

MORPHOPHYSIOLOGY OF CASHEW ROOTSTOCK UNDER SALINE WATER IRRIGATION AND POTASSIUM SILICATE DOSES

ABSTRACT

Aims: the present study aimed to evaluate the morphophysiology of “Crioulo” cashew rootstocks subjected saline water irrigation and potassium silicate doses.

Study design: The experimental design was the randomized block, corresponding to five levels of irrigation water electrical conductivity – ECw and five doses of potassium silicate

Place and Duration of Study: The study was carried out in a greenhouse at the Center of Sciences and Agri-Food Technology of the Federal University of Campina Grande, Campus of Pombal – PB, Brazil, between august and november of 2017.

Methodology: The experiment was set in a randomized block design, with treatments arranged in a 5 x 5 factorial scheme, corresponding to five levels of irrigation water electrical conductivity – ECw (0.3; 1.0; 1.7; 2.4 and 3.1 dS m⁻¹) and five doses of potassium silicate (0, 250, 500, 750 and 1000 mg L⁻¹) applied on the leaves, with four replicates and two plants per plot. The plant material was the “Crioulo” cashew genotype, adapted to semi-arid conditions, obtained from a commercial exploitation area located in the municipality of Severiano Melo – RN, Brazil, and widely used in the production of rootstocks in seedling production nurseries of the region.

Results: irrigation with 1.7 dS m⁻¹ water causes acceptable reduction of 10% in the morphophysiology of “Crioulo” cashew; The estimated potassium silicate dose of 524,78 mg L⁻¹ led to improvements in the physiology, morphology and quality of the cashew rootstocks.

Conclusion: irrespective of irrigation water salinity, fertilization with potassium silicate may improve the morphophysiological characteristics of cashew rootstocks.

Keywords: *Anacardium occidentale* L., abiotic stress, fertilization management, seedling production.

1. INTRODUCTION

Cashew (*Anacardium occidentale* L.) is a tropical fruit tree native to Brazil and widely cultivated in the Northeast region due to its adaptation to the edaphoclimatic conditions. Such situation makes this region the largest producer of cashew nut, with planted area of approximately 616,189 ha, responsible for about 98.7% of the national production, and the states of Ceará (42,597 t), Rio Grande do Norte (33,912 t) and Piauí (28,292 t) are the main cashew nut producers [1].

Despite such high production, the yield of plantations in Northeast Brazil is considered low in comparison to other regions of the country, around 157 kg ha⁻¹, which is attributed mainly to the large genetic variability of the plant material. As an alternative, grafted seedlings have gained prominence as they make possible to use genetic materials more productive and adapted to the edaphoclimatic conditions, allowing to reproduce qualities of economic interest from the mother plant and promote early and homogeneous production [2].

Therefore, producing quality seedlings is a decisive step for a successful process, but it has been limited by the long periods of drought which force seedling production nurseries to use waters with high concentrations of salts in irrigation, thus limiting rootstock quality by saline stress [3].

To mitigate the effects caused by salts, fertilization techniques such as potassium fertilization have stood out, because potassium participates in various biological processes in plant cells, such as enzymatic activation, respiration, photosynthesis and competition with toxic elements, besides enhancing water balance [4,5]. Besides that, there is also the adoption of silicon, which lessens the toxic effects induced by the excess Na⁺ in the cell compartments and increases the antioxidant

34 defense capacity in various plant species, by enhancing the activity of enzymes associated with plant
35 defense mechanism [6].

36 In this context, this study aimed to evaluate the morphophysiology of “Crioulo” cashew rootstocks
37 subjected to saline water irrigation and potassium silicate doses.

38

39 2. MATERIAL AND METHODS

40

41 2.1 Location of the experiment

42 The study was carried out in a greenhouse at the Center of Sciences and Agri-Food Technology of
43 the Federal University of Campina Grande, Campus of Pombal – PB, Brazil, at the geographic
44 coordinates 6°48'16" S and 37°49'15" W, and altitude of 174 m.

45

46 2.2 Description of treatments

47 The experiment was set in a randomized block design, with treatments arranged in a 5 x 5 factorial
48 scheme, corresponding to five levels of irrigation water electrical conductivity – ECw (0.3; 1.0; 1.7; 2.4
49 and 3.1 dS m⁻¹) and five doses of potassium silicate (0, 250, 500, 750 and 1000 mg L⁻¹) applied on the
50 leaves, with four replicates and two plants per plot.

