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Tolerance of guava rootstocks under salt stress

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A B S T R A C T

This study aimed to evaluate the tolerance of guava rootstocks under salt stress in the initial development stage. The experiment was conducted in a greenhouse in a randomized block design in a 5 x 3 factorial, consisting of five levels of irrigation water salinity (0.6, 1.2, 1.8, 2.4 and 3.0 dS m^{-1}) and three guava rootstocks ('Crioula', 'Paluma' and 'Ogawa'), with four replicates and four plants per replicate. Emergence, growth and phytomass accumulation were evaluated 30 days after sowing. Increased salinity restricts guava emergence, growth and phytomass accumulation, and the most drastic effects occur at levels higher than 1.8 dS m^{-1}. The cultivar 'Crioula' is more tolerant to salinity in relation to 'Paluma' and 'Ogawa', and can be indicated as rootstock.

Palavras-chave:
Psidium guajava L.
irrigação
salinidade
propagação

Tolerância de porta-enxertos de goiabeira ao estresse salino

R E S U M O

Objetivou-se, com este trabalho, avaliar a tolerância de porta-enxertos de goiabeira sob estresse salino na fase inicial de desenvolvimento. O experimento foi conduzido em casa de vegetação em delineamento experimental em blocos casualizados, no esquema fatorial 5 x 3, constituído de cinco níveis de salinidade da água de irrigação (0,6; 1,2; 1,8; 2,4 e 3,0 dS m^{-1}) e três porta-enxertos de goiabeira (Crioula, Paluma e Ogawa), com quatro repetições e quatro plantas por repetição. Após 30 dias da semeadura foram avaliados a emergência, o crescimento e o acúmulo de fitomassa. O aumento da salinidade restringe a emergência, o crescimento e o acúmulo de fitomassa da goiabeira sendo os efeitos mais drásticos em níveis superiores a 1,8 dS m^{-1}. A cultivar Crioula é mais tolerante à salinidade em relação às cultivares Paluma e Ogawa, podendo ser indicada como porta-enxerto.

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Introduction

Guava (*Psidium guajava* L.) is a fruit crop of tropical and subtropical climate produced in all states of Brazil, where the Northeast region is the main producer of the fruit, contributing with 42.2% to the national production (145,745 t) (IBGE, 2012).

Guava cultivation in Northeast Brazil prevails in irrigated areas of the semiarid region, which undergo frequent periods of water shortage, low rainfalls along the year, besides the presence of high concentrations of salts dissolved in the waters available for irrigation, affecting the development of the crops (Ayers & Westcot, 1999; Távora et al., 2001; Gurgel et al., 2007; Freitas & Alves, 2008; Cavalcante et al., 2010; Sá et al., 2013).

Thus, there is the need to incorporate strategies that improve crop performance under saline conditions, such as the identification of tolerant materials, as a viable strategy in the short term, because the tolerance to salinity depends on species, phenological stage, characteristics of the salts and salt stress intensity and duration (Ayers & Westcot, 1999; Ashraf & Harris, 2004; Gurgel et al., 2007; Sá et al., 2013).

Távora et al. (2001), Gurgel et al. (2007) and Cavalcante et al. (2010) point out, in preliminary studies, the initial growth stage of guava as the most sensitive to salt stress for the cultivars 'Rica', 'Ogawa' and 'Paluma', which are the most important in Brazil, in both the economic aspect and cultivated area. Therefore, the identification of rootstocks tolerant to salinity emerges as a promising alternative to allow the cultivation of the already existing commercial cultivars, with satisfactory yield under saline conditions. Given the above, this study aimed to evaluate the tolerance of guava rootstocks under salt stress in the initial development stage.

Material and Methods

The experiment was carried out from December 23, 2013, to January 21, 2014, in a greenhouse at the Center of Sciences and Agrifood Technology – CCTA of the Federal University of Campina Grande – UFCG, located in the municipality of Pombal-PB, Brazil (6º 47' 20" S; 143 37º 48' 01" W; 174 m).

