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IRRIGATION WITH SALINE WATER AND SILICATE FERTILIZATION IN THE CULTIVATION OF 'GIGANTE AMARELO' PASSION FRUIT[1]

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ABSTRACT - The Brazilian Northeast region suffers from some abiotic stresses that are responsible for the loss of agricultural production, such as long drought periods and high evapotranspiration, associated with the quality of the water, which induces the use of saline water as an alternative for the expansion of irrigated areas, and silicate fertilization contributes to reduce the effects of salinity under the Northeastern semi-arid conditions. The objective of this study was to evaluate the osmotic potential and physiological indices of yellow passion fruit seedlings under irrigation water salinity and silicate fertilization. The experiment was carried out under greenhouse conditions at the Federal University of Campina Grande, Pombal-PB, Brazil, in a randomized block design in a 5 x 5 factorial scheme, relative to five levels of electrical conductivity of irrigation water - ECw (0.3; 1.0; 1.7; 2.4 and 3.1 dS m^{-1}) and five doses of silicate fertilization (0; 25; 50; 75 and 100 g silicon per plant) in four replicates and two plants per plot. The application of 50, 75 and 100 g silicon per plant reduced the osmotic potential in the leaf tissues of 'Gigante Amarelo' passion fruit plants. Water salinity lower than 1.3 dS m^{-1} resulted in an increase in chlorophyll *b* content; increase in carotenoid content was observed in plants subjected to silicon doses of 25 and 100 g per plant. Salinity levels above 1.1 dS m^{-1} compromised the performance of photosystem II of passion fruit plants when subjected to silicon doses.

Keywords: *Passiflora edulis* f. flavicarpa. Salinity. Silicon.

IRRIGAÇÃO COM ÁGUAS SALINAS E ADUBAÇÃO SILICATADA NO CULTIVO DE MARACUJAZEIRO GIGANTE AMARELO

RESUMO - O Nordeste brasileiro sofre com alguns estresses abióticos que são responsáveis pela perda de produção agrícola, como os longos períodos de estiagem e elevada evapotranspiração, associado à qualidade das águas que induz ao uso de águas salinas como alternativa para expansão das áreas irrigadas, com isto a adubação silicatada contribui para redução dos efeitos da salinidade nas condições de semiárido nordestino. Objetivou-se avaliar o potencial osmótico e os índices fisiológicos de mudas de maracujazeiro amarelo sob salinidade da água de irrigação e adubação silicatada. O experimento foi desenvolvido em condições de casa de vegetação na Universidade Federal de Campina Grande, Pombal-PB, em delineamento de blocos ao acaso em esquema fatorial 5 x 5, relativo a cinco níveis de condutividade elétrica da água de irrigação - CEa (0,3; 1,0; 1,7; 2,4 e 3,1 dS m^{-1}) e cinco doses de adubação silicatada (0; 25; 50; 75 e 100 g de silício por planta) em quatro repetições e duas plantas por parcela. A aplicação de 50, 75 e 100 g por planta de silício reduziu o potencial osmótico nos tecidos foliares das plantas de maracujazeiro 'Gigante Amarelo'. A salinidade da água menor que 1,3 dS m^{-1} resultou em incremento no conteúdo de clorofila *b*; aumento nos teores de carotenoides foi verificado nas plantas submetidas as doses de 25 e 100 g de silício. Níveis salinos acima de 1,1 dS m^{-1} comprometeram o desempenho do fotossistema II das plantas de maracujazeiro quando submetidas as doses de silício.

Palavras-chave: *Passiflora edulis* f. flavicarpa. Salinidade. Silício.

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INTRODUCTION

Passion fruit (*Passiflora edulis* f. flavicarpa) is cultivated in almost all Brazilian territory, by small, medium and large producers, mainly in family farming, generating employment and income and showing socioeconomic importance, due to the internal and external consumer markets, for both fresh fruit and various products, such as juices, sweets and jams (JESUS et al., 2018a).

Yellow passion fruit is considered a short-cycle plant, with the beginning of production between 6 and 9 months after planting, having a production cycle of two years or less in the Brazilian producing regions. Thus, this crop requires a greater investment by the producer in the acquisition of high -quality seedlings, and seedling production a crucial phase in the development of plants to obtain good yields (SILVA, 2012).