51 Solutions of different salinity levels were prepared by the addition of NaCl, CaCl₂ and MgCl₂,
52 maintaining a proportion equivalent to 7:2:1, respectively, in the water from the local supply system
53 (0.3 dS m⁻¹). This proportion is commonly found in waters used for irrigation in the Northeast region
54 [7]. Saline levels were selected based on [8].

55 The source of potassium silicate was the commercial product Quimifol Silício, composed of 10%
56 silicon (Si) and 10% potassium (K), completely soluble in water. Due to the scarcity of studies using
57 potassium silicate in seedlings, the doses were based on the K recommendation for pots, 150 mg of K
58 dm⁻³, proposed by [9].

59 The plant material was the “Crioulo” cashew genotype, adapted to semi-arid conditions, obtained from
60 a commercial exploitation area located in the municipality of Severiano Melo – RN, and widely used in
61 the production of rootstocks in seedling production nurseries of the region.

62 2.3 production of rootstocks

63 The plant material was the “Crioulo” cashew genotype, adapted to semi-arid conditions, obtained from
64 a commercial exploitation area located in the municipality of Severiano Melo – RN, and widely used in
65 the production of rootstocks in seedling production nurseries of the region.

66 Sowing was performed on August 29, 2017, in polyethylene bags with capacity for 1150 mL,
67 perforated at the bottom to allow free drainage. One seed was planted in each bag and the substrate
68 was maintained at field capacity using public-supply water (ECw of 0.3 dS m⁻¹) along the period of
69 germination and emergence of seedlings. The bags were placed on a metal bench, at 0.8 m height
70 from the soil.

71 The bags were filled with substrate composed of 85% soil, 10% fine sand and 5% aged bovine
72 manure. The physical and chemical characteristics of soil are presented in Table 1, determined
73 according to the methodologies proposed by [10].

74 **Table 1. Chemical and physical characteristics of the substrate used in the experiment**

Chemical characteristics								
pH	ECse	P	K ⁺	Na ⁺	Ca ²⁺	Mg ²⁺	Al ³⁺	H + Al ³⁺
CaCl ₂ 1:2,5	dS m ⁻¹	mg dm ⁻³	cmol _c dm ⁻³					
7.41	1.21	15,40	0.43	1.17	7.80	1.70	0.00	0.00
Physical characteristics								
Sand	Silt	Clay	AD	DP	Total porosity	Textural class		

..... g kg ⁻¹	 g cm ⁻³	%	
778 136 76	1.48 2.86	48	Sandy loam

75

76 *pH – hydrogen potential, Ca²⁺ and Mg²⁺ extracted with 1 mol L⁻¹ KCl at pH 7.0; Na⁺ and K⁺ extracted using 1*
77 *mol L⁻¹ NH₄OAc at pH 7.0; Al³⁺++H⁺ extracted using 1 mol L⁻¹ CaOAc pH 7.0; ECse – electrical conductivity of*
78 *the saturation extract; AD - Apparent density; DP –particle density.*

79 2.4 application of treatments

80 Saline solutions began to be applied at 30 days after sowing (DAS), manually, through daily
81 irrigations. The applied volume was determined through drainage lysimetry, by daily providing the
82 evapotranspired water volume to bring the soil to field capacity, equivalent to difference between the
83 applied volume and the volume drained in the previous irrigation. Every 15 days, a leaching fraction of
84 0.10 was also applied, based on the volume applied in this period, to reduce salt accumulation in the
85 substrate.

86 Potassium silicate fertilizations began at 31 DAS, split into weekly foliar applications, for five weeks,
87 performed in the late afternoon using sprayers. Eight liters of solution were used for each dose of
88 potassium silicate, applying a total volume of 200 mL per plant. Phytosanitary control was performed
89 along with sowing, by applying a sulfur-based product, registered for the crop and characterized by
90 fast initial action and short persistence. Weeding was carried out always when necessary, to control
91 the incidence of invasive plants which could damage the crop.

92 2.5 Variables analyzed

93 At 55 DAS an LCPro+ infrared gas analyzer (IRGA) was used to measure gas exchanges in the
94 cashew rootstocks, based on leaf transpiration (E), intercellular CO₂ concentration (Ci), stomatal
95 conductance (gs) and CO₂ assimilation rate (A), and these data were used to calculate water use
96 efficiency (WUE = A/E). Gas exchange measurements were performed from 7:00 to 9:00 a.m. in a
97 fully expanded mature leaf, using artificial light source with intensity of 1200 MJ m⁻² s⁻¹ and CO₂ from
98 the atmosphere at 2.5 m height.