The experimental design was randomized blocks, in a 5 x 3 factorial scheme, which consisted of five levels of irrigation water salinity (0.6, 1.2, 1.8, 2.4 and 3.0 dS m^{-1}), corresponding to a level below the salinity threshold of the crop, the salinity threshold (1.2 dS m^{-1}) and three levels above it (Távora et al., 2001), and three guava rootstocks ('Crioula', 'Paluma' and 'Ogawa'), totaling 15 treatments, with four replicates and four plants per replicate.

Sowing was performed in tubes (0.3 dm^3) filled with substrate composed of soil (Fluvic Neosol), sand and sheep manure at the proportion of 2:1:1 (Table 1). Three seeds were equidistantly planted in each tube at the depth of 1 cm. The seeds of the cultivar 'Crioula' were obtained from non-commercial plantations of the municipality of Pombal-PB and the seeds of the other cultivars ('Paluma' and 'Ogawa') were obtained, respectively, from the State Company for Agricultural Research of Paraíba – EMEPA and from the Federal Institute of Paraíba – IFPB, both situated in the municipality of Sousa-PB.

Irrigations were performed once a day, in order to maintain soil moisture close to field capacity, based on the drainage lysimeter method, and the applied water depth was added to a leaching fraction of 20%. The volume applied (Va) per container was obtained by the difference between the previous water depth (Lp) and the mean drainage (d), divided by the number of containers (n), as indicated in Eq. 1:

$$\mathrm{Va} = \frac{\mathrm{Lp} - \left(\frac{\mathrm{D}}{\mathrm{n}}\right)}{(1 - \mathrm{LF})} \tag{1}$$

The irrigation water with various salinity levels was prepared considering the relationship between ECw and the concentration of salts (10 * meq L^{-1} = 1 dS m^{-1} of ECw), according to Rhoades et al. (1992), valid for ECw of 0.1 to 5.0 dS m^{-1}, which encompass the tested levels. Water from the local supply system (ECw = 0.3 dS m^{-1}) was used, and the salts (NaCl) were added as necessary (Table 2).

For the preparation of the waters with the respective electrical conductivity (EC) values, the salts were weighed according to the treatment and water was added until achieving the desired EC level, confirming the values with a portable conductivity meter, whose conductivity was adjusted to the temperature of 25 ºC. After preparation, the salinized waters were stored in 30-L plastic containers, one for each ECw level, properly protected to avoid evaporation, entry of rainfall water and contamination with materials that could compromise quality.

Along the experiment, plants were daily monitored for emergence, by counting the number of emerged plants, i.e., with the cotyledons above the soil level. Thus, the number of emerged plantlets referring to each count was obtained by the

Table 1. Chemical characteristics of the substrate composed of soil, sand and sheep manure, used in the production of guava rootstocks

	EC[1] dS m^{-1}	pH H_2O	P mg dm^3	K^+	Ca^{+2}	Mg^{+2}	Na^+	Al^{3+}	$H^+ + Al^{3+}$	SB[1]	T[1]	OM[1] g kg^{-3}
				cmol$_c$ dm^{-3}								
Soil	0.09	8.07	3.00	0.32	6.40	3.20	0.18	0.00	0.00	9.92	9.92	16.0
Manure	6.26	7.75	56.00	24.64	7.70	15.90	9.18	0.00	0.00	57.42	57.42	180.0

According to the methodology described by Claessen (1997); [1]SB – Sum of bases; EC – Electrical conductivity; T – Cation exchange capacity; OM – Organic matter

Table 2. Chemical analysis of the water used to prepare the solutions

ECw dS m^{-1}	pH	K	Ca	Mg	Na	SO_4^{-2}	CO_3^{-2}	HCO_3^-	Cl^-	SAR[1] (mmol L^{-1})$^{0.5}$
		mmol$_c$ L^{-1}								
0.3	7.0	0.3	0.2	0.6	1.4	0.2	0.0	0.8	1.3	2.21

[1]SAR – Sodium adsorption ratio

difference between the read value and the value of the previous day. Hence, emergence speed (ES) was calculated using the number of emerged plants for each reading, according to the formula described by Schuab et al. (2006):

$$ES = \frac{(N_1G_1) + (N_2G_2) + ... + (N_nG_n)}{G_1 + G_2 + ... + G_n} \quad (2)$$

where:

ES - emergence speed (days);

G - number of emerged plantlets in each count; and,

N - number of days from sowing to each count.

