivity
nitrogen

A B S T R A C T

The objective of this research was to evaluate the growth and formation of fresh and dry weight of 'Crioula' guava rootstock irrigated with waters of different saline levels and nitrogen (N) doses, in an experiment conducted in plastic tubes under greenhouse conditions. The experimental design was randomized blocks, in a 5 x 4 factorial scheme with four replicates, and the treatments consisted of five levels of water electrical conductivity - ECw (0.3, 1.1, 1.9, 2.7 and 3.5 dS m^{-1}) and four N doses (70, 100, 130 and 160% of the N dose recommended for the cultivation of guava seedlings, cv. 'Paluma'). The dose referring to 100% corresponds to 773 mg of N dm^{-3}. The highest growth of 'Crioula' guava rootstock was obtained with ECw of 0.3 dS m^{-1} and fertilization of 541.1 mg N dm^{-3} of soil; increasing N doses did not reduce the deleterious effect of the salt stress on the growth and phytomass formation of 'Crioula' guava rootstock; irrigation with water of up to 1.75 dS m^{-1}, in the production of guava rootstocks, promotes acceptable reduction of 10% in growth and quality of the seedlings.

Palavras-chave:
Psidium guajava L.
condutividade elétrica da água
nitrogênio

Formação de porta-enxerto de goiabeira 'Crioula' sob irrigação com águas salinizadas e adubação nitrogenada

R E S U M O

Objetivou-se, com esta pesquisa, avaliar a formação de porta-enxerto de goiabeira 'Crioula' irrigada com águas de distintos níveis de salinidade e doses de nitrogênio, em experimento conduzido em tubetes sob condições de ambiente protegido. Utilizou-se o delineamento experimental de blocos casualizados, em esquema fatorial 5 x 4, com quatro repetições, sendo os tratamentos compostos de cinco níveis de condutividade elétrica da água – CEa (0,3; 1,1; 1,9; 2,7 e 3,5 dS m^{-1}) e quatro doses de nitrogênio (70, 100, 130 e 160% de N da dose recomendada para cultivo de mudas de goiabeira cv. Paluma). Sendo a dose referente a 100% correspondente a 773 mg de N dm^{-1}. O maior crescimento de porta-enxerto de goiabeira 'Crioula' foi obtido com água de condutividade elétrica de 0,3 dS m^{-1} e adubação com 541,1 mg de N dm^{-3} de solo; doses crescentes de nitrogênio não reduziram o efeito deletério do estresse salino sobre o crescimento e a formação de fitomassa de porta-enxerto de goiabeira cv. Crioula; a irrigação com água de até 1,75 dS m^{-1}, na produção de porta-enxerto de goiabeira, promove redução aceitável de 10% no crescimento e na qualidade de mudas.

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Introduction

Guava (*Psidium guajava* L.), belonging to the Myrtaceae family, native to tropical American regions, is naturally distributed over the entire Brazilian territory, where it produces fruits of high nutritive value and great acceptance in the market, for both fresh consumption and agro-industrial activities, which use it for the processing of various products (Oliveira et al., 2015).

The occurrence of long periods of drought and annual irregularity of rainfalls in the Brazilian semiarid region makes the practice of irrigation indispensable to guarantee agricultural production with safety (Lima et al., 2014). However, it is common in the region the use of water sources with high concentration of salts, especially sodium, leading to negative effects on soils and crops (Neves et al., 2009).

The utilization of water with excess of salts in irrigation can limit agricultural production, due to the reduction in the osmotic potential, toxicity of specific ions and nutritional imbalance, besides other indirect effects resulting from physical and chemical alterations in the soil (Khan & Panda, 2008). Plant tolerance to salinity varies depending on species, cultivars of a same species and factors such as type and concentration of salts, period of exposure, phenological stage, as well as their interaction (Neves et al., 2008).