99 Treatment effects on plant growth were evaluated by measuring, from 35 to 75 DAS, the absolute
100 growth rates (AGR) in plant height (AGR_{PH}) and stem diameter (AGR_{SD}). The absolute growth rate
101 was determined using the methodology proposed by [11], according to Equation 1:

$$102 \quad AGR = \frac{(A_2 - A_1)}{(t_2 - t_1)} \quad \text{Eq. 1}$$

103 where: AGR = absolute growth rate; A₂ = plant growth at time t₂; A₁ = plant growth at time t₁; and t₂ –
104 t₁ = time difference between measurements.

105 At 75 DAS, plants were separated into stems, leaves and roots, placed in paper bags to dry in a
106 forced-air oven at 65 °C until constant weight, and weighed on precision scale (0.01 g) to obtain shoot
107 dry phytomass – SDP (leaf dry phytomass + stem dry phytomass) and total dry phytomass – TDP
108 (SDP + root dry phytomass).

109 Rootstock quality was assessed by the Dickson quality index (DQI) for seedlings, using the formula of
110 [12], according to Equation 2.

$$111 \quad DQI = \frac{(TDP)}{(PH/SD) + (SDP/RDP)} \quad \text{Eq. 2}$$

112 where: DQI = Dickson quality index; PH = plant height (cm); SD = stem diameter (mm); TDP = total
113 dry phytomass (g); SDP = shoot dry phytomass (g); and RDP = root dry phytomass (g).

114 2.6 Statistical analysis

The variables were subjected to analysis of variance by F test (.01 and .05 probability levels) and, in cases of significant effect, linear and quadratic polynomial regressions were applied, using the statistical program SISVAR [13]. Regression models were chosen based on the best fit considering the coefficient of determination (R^2) and a probable biological explanation.

3. RESULTS AND DISCUSSION

According to the summary of analysis of variance (Table 2), irrigation water salinity and potassium silicate doses had significant effect on stomatal conductance, intercellular CO_2 concentration and CO_2 assimilation rate. For transpiration, there was only significant effect of irrigation water salinity, whereas potassium silicate doses had effect on water use efficiency. Apart from that, the interaction between irrigation water salinity and potassium silicate doses had no significant effect on “Crioulo” cashew rootstocks at 55 DAS for any of the studied variables.

Table 2. Summary of analysis of variance for the physiological variables stomatal conductance (g_s), intercellular CO_2 concentration (C_i), CO_2 assimilation rate (A), leaf transpiration rate (E) and water use efficiency (WUE) in “Crioulo” cashew rootstocks subjected to saline water irrigation and potassium silicate doses at 55 days after sowing (DAS).

Source of variation	DF	Mean squares				
		g_s	C_i	A	E	WUE
Saline levels (SL)	4	0.0057**	507.2*	20.80**	0.63**	0.302 ^{ns}
Linear regression	1	0.015**	1529.6**	39.00**	2.17**	0.05 ^{ns}
Quadratic regression	1	0.004**	139.24 ^{ns}	16.00**	0.04 ^{ns}	0.02 ^{ns}
Potassium silicate (PS)	4	0.0013**	876.3**	8.78**	0.05 ^{ns}	0.354**
Linear regression	1	0.0016*	2.40 ^{ns}	0.93 ^{ns}	0.05 ^{ns}	0.295*
Quadratic regression	1	0.0012*	3320**	33.93**	0.11 ^{ns}	0.97**
Interaction (SL*PS)	16	0.0006 ^{ns}	345.54 ^{ns}	4.40 ^{ns}	0.15 ^{ns}	0.352 ^{ns}
Blocks	2	0.0004 ^{ns}	282.24 ^{ns}	0.12 ^{ns}	0.12 ^{ns}	0.19 ^{ns}
CV (%)		26.75	6.33	11.18	16.41	8.41