After stabilization of emergence 30 days after sowing (DAS), emergence percentage (EP) (%) was determined by the ratio between the number of emerged plants and the number of planted seeds.

At 30 DAS, plant height (PH) (cm) was determined using a graduated ruler, as the distance from the soil to the apex of the plant. Stem diameter (SD) was determined at 1 cm from the soil surface and the number of leaves (NL) through the count of active leaves. Immediately after, plants were collected, divided into shoots and roots and dried in a forced-air oven at 65 °C until constant weight. Then, the material was weighed on an analytical scale for the determination of shoot dry phytomass (SDP) (g) and root dry phytomass (RDP) (g), which were summed to obtain the total dry phytomass (TDP).

The obtained data were subjected to analysis of variance by F test and, in case of significance, regression analyses were applied for the factor levels of irrigation water salinity and Tukey test for the factor rootstocks, both at 0.05 probability level, using the statistical software SISVAR® (Ferreira, 2011).

Results and Discussion

The variable emergence speed, there was significant difference ($p < 0.05$) only between cultivars (Figure 1A). For emergence percentage and plant height, there was significant effect ($p < 0.05$) only of the levels of irrigation water salinity (Figures 1B and 2). There was significant influence ($p < 0.05$) of the interaction between irrigation water salinity and guava cultivars on the variables stem diameter, number of leaves and shoot, root and total dry phytomass (Figures 3 and 4).

The cultivar ‘Ogawa’ needed a greater number of days for emergence (21.25 days) in relation to the cultivars ‘Crioula’ (15.08 days) and ‘Paluma’ (16.46 days), regardless of the saline level. Thus, it denotes the lower vigor of its seeds in relation to the others (Figure 1A). Emergence percentage showed a quadratic behavior, with maximum value at the level of 1.33 dS m^{-1} (Figure 1B). Undoubtedly, the increase in irrigation water salinity to up to 1.33 dS m^{-1} promoted a slight dispersion of the colloids of the substrate, facilitating the emergence of the plantlets. However, irrigation with water of higher saline level intensified the reduction in the osmotic potential of the substrate, especially by the more expressive concentration of Na^+ in relation to the other ions, thus promoting reductions in plantlet emergence due to the deleterious effects of the salt stress (osmotic and ionic) on the seeds.