In addition, the Northeast region has low rainfall, irregular rains and high water losses by evaporation, with more than 60% of areas under semiarid climate (MEDEIROS et al., 2012), which leads to high concentrations of salts in groundwater, artesian wells, rivers and dams, affecting the quality of water that is destined for irrigation, among other purposes. Salinity causes lower water availability to plants due to decrease in the osmotic potential of the soil solution, reducing it to the point that the plant cannot extract water easily (LIMA et al., 2018). Thus, these stresses can originate naturally, when related to pedogenesis, or from anthropogenic action, when it causes the greatest economic impact (JAYAKANNAN et al., 2015).

Among the alternatives to reduce the deleterious effects of salinity on plants, silicon (Si) has shown a promising action. Si brings several benefits for crops regarding tolerance to salt stress, such as increase in photosynthetic rate and in the capacity of antioxidant defense under water deficit (JESUS et al., 2018b). Studies have shown beneficial effects of Si on some crops (tomato, maize) when subjected to salt stress conditions, with increase in leaf area, chlorophyll content and improvement of chloroplast structure, which increase photosynthetic activity, causing plants to develop better even under stress conditions (TAHIR et al., 2012; KIM et al., 2017).

In this context, the objective of the present study was to evaluate the osmotic potential, photosynthetic pigments and photochemical efficiency of yellow passion fruit as a function of irrigation with water of different salinity levels and silicate fertilization.

MATERIAL AND METHODS

The experiment was conducted under greenhouse conditions at the Center ofSciences and Agrifood Technology of the Federal University of Campina Grande, in the municipality of Pombal-PB, Brazil, located at 6º47'3" S, 37º49'15" W and altitude of 193 m.

The design was in randomized blocks, with the treatments arranged in a 5 x 5 factorial scheme, corresponding to five levels of electrical conductivity of irrigation water - ECw (0.3; 1.0; 1.7; 2.4 and 3.1 dS m^{-1}) and five silicon doses (0; 25; 50; 75 and 100 g silicon per plant) with two plants per plot and four replicates, totaling 200 experimental units. Water salinity levels were established based on studies conducted by Andrade et al. (2019), who evaluated ECw ranging from 0.7 to 2.8 dS m^{-1}. The ECw levels were prepared by the addition of iodine-free sodium chloride (NaCl), with 99% purity, in the municipal supply water of the city of Pombal-PB (0.3 dS m^{-1}), following the relationship between the concentration of salts (Cs) and the desired electrical conductivity-ECw (RICHARDS, 1954) through the following expression: Cs = 640 x(ECw – 0.3 dS m^{-1}).

Where: Cs = Concentration of sodium chloride (mg L^{-1});

ECw = Pre-established electrical conductivity (dS m^{-1}).

The Si doses were supplied through potassium silicate (50% SiO_2 and 4% K_2O). This product is a multi-mineral compound that also contains selenium, vanadium, calcium, zinc, phosphorus and other trace elements.

The seedlings originated from seeds of hybrid 'BRS Gigante Amarelo' passion fruit (BRS GA1) adapted to altitudes between 376 and 1,100 m, planted at any time of the year, bearing fruits that weigh from 120 to 350 g and with pulp yield generally above 40% (JESUS et al., 2017).

The seedlings were grown in plastic bags with dimensions of 15 x 20 cm and capacity of 1,25 dm^3, filled with 2:1:1 substrate (soil, sand and decomposed cattle manure) on a volume basis. Soil moisture content was increased to field capacity using water with the lowest salinity level (ECw = 0.3 dS m^{-1}), adding water until free drainage occurred. Two seeds were sown per bag and thinning was performed 7 days after seedling emergence, leaving only one plant per container, when they were about 10 cm tall.

Irrigation was performed daily, manually, applying water of the respective treatment and was based on the drainage lysimetry principle (BERNARDO; SOARES; MANTOVANI, 2013). The volume applied in each irrigation event was determined by the difference between the volume applied and the volume drained in the previous event, plus a leaching fraction of 0.15 applied every 20 days. Irrigation with saline water started 30 days after sowing (DAS) and was performed daily until 60 DAS.

Silicon doses were applied dissolved in irrigation water from 30 DAS, weekly, totaling four applications of 0, 6.25, 12.5, 18.75 and 25 g per plant until 60 DAS. The physical and chemical characteristics (Table 1) of the substrate used for producing the seedlings were determined according to the methodology of Teixeira et al. (2017).

Table 1. Physical and chemical characteristics of the soil used for the production of yellow passion fruit seedlings.