** $P < 0.01$; * $P < 0.05$; ^{ns} $P > 0.05$

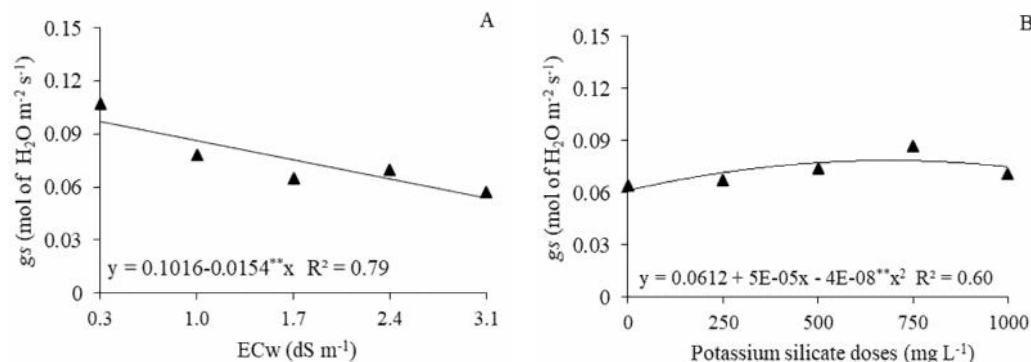


Figure 1. Isolated effect of irrigation water electrical conductivity (A) and potassium silicate doses (B) on stomatal conductance – gs in “Crioulo” cashew rootstock at 55 DAS.
** $P < 0.01$

Stomatal conductance (gs) was the parameter most affected by irrigation water salinity (Figure 1A), with linear reduction of about 15.16% per unit increase in ECw, resulting in total decrease of 42.45% in the gs of plants subjected to irrigation with ECw of 3.1 dS m⁻¹, compared with those irrigated with the lowest saline level (0.3 dS m⁻¹). This is related to stomatal closure, which reduces water vapor exit and CO₂ diffusion to carboxylation sites, leading to decrement in intracellular CO₂ concentration and subsequent reduction in net photosynthesis [14].

Potassium silicate doses caused a quadratic polynomial effect (Figure 1B) and the estimated dose of 625 mg L⁻¹ led to a 25.54% increment in stomatal conductance compared with the rootstock which received no foliar application of potassium silicate. This is explained by stomatal regulation, promoted by the increase in the availability of potassium and silicon, which act in the control of stomatal opening and closure [14].

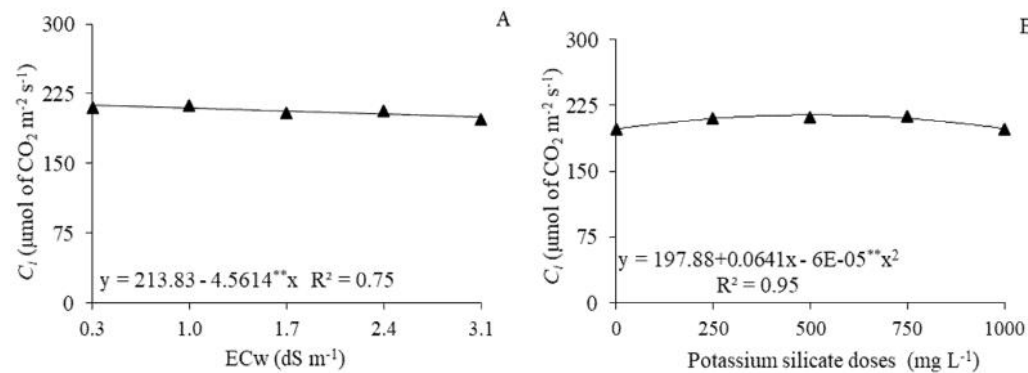


Figure 2. Isolated effect of irrigation water electrical conductivity (A) and potassium silicate doses (B) on intercellular CO₂ concentration – Ci in “Crioulo” cashew rootstock at 55 DAS.
** $P < 0.01$

Despite the substantial reduction in stomatal opening, the intercellular CO₂ concentration (Figure 2A) decreased by only 2.13% per unit increase in irrigation water electrical conductivity, reaching a total reduction of 12.77 μmol of CO₂ m⁻² s⁻¹ (6%) between the highest and lowest ECw levels (3.1 and 0.3 dS m⁻¹, respectively). This fact demonstrates that CO₂ demand for photochemical processes was not significantly damaged by stomatal closure.

Potassium silicate doses caused a quadratic effect on Ci (Figure 2B), with the best results at the dose of 530 mg L⁻¹ (214.999 μmol of CO₂ m⁻² s⁻¹), 8.65% higher than that of plants under no foliar application of the product. This is related to the increase in stomatal conductance at the potassium silicate doses, promoting greater CO₂ entry through stomatal opening.