Thus, the use of saline waters in agriculture becomes conditioned to the tolerance of crops to salinity and the management of practices such as irrigation and fertilization. Among the main technologies used to increase crop yield, the nutritional supply of nitrogen (N) stands out (Marinho et al., 2010), because this element participates in the formation of proteins, amino acids and chlorophyll, among other molecules that are important in plant metabolism (Flores et al., 2001). Furthermore, N accumulation in plant tissues is an important factor in the regulation of the carbon flow towards a more intense synthesis of proteins (high N content) or carbohydrates (low N content) (Lawlor, 2002).

Therefore, this study aimed to evaluate the formation of 'Crioula' guava rootstocks irrigated with waters of different saline levels and N doses.

Material and Methods

The study was carried out in 2014 in a protected environment (greenhouse) at the Center of Sciences and Agri-food Technology of the Federal University of Campina Grande (CCTA/UFCG), Campus of Pombal, PB, Brazil (6º 48'16" S; 37º 49'15" W; 144 m).

The experimental design was completely randomized blocks, in a 5 x 4 factorial scheme with four replicates, and the treatments consisted of different levels of electrical conductivity of the irrigation water (EC_w), applied manually and daily, based on drainage lysimetry (0.3, 1.1, 1.9, 2.7 and 3.5 dS m^{-1}), associated with N fertilization doses (70, 100, 130 and 160% of N). The dose referring to 100% corresponds to 773 mg of N dm^{-3} (Dias et al., 2012).

Waters of different saline levels were obtained using freshwater from the water supply system (EC_w of 0.3 dS m^{-1}) mixed with sodium chloride (NaCl), calcium chloride ($CaCl_2.2H_2O$) and magnesium chloride ($MgCl_2.6H_2O$), at the proportion of 7:2:1, a ratio that prevails in the main water sources available for irrigation in the Brazilian northeast region (Medeiros, 1992), according to the relationship between EC_w and the concentration of salts ($mmol_c$ L^{-1} = EC x 10) (Rhoades et al., 2000).

'Crioula' guava was used, because it is a rustic genetic material with easy propagation, tolerance to pests and diseases, especially guava rust (*Puccinia psidii Wint.*) and for being one of the most cultivated in the Brazilian northeast region (Oliveira et al., 2012).

The experiment was conducted using 288-cm^3 plastic tubes (19 x 6.3 cm), with an opening at the bottom to allow free drainage. The containers were arranged on trays with capacity for 54 tubes, supported by metal workbenches (angle brackets), at a height of 0.8 m from the soil.

The tubes were filled with substrate composed of Fluvic Neosol + sand + aged bovine manure, at the proportions of 82, 15 and 3%, respectively, and its physical and chemical characteristics (Table 1) were determined according to Claessen (1997) and analyzed at the Soil and Plant Laboratory of the CCTA/UFCG.

Sowing was performed by planting four seeds per tube at a depth of 1.0 cm. After germination and after plants showed two pairs of fully expanded true leaves, thinning was performed and only the most vigorous plantlet was left in each tube. In addition, other cultural tracts were performed, such as manual weedings and superficial scarification of the substrate.

Treatment application began 25 days after emergence (DAE). Irrigations with saline waters were performed, according to the treatment, based on plant water demand, through the process of drainage lysimetry, and the volume retained in the tube was daily applied in order to maintain the soil at field capacity, determined by the difference between the applied volume and the volume drained in the previous irrigation. Irrigations were performed twice a day, in the early morning and late afternoon. Every 15 days, a leaching fraction of 15% was applied, based on the volume applied in this period, in order to reduce the salinity of the saturation extract of the substrate.