Chemical characteristics									
pH (H_2O) (1:2.5)	OM (dag kg^{-1})	P (mg kg^{-1})	K^+	Na^+	Ca^{2+}	Mg^{2+}	$H^+ + Al^{3+}$	ESP (%)	ECse (dS m^{-1})
			....(cmol$_c$ kg^{-1})................................						
7.00	3.80	11.99	0.38	0.09	2.42	5.84	0.00	1.05	0.75
Physical characteristics									
Size fraction (g kg^{-1})			Textural class	Water content (kPa)		AW	Total porosity (%)	BD	PD
Sand	Silt	Clay		33.42	1519.5 (dag kg^{-1})	....		------(kg dm^{-3})------	
853.00	130.70	16.30	LS	11.60	4.23	6.93	44.20	1.50	2.69

OM - Organic matter: Walkley-Black Wet Digestion; Ca^{2+} and Mg^{2+} extracted with 1 M KCl at pH 7.0; Na^+ and K^+ extracted using 1 M NH4OAc at pH 7.0; H^+ + A^{l3+} extracted using 0.5 M CaOAc at pH 7.0; ESP – Exchangeable sodium percentage; ECse - electrical conductivity of the soil saturation extract; LS - Loamy sand; AW - Available water; BD - Bulk density; PD - Particle density.

Nitrogen and potassium fertilization was performed weekly; potassium fertilization was based considering the content of the element existing in potassium silicate. Phosphorus fertilization was applied as basal dose according to Santos (2001). In fertilization, the sources of nitrogen, phosphorus and potassium were urea, MAP and potassium chloride, respectively.

NPK fertilization was performed with the dose of 100 mg of N, 150 mg of K_2O and 300 mg of P_2O_5 kg^{-1} of soil. The following quantities were applied per plant: 0.217 g of urea, 1.4 g of monoammonium phosphate and 0.56 g of potassium chloride, split into 4 portions and supplied through fertigation, from 20 DAS.

Micronutrient applications were performed weekly from 30 DAS using the commercial product Quimifol (N - 14%; P_2O_5 - 18%; K_2O - 20%; Mg - 1%; S - 1.50%; B - 0.03%; Mn - 0.10%; Mo - 0.02%; Zn - 0.10%) in concentration of 0.5 g L^{-1} (CAVALCANTI, 2008). Cultural practices and phytosanitary treatments were performed as needed.

At 60 DAS, when passion fruit seedlings were in conditions for field transplanting, their leaves were evaluated for osmotic potential, photosynthetic pigments (chlorophyll *a*, chlorophyll *b* and carotenoids) and photochemical efficiency (initial fluorescence - Fo, maximum fluorescence - Fm, variable fluorescence - Fv and quantum efficiency of photosystem II - Fv/Fm).

Osmotic potential was determined extracting leaf sap. Leaves were placed inside an Eppendorf tube previously perforated at the base, which functioned as a mini-filter. A glass rod was then used to press the leaf tissue, extracting the sap, which was collected in another Eppendorf tube. After that, the extract was centrifuged at 10,000 x g for 10 min at 4 ºC. A 10-µL aliquot of the supernatant was used to determine the osmolality of the passion fruit leaf tissue using a vapor pressure osmometer, Wescor® 5520 model. Osmotic potential values were obtained from the osmolality (mmol kg^{-1}) of the leaf tissue sap, using the van't Hoff equation (SOUZA et al., 2012) and then converted into MPa, according to equation 1:

$$\psi s\ (\text{MPa}) = -C\left(\frac{mOsmol}{kg}\right) x\ 2.58\ x\ 10^{-3} \quad (1)$$

where:

Ψs = leaf osmotic potential, MPa

C= osmolality of the sample, found in the osmometer reading.

Chlorophyll *a*, chlorophyll *b* and carotenoid contents were determined by the analytical method of Arnon (1949), using samples of five discs of the blade of the third leaf from the apex. In the extracts, the concentrations of chlorophyll and carotenoids were determined in the solutions with spectrophotometer at absorbance wavelength (ABS) of 470, 646, and 663 nm, using equations 2, 3 and 4:

$$\text{Chlorophyll } a \text{ (Chl } a) = 12.21 \text{ ABS663} - 2.81 \text{ ABS646} \quad (2)$$

$$\text{Chlorophyll } b \text{ (Chl } b) = 20.13 \text{ ABS646} - 5.03 \text{ ABS663} \quad (3)$$

$$\text{Total carotenoids (Car)} = (1000 \text{ ABS470} - 1.82 \text{ Chl } a - 85.02 \text{ Chl } b)\ /198 \quad (4)$$

The values obtained for chlorophyll *a*, chlorophyll *b* and carotenoid contents in the leaves were expressed in mg g^{-1} of fresh matter (mg g^{-1} FM).