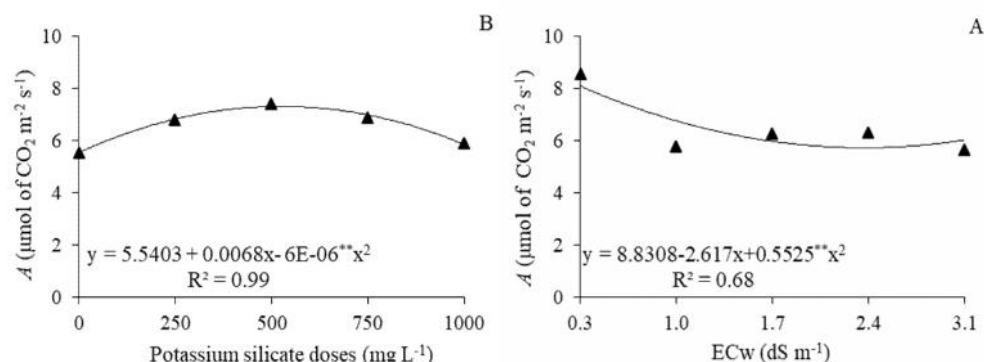


Figure 3. Isolated effect of irrigation water electrical conductivity (A) and potassium silicate doses (B) on CO₂ assimilation rate – A in "Crioulo" cashew rootstock at 55 DAS.

**** $P < 0.01$**

Regarding CO₂ assimilation rate as a function of irrigation water salinity (Figure 3A), as ECw increased there was a reduction in CO₂ assimilation and the maximum value of 8.10 $\mu\text{mol of CO}_2 \text{ m}^{-2} \text{ s}^{-1}$ was found at ECw of 0.3 dS m^{-1} . This type of behavior demonstrates that the decrease in photosynthesis is due not only to the reduction in stomatal opening, but also to the imbalance between production and removal of reactive oxygen species (ROS) generated during photosynthesis, causing metabolic alterations that culminate in oxidative damages such as lipid peroxidation, damages in cell membranes and degradation of proteins [15].

CO₂ assimilation rate showed a quadratic response as a function of the potassium silicate doses (Figure 3B), and the dose of 567 mg L^{-1} led to maximum value (7.46 $\mu\text{mol of CO}_2 \text{ m}^{-2} \text{ s}^{-1}$), which is 34.66% higher than that for plants under control treatment (dose 0) with potassium silicate (5.54 $\mu\text{mol of CO}_2 \text{ m}^{-2} \text{ s}^{-1}$). This result is due to the rise in K/N ratio in cashew leaves and increase in antioxidant enzymes by the silicon, which reduced the effect of sodium on the plant and, consequently, the nutritional imbalance, improving the photosynthetic processes [16,17].

A decreasing linear response was found for leaf transpiration rate (E), which diminished by 8.24% per unit increase in ECw. At electrical conductivity of 3.1 dS m^{-1} , this decline reached 23.08%, resulting in a reduction of 0.48 $\text{mmol of H}_2\text{O m}^{-2} \text{ s}^{-1}$ in transpiration when compared with plants under 0.3 dS m^{-1} salinity level. This circumstance may be related to an alternative to avoid the absorption of saline water by the plant, because it will maintain a lower sap flow and, consequently, lower absorption of toxic ions [5].

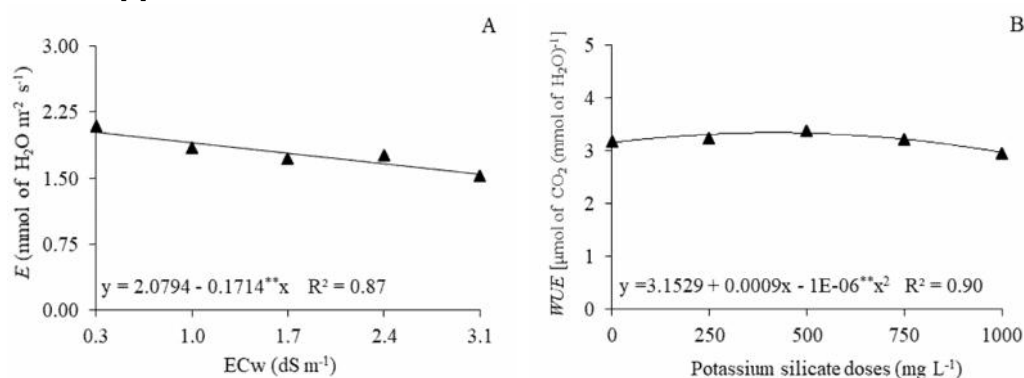


Figure 4. Isolated effects of irrigation water electrical conductivity on leaf transpiration rate – E (A) and of potassium silicate doses on water use efficiency – WUE (B) in "Crioulo" cashew rootstock at 55.