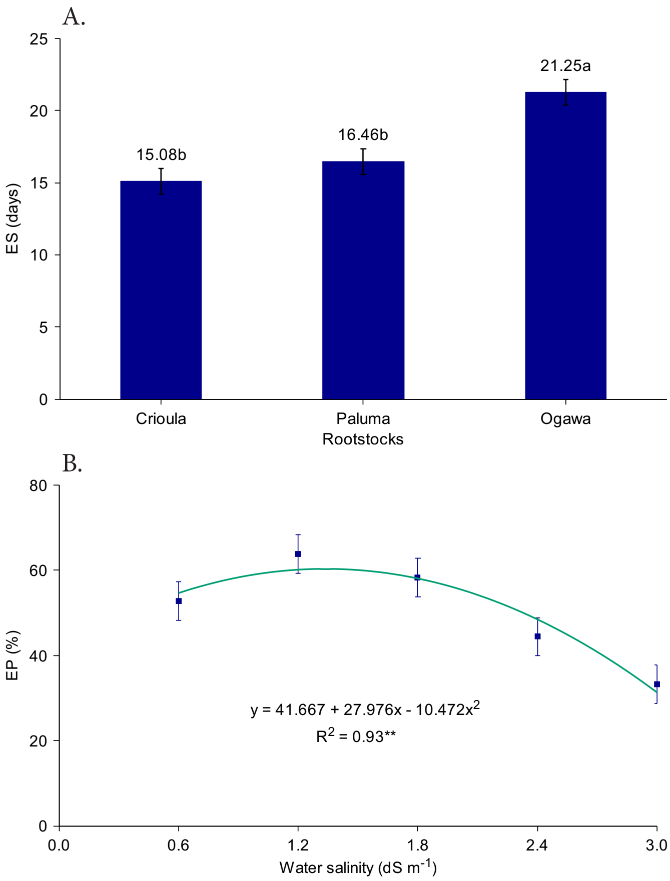

Figure 1. Emergence speed (ES) (A) and emergence percentage (EP) (B) of guava rootstocks as a function of levels of irrigation water salinity 30 days after sowing

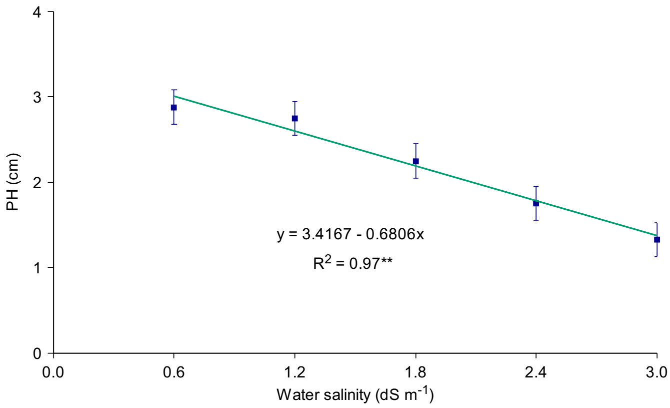

Figure 2. Plant height (PH) of guava rootstocks as a function of levels of irrigation water salinity 30 days after sowing

Data referring to guava emergence under saline conditions are scarce in the literature, but reductions in the emergence of fruit crops such as guava (Nobre et al., 2003), dwarf cashew (Sousa et al., 2011) and papaya (Sá et al., 2013) have been observed under salt stress conditions. These authors explain that the reduction in emergence is directly related to the reduction in the osmotic potential, which affects seed imbibition, consequently decreasing the number of emerged plantlets, causing a non-uniform stand.

There were linear reductions of 22.6% in the height of the rootstocks due to the increase in irrigation water salinity, regardless of the cultivar used (Figure 2). The highest levels of irrigation water salinity also reduced the growth in stem diameter and in number of leaves of guava plants (Figure