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

Textural classification	Apparent density kg dm^{-3}	Total porosity %	Organic matter g kg^{-1}	P mg dm^{-3}	Sorption complex ($cmol_c$ dm^{-3})			
					Ca^{2+}	Mg^{2+}	Na^+	K^+
Sandy loam	1.38	47.00	32	17	5.4	4.1	2.21	0.28

Saturation extract

pH_{se}	EC_{se} dS m^{-1}	Ca^{2+}	Mg^{2+}	K^+	Na^+	Cl^-	SO_4^{2-}	CO_3^{2-}	HCO_3^-	Saturation %
		$mmol_c$ L^{-1}								
7.41	1.21	2.50	3.75	4.74	3.02	7.50	3.10	0.00	5.63	27.00

pH_{se} – pH of the saturation extract of the substrate; EC_{se} – Electrical conductivity of the saturation extract of the substrate at 25 °C

N fertilization began at 25 DAE and was divided into 14 equal applications, weekly performed using urea (45% of N) as the N source, through fertigation with water of 0.3 dS m^{-1} for all treatments.

'Crioula' guava rootstock growth was evaluated at 190 DAE, based on stem diameter (SD), number of leaves (NL) and leaf area (LA), while phytomass accumulation was measured through the variables stem fresh phytomass (SFP) and leaf fresh phytomass (LFP). Additionally, stem dry phytomass (SDP), leaf dry phytomass (LDP), root dry phytomass (RDP) and total dry phytomass (TDP) were also quantified.

Stem diameter was measured at a height of 5 cm from the base of the plant. The number of leaves was determined based on a simple count, considering leaves with fully opened leaf blades. Leaf area was obtained according to the equation used by Lima et al. (2012)

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

where:

LA - leaf area, cm^2; and,

L - midrib length, cm.

For the determination of phytomass accumulation, the stem of each plant was cut close to the soil and the plants were separated into stem and leaves, and immediately weighed on a precision scale (0.001 g), for the determination of stem and leaf fresh phytomass. After weighing the fresh masses, the different plant parts (leaves, stem and roots) were separately placed in properly identified paper bags and dried in a forced-air oven at 65 °C until constant weight, for the determination of LDP, SDP and RDP, whose sum resulted in the TDP.

The data were evaluated through analysis of variance by F test at 0.05 and 0.01 probability levels and, in cases of significance, linear and quadratic polynomial regressions were applied using the statistical program SISVAR (Ferreira, 2011).

Results and Discussion

According to the summary of the analysis of variance (Table 2), there was significant effect of the levels of irrigation water salinity on the stem diameter (mm) of the rootstocks. For the factor N fertilization, there was significant difference for stem diameter, number of leaves and leaf area (cm^2). There was no significant interaction between irrigation water salinity and N doses (S x ND) for any of the studied variables.

Table 2. Summary of the analysis of variance for stem diameter (SD) (mm), number of leaves (NL) and leaf area (LA) (cm^2) of 'Crioula' guava rootstocks under irrigation with waters of different saline levels and nitrogen (N) doses

Source of variation	DF	Mean square		
		SD	NL	LA
Saline level (S)	4	0.68^{**}	7.46^{ns}	292.01^{ns}
Linear regression	1	2.22^{**}	1.38^{ns}	434.41^{ns}
Quadratic regression	1	0.02^{ns}	6.21^{ns}	0.45^{ns}
N doses (ND)	3	1.05^{**}	144.32^{**}	29160^{**}
Linear regression	1	3.14^{**}	431.60^{**}	83726^{**}
Quadratic regression	1	0.001^{ns}	1.37^{*}	3407^{ns}
Interaction S*ND	12	0.10^{ns}	2.69^{ns}	1006^{ns}
Blocks	3	0.03^{ns}	2.55^{ns}	2496^{ns}
CV (%)		7.64	21.45	23.71

ns, **, *Respectively not significant and significant at $p < 0.01$ and $p < 0.05$

The increase in irrigation water salinity negatively affected 'Crioula' guava SD and, according to the regression equation (Figure 1A), there was a decreasing linear effect, with reduction of 4.15% per unit increase in EC_w. Plants subjected to irrigation with EC_w of 3.5 dS m^{-1} showed a decrease of 16.6% in SD, in comparison to plants irrigated with water of the lowest saline level (0.3 dS m^{-1}).