**** $P < 0.01$**

For water use efficiency, potassium silicate applications on "Crioulo" cashew rootstocks led to a quadratic effect according to the regression equation (Figure 4B), with maximum point at the

estimated dose of 450 mg L⁻¹, thus increasing WUE by 6.48% compared with plants under no application of the product. Such fact may be related to the formation of a cuticle-silica double layer in the stomata, which reduces transpiration and water demand by plants [17].

Based on the results of the analysis of variance (Table 3), irrigation water salinity and potassium silicate doses isolately had significant effect on all variables studied at 75 DAS (absolute growth rates in plant height and stem diameter; shoot and total dry phytomass; and Dickson quality index). Nonetheless, there was no significant effect of the interaction between factors (S x KD) on these variables.

Table 3. Summary of analysis of variance for absolute growth rates in plant height (AGR_{PH}) and stem diameter (AGR_{SD}), shoot dry phytomass (SDP), total dry phytomass (TDP) and Dickson quality index (DQI) of “Crioulo” cashew rootstock subjected to saline water irrigation and potassium silicate doses, at 75 days after sowing (DAS).

Source of variation	DF	Mean squares				
		AGR _{PH}	AGR _{SD}	SDP	TDP	DQI
Saline levels (SL)	4	0.0522 ^{**}	0.00039 ^{**}	2.43 ^{**}	4.086 ^{**}	0.030 ^{**}
Linear regression	1	0.1410 ^{**}	0.00117 ^{**}	7.99 ^{**}	15.59 ^{**}	0.074 ^{**}
Quadratic regression	1	0.0370 ^{**}	0.00008 ^{ns}	0.04 ^{ns}	0.009 ^{ns}	0.002 ^{ns}
Potassium silicate (PS)	4	0.0179 ^{**}	0.00008 [*]	1.52 ^{**}	2.174 [*]	0.021 [*]
Linear regression	1	0.0121 ^{ns}	0.00006 ^{ns}	0.15 ^{ns}	0.158 ^{ns}	0.031 [*]
Quadratic regression	1	0.0486 ^{**}	0.00026 ^{**}	5.55 ^{**}	7.812 ^{**}	0.048 [*]
Interaction (SL*PS)	16	0.0090 ^{ns}	0.00004 ^{ns}	0.21 ^{ns}	0.561 ^{ns}	0.004 ^{ns}
Blocks	2	0.0134 [*]	0.00002 ^{ns}	0.33 ^{ns}	2.187 [*]	0.0001 ^{ns}
CV (%)		14.06	15.91	10.90	13.23	15.14

^{**} $P < 0.01$; ^{*} $P < 0.05$; ^{ns} $P > 0.05$

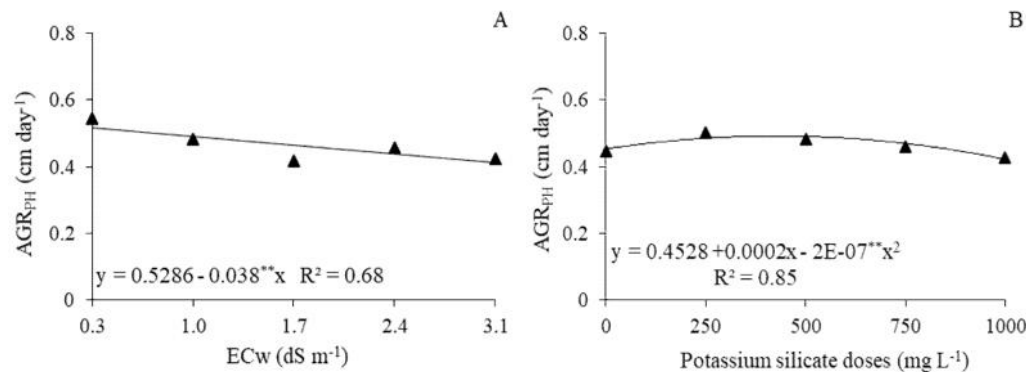


Figure 5. Isolated effect of irrigation water electrical conductivity (A) and potassium silicate doses (B) on the absolute growth rate in plant height – AGR_{PH} in “Crioulo” cashew rootstock at 55 DAS.
**** $P < 0.01$**

