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REGULAR ARTICLE

Salt stress and ambience in the culture of yellow passion-fruit

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Abstract

Salt stress negatively affects the emergence and initial growth of crops. However, the use of protected environments emerges as an alternative to enhance these parameters. In this sense, the objective was to evaluate the effect of different environments and the salinity of the irrigation water on the emergence and development of yellow passion-fruit seedlings. The experiment was conducted at the University for International Integration of the Afro-Brazilian Lusophony, in the city of Redenção, Ceará. The experimental design was entirely randomized in a subdivided plot scheme, with four cultivation environments under different shading screens (black screen; white screen; red screen; all with 50% shading; and full sun), and two electrical conductivities of irrigation water: 0.3 dS m^{-1} and 3.0 dS m^{-1}, with five repetitions of 25 seeds. The protected environment with 50% black roofing stood out from the others providing a better percentage of emergence, seedling height, stem diameter, number of leaves and radicle length in yellow passion-fruit. The deleterious effects of salts on the rate of emergence and shoot dry matter were reduced when the 50% black shade cloth was used. Irrigation with water of higher conductivity caused reductions and retardation in the emergence of passion-fruit. Besides negatively affecting seedling height, stem diameter and shoot dry matter.

Keywords

Passiflora edulis; shading screens; salinity; emergence.

Introduction

The semi-arid region presents scarce water resources with respect to water quality, as in the Brazilian Northeast. Thus, the water used for agricultural production in these regions has a high concentration of salts, which results in the accumulation of specific ions in the soil, causing morphophysiological and nutritional disturbances and even toxicity in crops in these agrosystems (Sales et. al., 2021; Sousa et. al., 2020).

In addition, irrigation water salinity can affect germination processes and seed vigor, impairing water uptake and/or causing an uptake of toxic ions by soaked seeds, also reducing initial growth (Freire et al., 2018, Silva Junior et al., 2020).

The yellow passion fruit (Passiflora edulis f. flavicarpa Deg.) is a moderately sensitive crop to salinity of irrigation water presenting threshold tolerance of 2.3 dS m^{-1} (Ayers & Westcot, 1999). It has great economic importance, and has become an alternative for several producers, but the use of seeds in the production of seedlings has been an obstacle in its propagation, with frequent reports of inhomogeneity and low germination of seeds mainly under irrigation with saline water (Freitas et. al., 2015; Freire et. al., 2018).

Agricultural ambience has been used to uniformize and decrease environmental effects such as solar radiation and extreme temperatures, becoming an important factor in the establishment and uniformity of orchards, in addition, it offers better conditions for emergence and initial growth even under salinity conditions (Goes et al., 2019; Natale et al., 2018; Silva Junior et. al., 2020).

Thus, it was aimed to evaluate the effect of different environments and salinity of irrigation water on the emergence and development of yellow passion fruit seedlings.

Materials and methods

The experiment was conducted between the months of September and October 2019, in the Auroras Seedling Production Unit (UPMA) belonging to the University for International Integration of the Afro-Brazilian Lusophony (UNILAB), Redenção, Ceará (latitude 4º 13' 33" S and longitude 38º 43'39" E). The climate of the region according

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to Köppen (1923) is classified as Aw', Tropical Hot Humid and Tropical Hot Sub Humid. The meteorological data obtained throughout the experimental period are presented in figure 1.

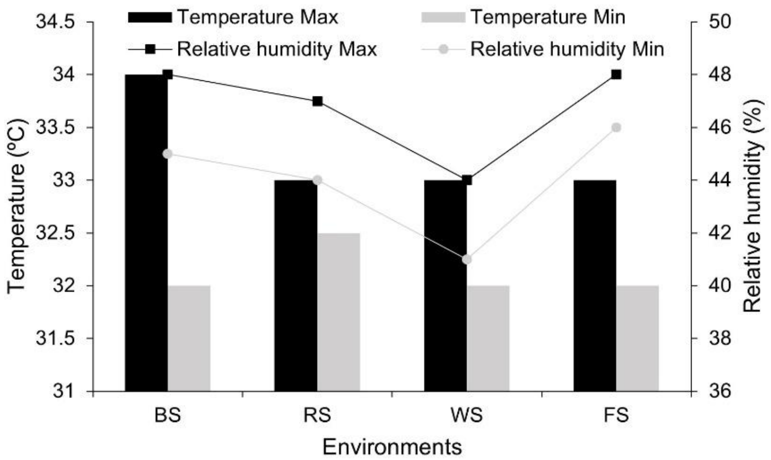

Figure 1. Meteorological data obtained throughout the experiment in the different environments used. BS - black screen; RS - red screen; WS - white screen; FS - full sun.