The reduction in SD probably results from the decrease in the osmotic potential of the soil solution, which compromises water absorption by roots, causing the plant to reduce photosynthesis; consequently, its growth will be affected. Under these conditions, the excess of salts in the soil leads to damages in various physiological and biochemical processes and may lead the plant to a water stress state, suffering with toxicity, which will result in serious damages to growth, development, production and yield (Esteves & Suzuki, 2008).

As to the factor N doses, according to the regression equation (Figure 1B), there was an SD reduction of 4.4% per increase of 30% in N doses, which caused a decrease of 0.54 mm (13.44%) in the comparison between plants under 160% of N and those under 70% of N. Dias et al. (2012), evaluating the effects of different N doses (0, 552, 823 and 1104 mg dm^{-3}) on the growth of 'Paluma' guava seedlings, observed that the N dose of 667 mg dm^{-3} promotes higher SD.

As observed for stem diameter (Figure 1B), the number of leaves and leaf area of 'Crioula' guava were also negatively

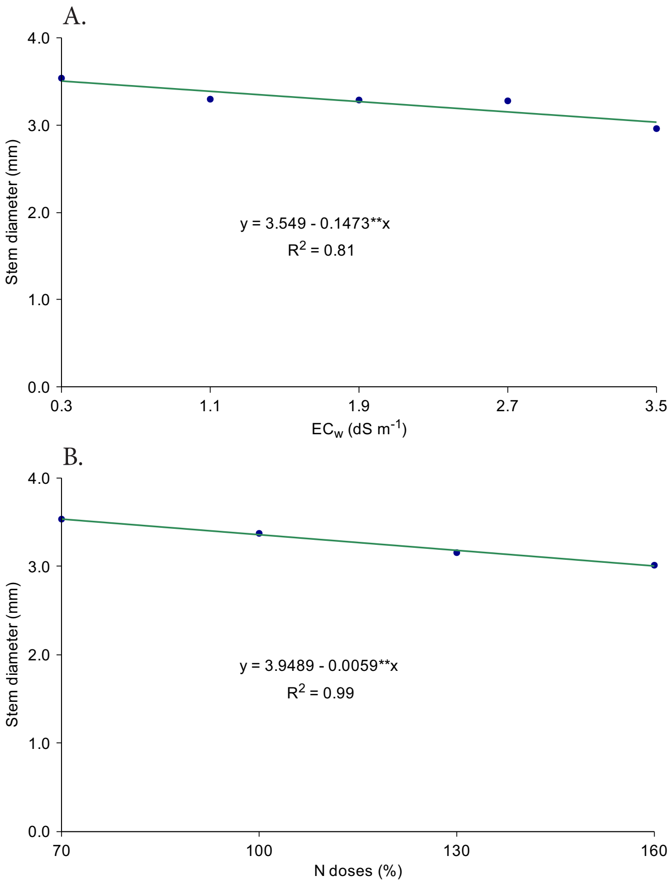

Figure 1. Stem diameter of 'Crioula' guava rootstocks under irrigation water salinity – EC_w (A) and nitrogen (N) doses (B) at 190 days after emergence

affected by the increase in N doses and, according to the regressions (Figure 2A and B), there were linear reductions of 10.51 and 10.61% in NL and LA, respectively, per increase of 30% in N doses. As a result, NL and LA decreased by 31.5 and 31.8%, respectively, considering plants fertilized with 160% of N in relation to those subjected to 70% of the N recommendation, at 190 DAE.

According to the summary of the analysis of variance (Table 3), there was significant effect of irrigation water salinity on stem fresh phytomass (SFP), stem dry phytomass (SDP), root dry phytomass (RDP) and total dry phytomass (TDP). In addition, the factor N doses significantly influenced leaf fresh phytomass (LFP) and leaf dry phytomass (LDP); however, there was no significant interaction between the studied factors (S x ND).