The absolute growth rate in plant height (AGR_{PH}) fitted best to a decreasing linear model as a function of the salinity levels (Figure 5A), with reduction of 7.19% per unit increase in ECw. The ECw of 3.1 dS m⁻¹ led to a reduction of 20.13% (0.106 cm day⁻¹) in comparison to plants subjected to ECw of 0.3 dS m⁻¹. [18] attribute these reductions to the effects of salts on cell turgor pressure, which reduces water content in the tissues, resulting in decrease of cell wall expansion, causing decline in plant growth. AGR_{PH} was also influenced by increasing potassium and silicon fertilization and, according to the regression equation, its response was quadratic (Figure 5B), with highest value (0.05 cm day⁻¹) at the estimated dose of 495 mg L⁻¹, which is 11.04% higher than that found in plants under no foliar application of the product. This effect is related to the photosynthetic gains of plants under foliar applications of potassium silicate, since they performed osmotic adjustment in their leaves by accumulating solutes, thus guaranteeing the maintenance of cell turgor and the consequent growth [16].

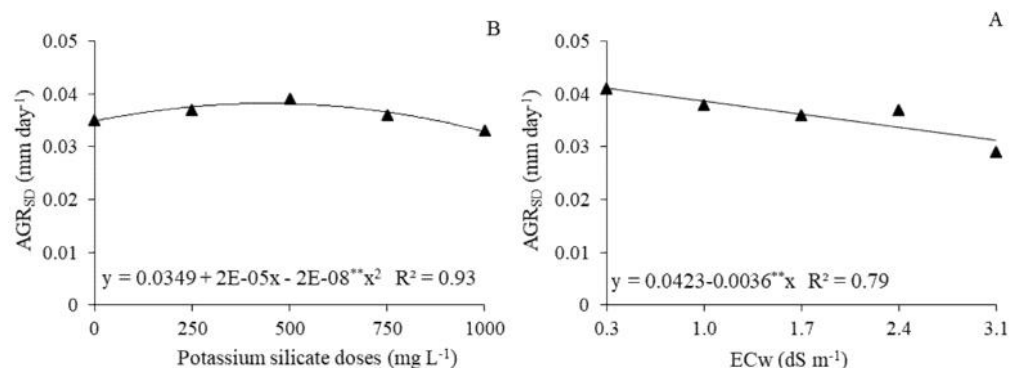


Figure 6. Isolated effect of irrigation water electrical conductivity (A) and potassium silicate doses (B) on the absolute growth rate in stem diameter – AGR_{SD} in “Crioulo” cashew rootstock at 55 DAS.
**** $P < 0.01$**

absolute growth rate in stem diameter (Figure 6A), increments in irrigation water salinity led to linear reductions of 8.51% per unit increase in ECw, which contributed to a total reduction of 0.010 mm day⁻¹ (23.83%) at ECw of 3.1 dS m⁻¹, in comparison to plants irrigated with salinity level of 0.3 dS m⁻¹. Such situation was also observed by Torres [3], studying the initial growth of early dwarf cashew from 10 to 70 days after germination. These authors attributed the decline caused by increased salinity to the diversion of energy substrates to processes of synthesis of organic compounds, osmotically active and necessary for compartmentalization and regulation in the transport of ions.

Regarding the factor potassium silicate doses, the best regression model for AGR^{SD} was the quadratic one (Figure 6B), with maximum gain at the dose of 485 mg L⁻¹, which was 14.33% superior to that found in the treatment with no application of the product. This effect may be related to the stimulus caused by potassium silicate in N use by the plant, allow for increments in absorption, assimilation, nutrition and, consequently, yield [4].

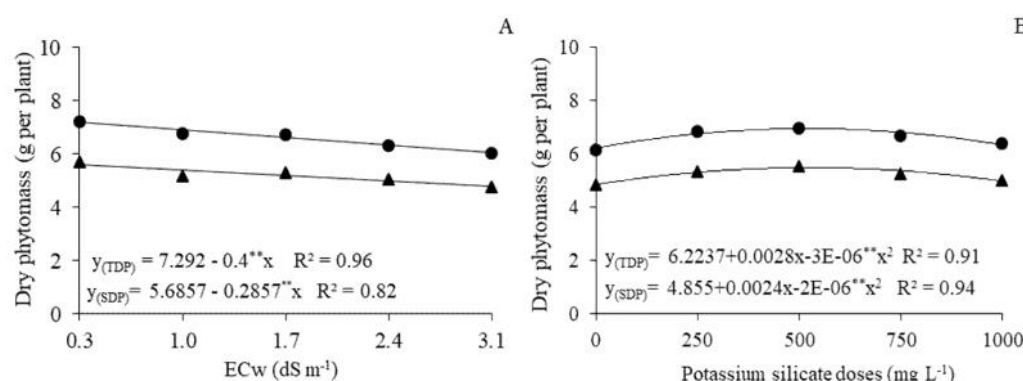


FIGURE 7. ISOLATED EFFECT OF IRRIGATION WATER ELECTRICAL CONDUCTIVITY AND POTASSIUM SILICATE DOSES on shoot dry phytomass – SDP (A) and total dry phytomass – TDP (B) of “Crioulo” cashew rootstock at 75 DAS.