The photochemical efficiency of passion fruit was determined based on the initial fluorescence (Fo), maximum fluorescence (Fm), variable fluorescence (Fv), quantum efficiency of PSII (Fv/Fm), in leaves pre-adapted to the dark using leaf clips for 30 minutes, between 7:00 and 8:00 a.m., in the median leaf of the seedling, using a pulse-modulated fluorometer, OS5p model from Opti Science.

The data were subjected to analysis of variance by F test ($p<0.05$ and $p<0.01\%$), and the means relative to the salinity x silicon interaction or to the individual effects of each of the sources of variation were analyzed by polynomial regression using the program Sisvar for data processing.

RESULTS AND DISCUSSION

The interaction between water salinity and silicon doses (Table 2) had significant effects on photosynthetic pigments (Chl *a*, Chl *b* and Car) and on leaf osmotic potential (ψs) of passion fruit seedlings at 60 DAS. This statistical behavior of the effects indicates a joint action of both sources (saline levels and silicon doses) of variation on the respective variables.

Table 2. Summary of the analysis of variance for osmotic potential (ψs) and contents of chlorophyll *a* (Chl *a*), chlorophyll *b* (Chl *b*) and carotenoids (Car) of ‘Gigante Amarelo’ passion fruit plants cultivated under irrigation water salinity and silicon doses, at 60 days after sowing.

Source of variation	DF	Mean squares			
		Ψs	Chl *a*	Chl *b*	Car
Saline levels (SL)	4	0.19^{**}	10.90^{*}	1.05^{*}	0.18^{ns}
Linear regression	1	0.71^{**}	16.59^{*}	1.52^{ns}	0.18^{ns}
Quadratic regression	1	0.005^{ns}	0.44^{ns}	1.25^{ns}	0.21^{ns}
Silicon doses (SD)	4	0.022^{ns}	1.20^{ns}	1.45^{*}	0.64^{*}
Linear regression	1	0.022^{ns}	9.05^{ns}	0.0034^{ns}	0.095^{ns}
Quadratic regression	1	0.046^{ns}	0.49^{ns}	1.07^{ns}	0.09^{ns}
Interaction (SL x SD)	16	0.026^{*}	8.47^{*}	1.68^{**}	0.44^{*}
Blocks	3	0.01^{ns}	10.19^{*}	1.80^{**}	0.12^{ns}
Residue	72	0.01	4.30	0.41	0.24
CV (%)		11.10	19.25	16.23	20.61

ns, *, **, respectively not significant, significant at $p<0.05$ and significant at $p<0.01$; DF - Degree of freedom; CV – Coefficient of variation.

For the leaf osmotic potential of plants (Figure 1A), there was a decreasing linear behavior with the increase in water salinity, with losses of 12.13, 14.28 and 10.62% per unit increase in the electrical conductivity of irrigation water in plants fertilized with silicon doses 0, 25 and 75 g per plant, respectively. In the same figure, it is also possible to observe that the increase in water salinity initially reduced the osmotic potential of the leaf sap to the lowest estimated values of -1.07 and -1.16 MPa among plants irrigated with water of 1.7 and 1.8 dS m^{-1} and fertilized with 50 and 100 g silicon per plant, respectively. However, water salinity above 1.7 and 1.8 dS m^{-1} increased the leaf osmotic potential to the highest values.

Reduction in the osmotic potential as a function of the increase of salt concentration in irrigation water is a response of the plant, to adjust the potential gradient and continue absorbing water and nutrients (CRUZ et al., 2018). Plants fertilized with Si doses of 50, 75 and 100 g per plant showed a lower reduction of osmotic potential. This lower reduction may be due to the deposition of the element in the leaf wall, increasing the strength and firmness of the cell walls, reducing cuticular transpiration and consequently increasing the intrinsic water use efficiency, evidencing a positive point for acclimation of the plant under saline conditions (JESUS et al., 2018b).