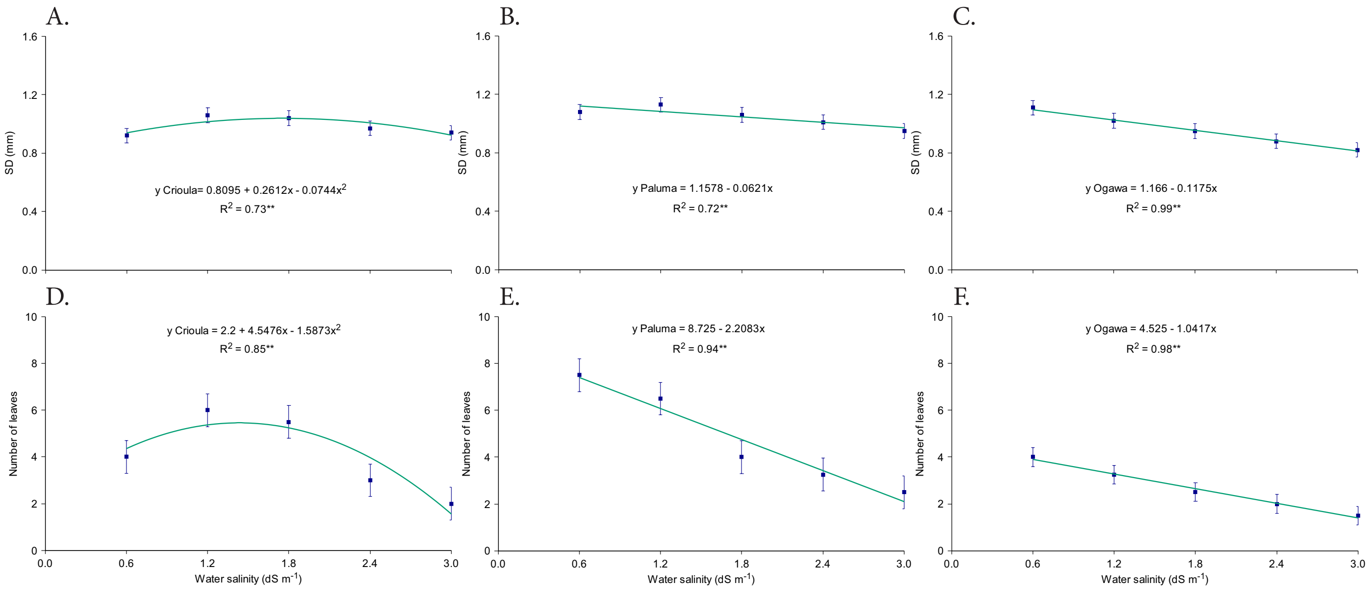

Figure 3. Stem diameter (SD) (A, B and C) and number of leaves (NL) (D, E and F) of guava rootstocks as a function of levels of irrigation water salinity 30 days after sowing

3). It is believed that the increase of sodium salts in the substrate caused toxicity to the guava rootstocks, affecting their physiological quality and compromising the absorption of water and nutrients, due to the reduction of the osmotic potential of the substrate and the competition between specific ions, leading to disorders in plant growth (Brito et al., 2008; Sousa et al., 2011; Sá et al., 2013; Taiz & Zeiger, 2013).

SD and NL decreased with the increase in salinity. For the cultivar 'Crioula', there was a quadratic behavior with maximum growth values at the levels of 1.75 and 1.43 dS m^{-1}, for SD and NL, respectively (Figures 3A and D); for the other cultivars, there was a decreasing linear behavior as a function of the increase in salinity, with reductions of 0.06 mm and 2.20 leaves for the cultivar 'Paluma' and 0.11 mm and 1.04 leaves for the cultivar 'Ogawa', for every unit increment in irrigation water salinity (Figures 3B, C, E and F), thus indicating the higher sensitivity of the cultivars 'Paluma' and 'Ogawa', compared with 'Crioula'. Considering that the diameter of the rootstocks is one of the most limiting factors for the production of seedlings through grafting (Souza et al., 2013) and that leaves are the organs responsible for the photosynthetic activity of the plants (Taiz & Zeiger, 2013), drastic reductions in these components, as observed in 'Paluma' and 'Ogawa' rootstocks under salt stress, are limiting for the propagation of the crop. Thus, the incorporation of the cultivar 'Crioula', more tolerant to salinity, as rootstock will lead to improvements in the performance of these plants.

Reductions in the growth of guava plants under saline conditions were also reported by Gurgel et al. (2007), studying the cultivars 'Rica' and 'Ogawa'. Additionally, significant reductions in the initial growth of fruit crops irrigated with saline water have also been observed by Brito et al. (2008) in the production of seedlings of citrus rootstocks, Silva & Amorim (2009) in the production of 'umbu' seedlings and Silva & Amorim (2009) in the production of noni seedlings.