The increase in EC_w negatively affected SFP and SDP of guava rootstocks and, according to the regression equations (Figure 3A), there were respective reductions of 7.2 and 7.6% per unit increase in EC_w, equivalent to SFP and SDP decreases of 28.8 and 30.6% considering plants irrigated with water of 3.5 dS m^{-1} and those under the lowest saline level (0.3 dS m^{-1}). The low water availability resulting from the reduction in the osmotic potential, due to the high saline concentration, reduced SFP and SDP possibly because of physiological alterations in the plant, such as stomatal closure; consequently, it reduces CO_2 assimilation and photosynthetic rate, directly affecting phytomass production (Willadino & Camara, 2004).

As observed for SD, NL and LA, the different N doses also negatively affected SFP and SDP of 'Crioula' guava rootstocks

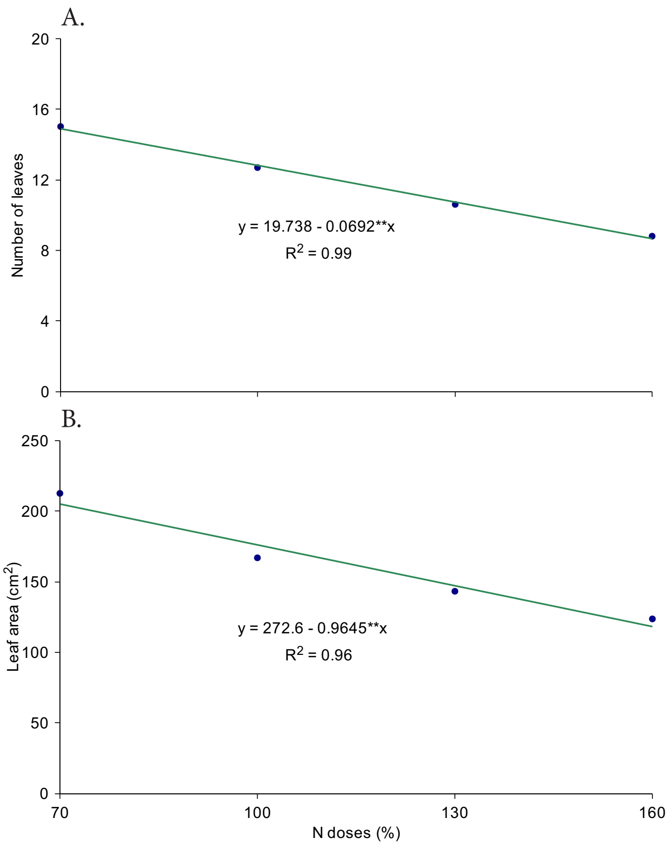

Figure 2. Number of leaves (A) and leaf area (B) of 'Crioula' guava rootstocks as a function of nitrogen (N) doses at 190 days after emergence