The leaf contents of chlorophyll *a* (Figure 1B) of yellow passion fruit increased by 18.15 and 8.52% per unit increase in ECw between plants under 0 and 25 g silicon per plant, respectively. Plants fertilized with 50, 75 and 100 g per plant of Si produced the highest estimated contents of chlorophyll *a* (11.80, 12.22 and 11.74 mg g^{-1} FM), irrigated with waters of 1.6, 1.0 and 2.5 dS m^{-1}, respectively, with a subsequent reduction.

Salt stress reduces the osmotic potential of soil water, reduces the absorption of water and nutrients, and causes the closure of stomata so that the plant can reduce water losses by transpiration, which consequently inhibits photosynthetic activity (REIS et al., 2016). According to Costa et al. (2018), after accumulating in plant cell walls, silicon reduces water loss through stomata and increases photosynthetic rate and the contents of photosynthetic pigments.

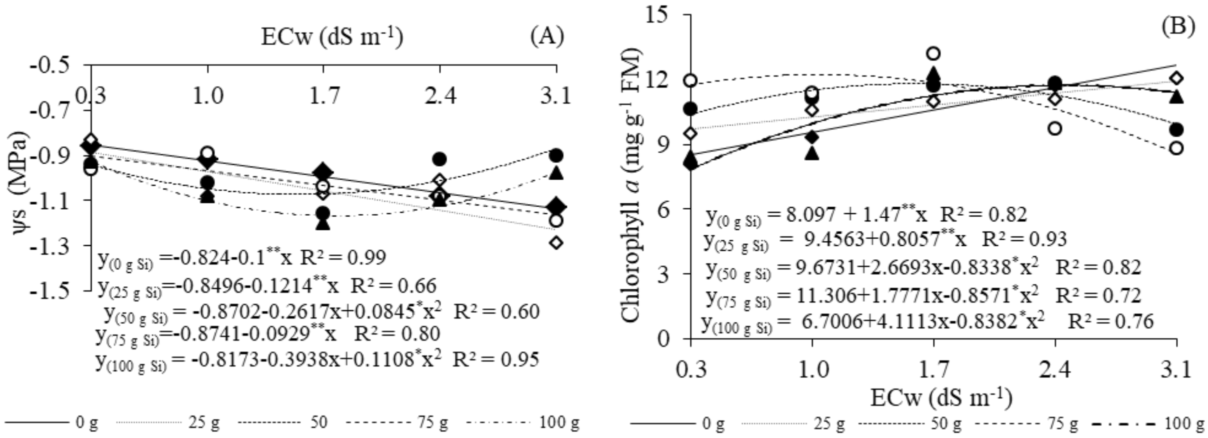

Figure 1. Leaf sap osmotic potential – ψs (A) and chlorophyll *a* content (B) of ‘Gigante Amarelo’ passion fruit plants as a function of the interaction between water salinity – ECw and silicate fertilization, at 60 days after sowing.

The highest contents of chlorophyll *b* (Figure 2A) of 4.98, 4.41, 4.18, 4.53 and 3.96 mg g^{-1} FM were quantified in plants irrigated using water with estimated ECw of 2.7, 0.7, 1.7, 0.8 and 1.6 dS m^{-1}, respectively, in soil without (0) and with 25, 50, 75 and 100 g silicon per plant. Irrigation with waters above each estimated value led to reduction in chlorophyll *b* contents in passion fruit leaves, regardless of silicon dose. However, the application of silicon at doses of 50 and 75 g under low water salinity (1.7 dS m^{-1}) resulted in increments in chlorophyll *b* content. According to Munns and Tester (2008), losses in chlorophyll contents are responses to the deleterious effects of excess salts in irrigation water, compromising physiological and biochemical activities. Under salt stress, the activity of the chlorophyllase enzyme, which degrades molecules of the photosynthesizing pigment, is stimulated and causes destruction of chloroplasts, with effect on the loss of the activity of pigmentation proteins.

Cavalcante et al. (2011) evaluated chlorophyll and carotenoid contents in yellow passion fruit irrigated with saline water (ECw ranging from 0.5 to 4.5 dS m^{-1}) and found that the increase in irrigation water salinity up to 2.5 dS m^{-1} did not compromise the biosynthesis of these pigments, but ECw levels greater than 2.5 dS m^{-1} hampered the photosynthetic efficiency of the plants.