The increase in the concentration of sodium salts in the irrigation water reduced the phytomass accumulation of the guava plants, regardless of the cultivar (Figure 4). The cultivar 'Paluma' obtained the highest SDP accumulation at all levels of irrigation water salinity, in comparison to the other studied cultivars. However, this cultivar suffered the highest reductions with the increase in salinity, on the order of 0.0033 g for every unit increase in water salinity, whereas the cultivars 'Crioula' and 'Ogawa' reduced only by 0.0024 and 0.0014 g, respectively (Figures 4A, B and C). The increase in the contents of salts in the substrate directly contributes to the reduction of the soil osmotic potential, restricting the absorption of water and nutrients by the plants. In addition, the high concentrations of sodium salts in the soil cause ionic and hormonal alterations in the plants (Taiz & Zaiger, 2013; Sá et al., 2015), which aggravate over time and may lead to plant death, due to the toxicity caused by this ion.

For RDP, the cultivars 'Paluma' and 'Crioula' responded in a similar way to the increase in water salinity, with reductions of 0.0018 g for every unit increase in irrigation water salinity. However, the cultivar 'Ogawa' showed reductions of only 0.0008 g (Figure 4D, E and F); for 'Ogawa', this index represents a reduction of 30% in root phytomass accumulation, while the cultivars 'Crioula' and 'Paluma' exhibited reductions of 32% for every unit increase in water salinity. Therefore, it can be claimed that 'Ogawa' has lower sensitivity of the root system to the accumulation of salts in the soil, compared with the others. This can be related to the mechanism of tolerance of the cultivar, which expands its root system in the search for essential nutrients and thus escaping the effects of the saline stress.

There was a decreasing linear response of TDP accumulation, as a reflex of SDP and RDP, with reductions of 0.0042, 0.0052 and 0.0022 g for the cultivars 'Crioula', 'Paluma' and 'Ogawa', respectively (Figures 4F, G and H), for every unit increase in water salinity. In addition, despite the lower reductions observed in the cultivar 'Ogawa', its growth is highly reduced in comparison to 'Crioula' and 'Paluma', since these cultivars, when cultivated at the salinity level of 2.4 dS m^{-1}, showed higher phytomass accumulation in relation to 'Ogawa' at the level of 0.6 dS m^{-1}. Therefore, it can be inferred that the cultivar 'Ogawa'