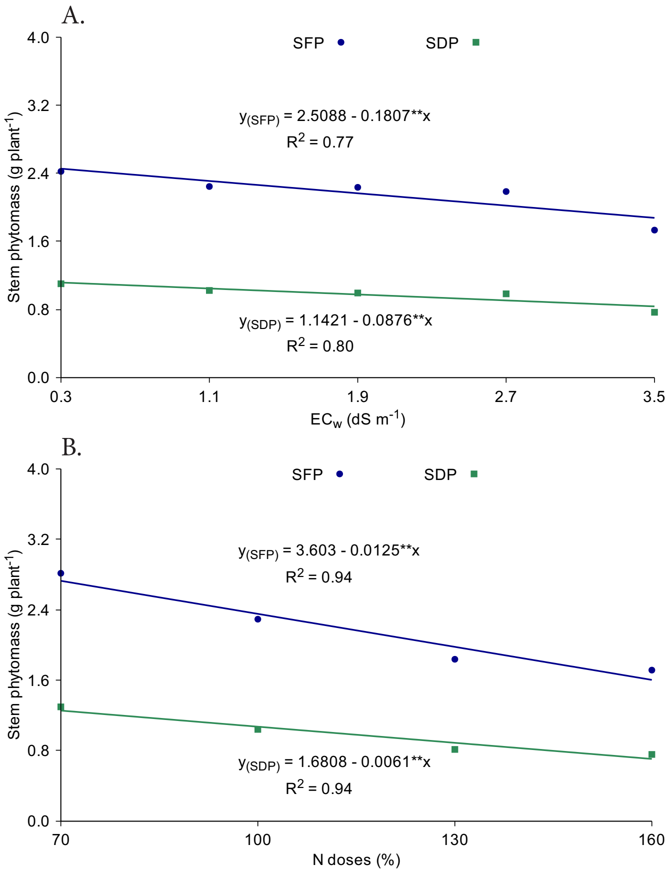

Figure 3. Stem fresh phytomass (SFP) and stem dry phytomass (SDP) of 'Crioula' guava rootstocks under irrigation water salinity – EC_w (A) and nitrogen (N) doses (B)

Table 3. Summary of the analysis of variance for stem fresh phytomass (SFP), stem dry phytomass (SDP), leaf fresh phytomass (LFP), leaf dry phytomass (LDP), root dry phytomass (RDP) and total dry phytomass (TDP) of 'Crioula' guava rootstocks under irrigation with waters of different saline levels and nitrogen (N) doses

Source variation	DF	Mean square					
		SFP	LFP	SDP	LDP	RDP	TDP
Saline levels (S)	4	1.08**	1.09ns	0.24**	0.09ns	0.67**	2.29**
Linear regression	1	3.34**	0.05ns	0.78**	0.08ns	2.57**	7.71**
Quadratic regression	1	0.41ns	3.55ns	0.07ns	0.17ns	0.01ns	0.68ns
N doses (ND)	3	4.98**	22.15**	1.19**	2.34**	0.31**	9.84**
Linear regression	1	14.06**	62.94**	3.38**	6.42**	0.74**	27.36**
Quadratic regression	1	0.83*	2.58ns	0.18*	0.58*	0.05ns	2.02*
Interaction (S*ND)	12	0.13ns	1.46ns	0.04ns	0.12ns	0.04ns	0.38ns
Blocks	3	0.14ns	0.95ns	0.01ns	0.06ns	0.02ns	0.03ns
CV (%)		16.72	26.40	18.44	24.12	20.27	16.35

ns, **, *Respectively not significant and significant at $p < 0.01$ and $p < 0.05$

at 190 DAE and, according to the regression equations (Figure 3A and B), there was a linear effect, with reductions on the order of 10.4 and 10.89% in SFP and SDP, respectively, per increase of 30% in N doses, which correspond to decreases of 31.2% in SFP and 32.66% in SDP considering plants subjected to fertilization with 160% of N, in relation to those under 70% of the N recommendation.

For LFP and LDP of 'Crioula' guava, based on the regressions (Figure 4), the increase in N doses promoted linear reductions of 11.2 and 10.6%, respectively, per increase of 30% in N doses. In the comparison between plants under 160% of N and those under 70% of N, there were reductions of 33.6 and 31.94% in LFP and LDP, respectively.

The increment in EC_w levels linearly reduced 'Crioula' guava rootstock growth, evaluated trough RDP accumulation and, according to the regression equation (Figure 5A), a reduction of 12.3% per unit increase in EC_w was estimated. In addition, plants irrigated with water of the highest EC_w (3.5 dS m^{-1}) showed a reduction of 0.51 g $plant^{-1}$ (49.38%) in RDP, in comparison to those under EC_w of 0.3 dS m^{-1}.

The fact that RDP was affected by the saline stress caused by the irrigation water salinity denotes the effect of alteration in the osmotic potential of the soil solution (Willadino & Camara, 2004). On the other hand, it should be pointed out that the root system of the guava rootstocks was confined in a restricted volume of substrate, due to the size of the container used in the study, which may also have contributed to the reduction in RDP. Gurgel et al. (2007), evaluating the effects of irrigation water salinity (EC_w from 0.5 to 4.5 dS m^{-1}) on the initial growth of two guava rootstocks ('Rica' and 'Ogawa'), also observed reduction in RDP and the cv. 'Rica' was more affected by the increase in water salinity, compared with 'Ogawa'.