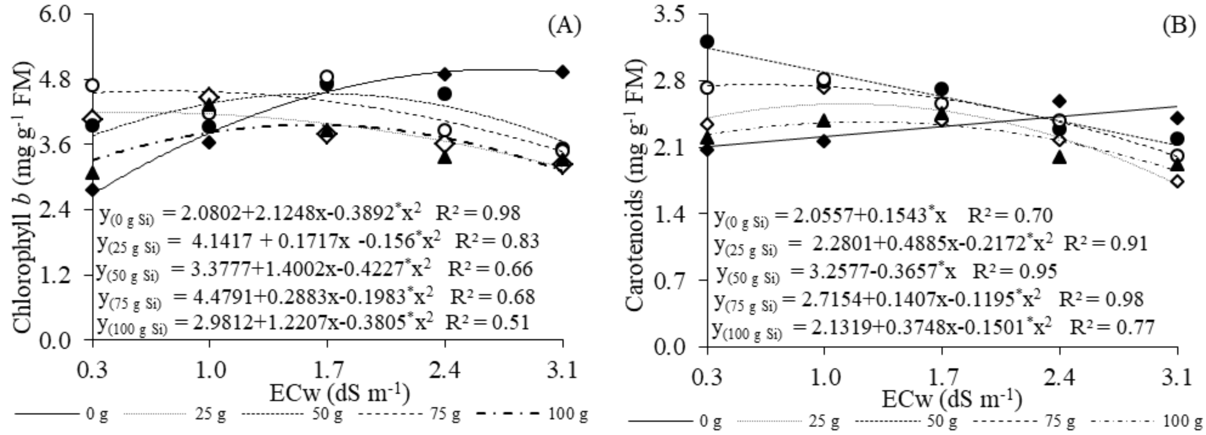

Figure 2. Contents of chlorophyll *b* (A) and carotenoids (B) in ‘Gigante Amarelo’ passion fruit plants as a function of the interaction between water salinity – ECw and silicon doses, at 60 days after sowing.

The increase in the salt concentration of the waters increased carotenoid contents in plants that did not receive Si application (0 g Si per plant), with an increment of 7.50% per unit increase in ECw. However, plants that received 50 g of Si per plant showed a linear decrease of 11.22% per unit increase in ECw (Figure 2B). On the other hand, plants treated with doses of 25, 75 and 100 g per plant produced the highest estimated values of carotenoids of 2.55, 2.75 and 2.36 mg g^{-1} FM, under irrigation using water with estimated salinity levels of 1.2, 0.8 and 1.4 dS m^{-1}, respectively. The increase in carotenoid contents in passion fruit plants fertilized with Si doses of 25, 75 and 100 g may be related to the fact that this element increases antioxidant action from non-enzymatic compounds such as carotenoids, significantly reducing chlorophyll degradation as well as oxidative stress, which is a consequence of excess salts (KIM et al., 2017).

According to the summary of the analysis of variance (Table 3), as observed for the contents of chlorophyll, carotenoids and leaf osmotic potential (Table 2), the interaction between salinity and silicate fertilization significantly influenced fluorescence and quantum yield of yellow passion fruit seedlings at 60 days after sowing.

Table 3. Summary of the analysis of variance for initial fluorescence (Fo), variable fluorescence (Fv), maximum fluorescence (Fm) and quantum efficiency of photosystem II (Fv/Fm) of ‘Gigante Amarelo’ passion fruit plants cultivated under irrigation water salinity and silicon doses, at 60 days after sowing.

Source of variation	DF	Mean squares			
		Fo	Fv	Fm	Fv/Fm
Saline levels (SL)	4	115798.46**	1322463.39**	541627.30**	0.036**
Linear regression	1	893.23^{ns}	452390.71**	7248.08^{ns}	0.11**
Quadratic regression	1	37955.71*	1082611.83**	132428.50^{ns}	0.021^{ns}
Silicon doses (SD)	4	12445.84^{ns}	417603.48**	53218.72^{ns}	0.028**
Linear regression	1	121734.44**	3871328.40**	1139287.50**	0.13**
Quadratic regression	1	5414.88^{ns}	88007.14^{ns}	38622.50^{ns}	0.0054^{ns}
Interaction (SL x SD)	16	33716.82**	342333.67**	112588.21**	0.037**
Blocks	3	4878.83^{ns}	22033.46^{ns}	33810.92^{ns}	0.0053^{ns}
Residue	72	6566.30	51111.19	42206.78	0.0061
CV (%)		9.42	8.78	5.77	10.83

ns, *, **, respectively not significant, significant at $p<0.05$ and significant at $p<0.01$; DF - Degree of freedom; CV – Coefficient of variation.