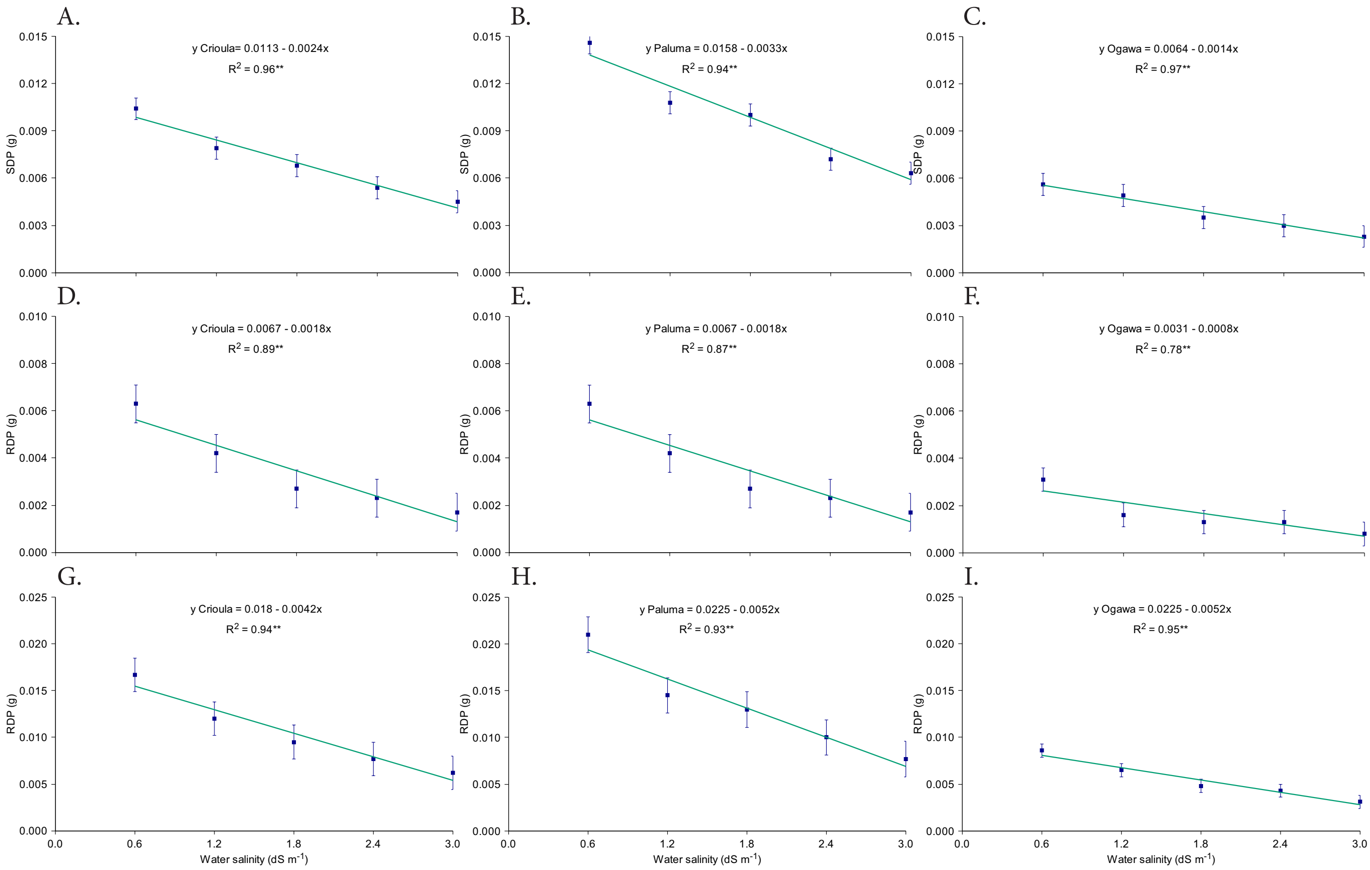

Figure 4. Shoot dry phytomass (SDP) (A, B and C), root dry phytomass (RDP) (D, E and F) and total dry phytomass (TDP) (G, H and I) of guava rootstocks as a function of levels of irrigation water salinity 30 days after sowing

does not meet the criteria of a good rootstock, which must be rustic, with fast growth and well adapted to the environment (Souza et al., 2013; Brito et al., 2014; Paiva et al., 2015).

Restrictions in the dry matter accumulation of guava seedlings subjected to salinity have been reported by Gurgel et al. (2007) in the cultivars ‘Rica’ and ‘Ogawa’, and by Cavalcante et al. (2010) in seedlings of the cultivar ‘Paluma’. These authors observed the high sensitivity of the cultivars ‘Ogawa’ and ‘Paluma’, which reached 70.54 and 92.6% of restriction to the root system and 77.4 and 81.5% of restriction to the shoots, respectively, as a function of more prolonged salt stress (80 and 70 days, respectively).

The reductions in phytomass accumulation of fruit crops under salt stress conditions also corroborate the results observed by Nobre et al. (2003), Brito et al. (2008), Silva & Amorim (2009), Sousa et al. (2011), Souto et al. (2013) and Sá et al. (2013) in the production of soursop rootstocks, citrus, ‘umbu’ seedlings, dwarf cashew, noni and papaya, respectively.

Conclusions

1. The increase in salinity restricts guava germination, growth and phytomass accumulation and the effects are more drastic at levels higher than 1.8 dS m^{-1}.

2. The cultivar ‘Crioula’ is more tolerant to salinity in relation to ‘Paluma’ and ‘Ogawa’, and can be indicated as rootstock for the other varieties.

3. The number of leaves and total dry phytomass are the variables most affected by the salts stress.

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