****P<0.01**

Increasing ECw levels negatively affected the phytomass production of “Crioulo” cashew rootstock (Figure 7A), causing reductions of 5.02% and 5.48% per unit increase in ECw for SDP and TDP, respectively. The highest saline level led to reductions of 0.8 g (14.06%) in SDP and 1.12 g (15.39%) in TDP, compared with plants irrigated with 0.3 dS m⁻¹ water. According to [14] losses of phytomass accumulation in plants under saline stress result from the abscission and reduction of leaf area, due to the early senescence caused by the toxic action of the excess salts in the irrigation water.

According to the regression equation (Figure 7B), the increment in potassium silicate doses caused quadratic effect on shoot dry phytomass and total dry phytomass, with maximum values found at doses of 600 mg L⁻¹ (5.57 g) for SDP and 465 mg L⁻¹ (5.57 g) for TDP, i.e., 14.83% and 10.51% higher than the values found in control plants, respectively. This increase results from the improvements in metabolism and photosynthesis, previously observed, due to potassium silicate.

For the Dickson quality index -DQI (Figure 8A), cashew rootstocks showed a linear reduction of 4.68% per unit increase in ECw, which led to a total reduction of 13.10% at the highest salinity level, compared with the ECw of 0.3 dS m⁻¹. Despite the substantial reduction, cashew seedlings at ECw of 3.1 dS m⁻¹ still had DQI higher than 0.5, being considered as of good quality for the establishment at the field, because the DQI was higher than 0.2 [12].

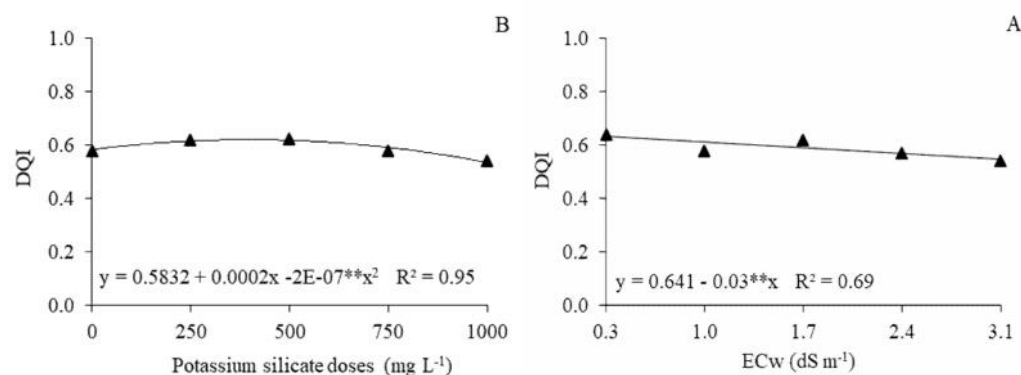


Figure 8. Isolated effect of irrigation water electrical conductivity (A) and potassium silicate doses (B) on Dickson quality index – DQI of “Crioulo” cashew rootstock at 75 DAS.
** $P < 0.01$

Increasing doses of potassium silicate caused quadratic effect on DQI (Figure 8B) and, according to the regression equation, maximum value of 0.63 was obtained in plants subjected to 500 mg L⁻¹. This value was 8,57% superior to that obtained in plants under no application of the product. This result demonstrates the improvements in seedling quality caused by the silicate, since DQI calculation takes into account the robustness and balance in phytomass distribution, thus considering several important parameters.

4. CONCLUSION

Gas exchanges, growth, phytomass production and DQI of cashew rootstocks are reduced by increasing irrigation water salinity, but irrigation with 1.7 dS m⁻¹ water causes acceptable reduction of 10% in the morphophysiology of “Crioulo” cashew;

The estimated potassium silicate dose of 524,78 mg L⁻¹ led to improvements in the physiology, morphology and quality of the cashew rootstocks.

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