Seedlings cultivated in soil without (0) and with 25 and 50 g silicon per plant showed the highest initial fluorescence of 998.24, 942 and 955.7 when irrigated using water with electrical conductivity of 1.1, 0.8 and 0.3 dS m^{-1}, whereas irrigation with waters above this ECw level led to reduction in the initial fluorescence of plants (Figure 3A). On the other hand, the increase in water salinity level caused losses of 2.76 and 7.82% per unit increase in ECw in the treatments with 75 and 100 g of Si per plant. The reduction in fluorescence in plants grown under salt stress conditions is caused by changes in the state of the thylakoid membranes of chloroplasts, thus triggering changes in the characteristics of fluorescence signals (LIMA et al., 2018).

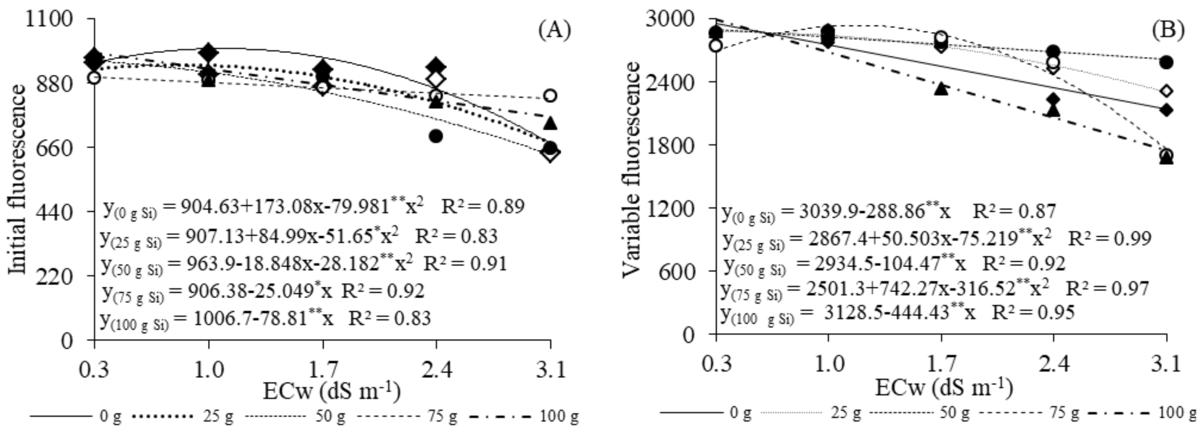

Figure 3. Initial fluorescence – Fo (A) and variable fluorescence – Fv (B) of ‘Gigante Amarelo’ passion fruit plants as a function of the interaction between water salinity - ECw and silicon doses, at 60 days after sowing.

According to Lucena et al. (2012), the initial fluorescence has an intrinsic relationship with fluorescence when quinone, which is the primary electron receptor of photosystem II, is completely oxidized, while the reaction center is open, thus indicating the activation of photochemical reactions in cells. Therefore, it is denoted that salinity levels above 1.1 dS m^{-1} affect the performance of photosystem II of passion fruit plants, also indicating the presence of this stress.

The increase in water salinity reduced the variable fluorescence of 'Gigante Amarelo' passion fruit with losses of 9.5, 3.5 and 14.2% per unit increase in ECw in plants fertilized with 0, 50 and 100 g of Si g per plant (Figure 3B). In plants under silicon doses of 25 and 75 g per plant, the increase in water salinity up to 0.6 and 1.2 dS m^{-1}, respectively, stimulated variable fluorescence up to the estimated maximum values of 2870.62 and 2936.23.

With regard to maximum fluorescence (Figure 4A), plants under 75 g of Si per plant had the highest value of 3682.2 under irrigation with waters of up to 1.3 dS m^{-1}. On the other hand, plants that did not receive Si (0 g Si per plant) and those that received 25, 50 and 100 g $plant^{-1}$ showed losses of 4.88, 3.56, 3.96 and 6.11% per unit increase in ECw. These reductions correspond to losses of 13.88, 10.06, 11.22 and 17.45%, respectively, between plants irrigated using water with the lowest and highest levels of electrical conductivity.