The different N doses also interfered negatively with RDP and, according to the regression equation (Figure 5B), there was a linear decrease, with reduction of 6.62% in RDP per increase of 30% in the studied N doses. There was a reduction of 0.26 g $plant^{-1}$ in RDP (Figure 5B), considering the values of plants under the highest N dose (160%) and those under the lowest N dose (70%).

According to regression equations (Figure 6A), there was a linear effect of the EC_w levels, with decrease of 7.0% in TDP

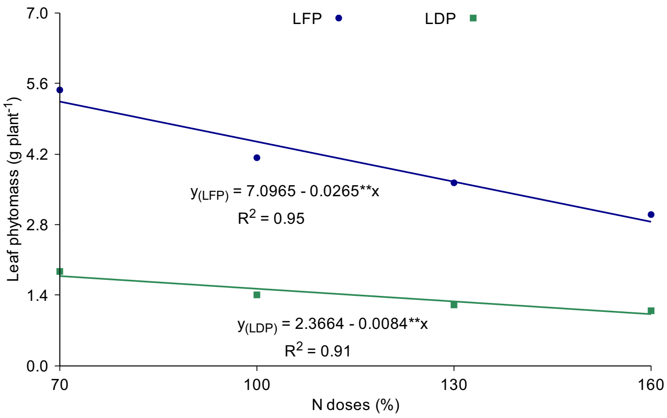

Figure 4. Leaf fresh phytomass (LFP) and leaf dry phytomass (LDP) of 'Crioula' guava rootstocks as a function of nitrogen (N) doses at 190 days after emergence

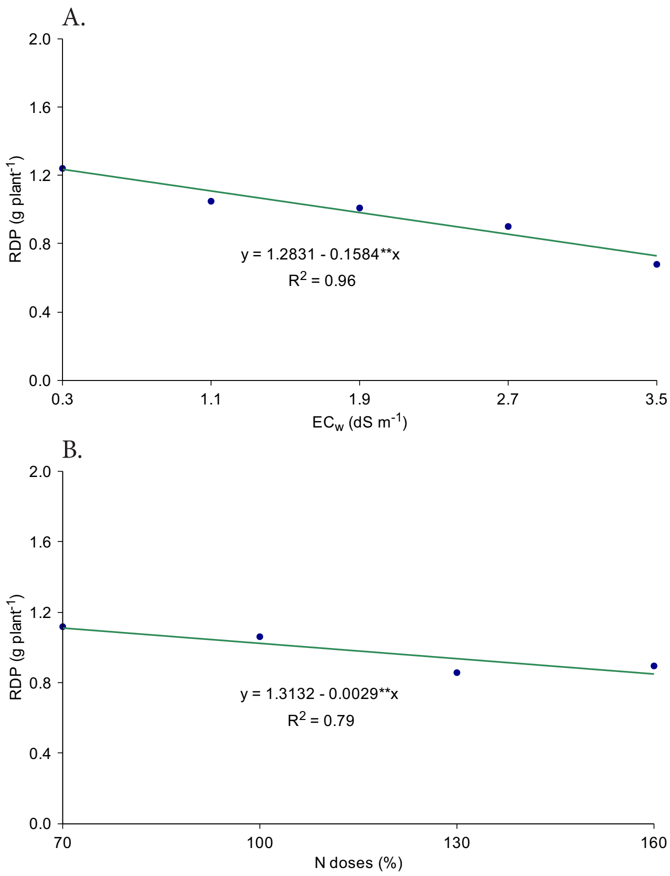

Figure 5. Root dry phytomass (RDP) of 'Crioula' guava rootstocks under irrigation water salinity – EC_w (A) and nitrogen (N) doses (B)

per unit increase in EC_w, i.e., as water saline levels increased from 0.3 to 3.5 dS m^{-1}, there was a reduction of 28.3% in TDP accumulation. TDP reduction under saline stress conditions may be attributed to the fact that the plant, in order to adjust osmotically, spends a certain amount of energy to accumulate sugars, organic acids and ions in the vacuole, energy that could be used in the accumulation of phytomass (Santos et al., 2012). Cavalcante et al. (2010), in an experiment with guava (cv. 'Paluma') planted in pots in a screen house, observed decreasing linear effect of EC_w on TDP, with reduction of 16.18% per unit increase in EC_w.