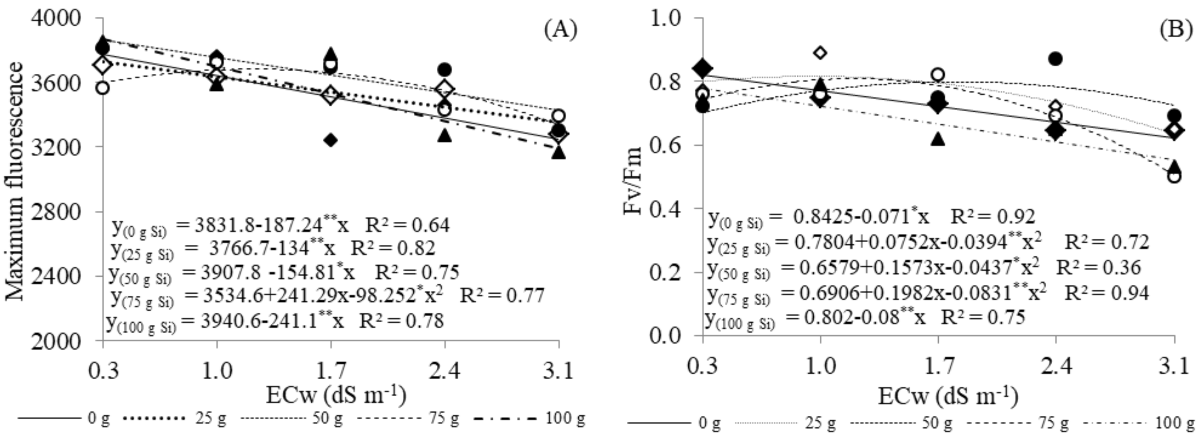

Figure 4. Maximum fluorescence - Fm (A) and quantum efficiency of photosystem II (Fv/Fm) (B) of 'Gigante Amarelo' passion fruit plants as a function of the interaction between water salinity levels – ECw and silicon doses at 60 days after sowing.

As observed for variable fluorescence (Figure 3B), the Si dose of 75 g per plant also promoted higher maximum fluorescence (Fm) in plants irrigated with water of up to 1.3 dS m^{-1}. Silicon contributed to the elimination of reactive oxygen species (ROS), due to the activation of the components responsible for the plant's defense system, which are the enzymes catalase and ascorbate peroxidase, involved in the conversion of hydrogen peroxide into water (KIM et al., 2017). This application also induces the second form of defense used by plants, which is through carotenoids.

The increase in water salinity from 0.3 to 3.1 dS m^{-1} inhibited by 24.2 and 28.7% the quantum efficiency of photosystem II (Fv/Fm) in plants that did not receive Si (0 g Si per plant) and those that received 100 g of Si per plant (Figure 4B). In the respective figure, it can be observed that the increase in water salinity to up to 1.0, 2.2 and 1.4 dS m^{-1} increased the quantum yield to the highest estimated values (0.81, 0.79 and 0.80) in plants grown in soil with 25, 50 and 75 g silicon per plant, as observed.

The reduction in quantum efficiency of photosystem II can be explained by the consequences of accumulations of Na^+ and Cl^- in chloroplasts, which directly affects the photosynthetic process, causing changes in the total content of pigments such as chlorophyll, reducing the performance of photosynthetic enzymes and also limiting the transport of electrons in chloroplasts, leading to reductions in the photochemical efficiency of photosystem II (HUANG et al., 2012).

The results related to the linear decrease and those obtained in plants irrigated using waters with salinity above the estimated maximum are in agreement with Freire et al. (2014), who evaluated quantum yield and gas exchange in yellow passion fruit under water salinity and concluded that salt stress inhibited the photochemical activity of photosystem II and net photosynthesis of plants. Also according to these authors, water salinity causes damage to the photosynthetic apparatus of passion fruit plants, compromising photosystem II depending on the time of exposure of plants to salt stress.

CONCLUSIONS

Application of 50, 75 and 100 g silicon per plant reduces the osmotic potential in the leaf tissues of 'Gigante Amarelo' passion fruit plants. Water salinity lower than 1.3 dS m^{-1} favors greater increase in chlorophyll *b* content; increase in carotenoid content is observed in plants subjected to Si doses of 25 and 100 g per plant. Salinity levels above 1.1 dS m^{-1} compromise the performance of photosystem II of passion fruit plants when subjected to silicon doses.

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