As to the effect of the increasing N doses on the total dry phytomass of 'Crioula' guava, according to the regression equation (Figure 6B), there was a decreasing linear response, with reductions of 9.7% per increase of 30% in N doses, which promoted increment of 1.56 g (29.24%) in the TDP of plants under 160% of N, in relation to those under 70% of N.

Based on the variables analyzed in this experiment, the supply of 70% of the recommended N dose for the production of guava rootstock (541.1 mg of N dm^{-3} of soil) met the demand of the plants, which is evidenced by the decrease in the values of growth and phytomass variables, when plants were fertilized with N doses higher than the previously mentioned dose. In addition, N dose higher than 541.1 mg dm^{-3} of soil may have increased the salinity level of the soil in the tube, a container with reduced volume (288 mL), and the salinity may have led to osmotic, toxic and/or nutritional effect, which, consequently, may have affected guava rootstock production.

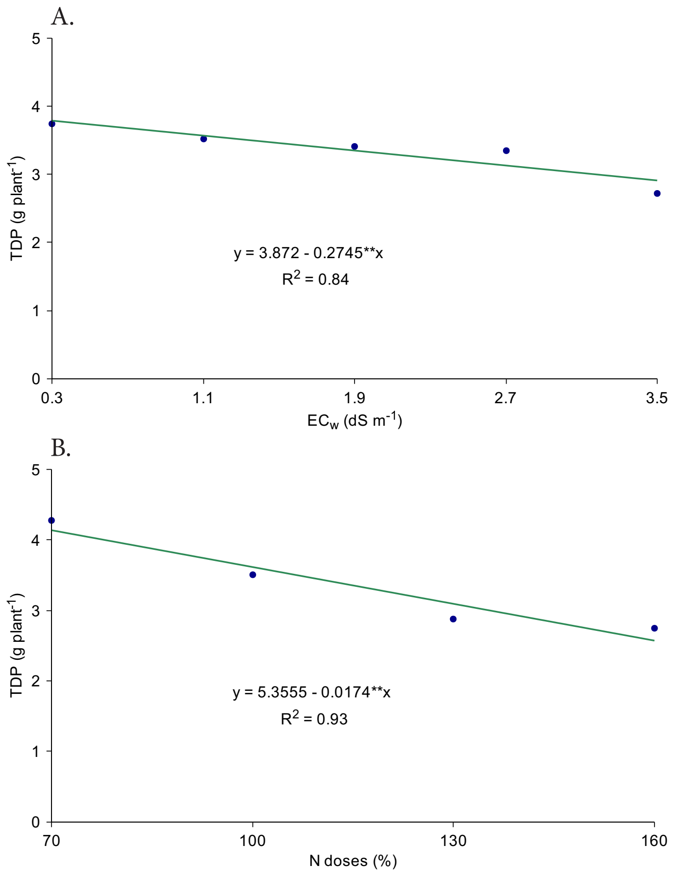

Figure 6. Total dry phytomass (TDP) of 'Crioula' guava rootstocks under irrigation water salinity – EC_w (A) and nitrogen (N) doses (B)

Conclusions

1. The highest growth of 'Crioula' guava rootstock is obtained using water with electrical conductivity of 0.3 dS m^{-1} and N fertilization of 541.1 mg dm^{-3} of soil.

2. Increasing N doses do not reduce the deleterious effect of saline water irrigation on the growth of 'Crioula' guava rootstocks.

3. Irrigation with water of up to 1.75 dS m^{-1}, in the production of guava rootstocks, promoted acceptable reduction of 10% in the growth and quality of seedlings.

Acknowledgments

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