The substrate used was obtained from a mixture of compost, sand, sandy soil, and bovine manure in a proportion of 1:1:1, respectively, whose chemical analysis results can be seen in Table 1.

Table 1. Chemical characteristics of the substrate before treatment

OM	N	P	Ca^{2+}	K^+	Mg^{2+}	Na^+	$H^+ + Al^{3+}$	Al	SB²	CEC³	V⁴	ECse⁵	pH
g kg^{-1}		mg kg^{-1}	---------- cmol$_c$ kg^{-1} ----------								%	dS m^{-1}	H_2O
14.74	0.93	20	4.90	0.58	0.90	0.26	0.33	0.00	6.64	6.97	95	1.34	7.00

[1]OM – organic matter; [2]SB – Sum of bases ($Ca^{2+} + Mg^{2+} + Na^+ + K^+$); [3]CEC – Cation exchange capacity - [$Ca^{2+} + Mg^{2+} + Na^+ + K^+ + (H^+ + Al^{3+})$]; [4]V – Base saturation - ($Ca^{2+} + Mg^{2+} + Na^+ + K^+$/ CTC) x 100; [5]ECse – Electrical conductivity of the saturated extract of the substrate.

The experimental design was entirely randomized in a subdivided plot scheme, where the plot corresponded to four growing environments under different shading screens (black screen - BS; white screen - WS; red screen - RS; all with 50% shading; and full sun - FS), and the subplot to two electrical conductivities of irrigation water (ECw: low salinity: 0.3 dS m^{-1} and high salinity: 3.0 dS m^{-1}) with five repetitions of 25 seeds.

The passion-fruit seeds used were Topseed® "Redondo Amarelo" type, sown in polystyrene trays with 200 cells of 40 cm^3 at two cm depth. The environments were built in a wooden structure with the area completely covered by the respective shading screens.

The saline water (3.0 dS m^{-1}) used for irrigation was obtained according to the methodology suggested by Rhoades et al. (2000) in which the amount of NaCl, $CaCl_2.2H_2O$ and $MgCl_2.6H_2O$ salts used to prepare the irrigation water was determined in order to obtain the desired ECw in the proportion 7:2:1 respectively, from the supply water of the experimental area, which represents the control treatment (0.3 dS m^{-1}). Irrigation was performed daily manually following the methodology proposed by Marouelli & Braga (2016), until water was drained through the bottom of the trays.

Until 28 days after sowing (DAS) the following variables were evaluated: emergence percentage (EP), through the number of emerged seedlings in correlation to the sown seeds; emergence velocity index (EVI), through daily counting of emerged seedlings, according to the methodology proposed by Maguire (1962); average time of emergence (ATE), according to Laboriau (1983) through daily counting of seeds, with the result expressed in days and the average speed of emergence (ASE), through the methodology of Carvalho & Carvalho (2009).

At the end of this period (28 DAS) the seedlings were evaluated for: seedling height (SH), by measuring from the base to the apex with a ruler graduated in centimeters; number of leaves (NL), by direct counting of fully expanded leaves; stem diameter (SD), by measuring the stem close to the substrate with a digital pachymeter in millimeters; radicle length (RL), by measuring the root system with a ruler graduated in centimeters. After these analyses, the seedlings were placed in paper bags previously identified and dried in an oven at 60 ºC for 72 hours until they reached a constant weight. These data were used to determine the shoot dry mass (SDM), weighed using an analytical balance (0.0001 g).

The data were submitted to analysis of variance (ANOVA). In the occurrence of significance for the interaction between environments versus salinity or isolated factors, Tukey test was processed at $p \leq 0.01$ and $p \leq 0.05$ using Assistat software 7.7 Beta (Silva & Azevedo, 2016).

Results and discussion

Table 2 shows that the interaction of factors influenced the emergence velocity index (EVI) and the average time of emergence (ATE). There was also an isolated effect of salinity for the average speed of emergence (ASE) and emergence percentage (EP), which was also influenced by the environments.

Table 2. Summary of the analysis of variance for emergence percentage (EP) emergence velocity index (EVI), average time of emergence (ATE) and average speed of emergence (ASE) of passion-fruit culture under different environments irrigated with low and high salinity water

Source of variation	DF	Mean Square			
		EP	EVI	ATE	ASE
Environments - A	3	1771.66**	0.24**	3.55^{ns}	0.00006^{ns}
Residue - A	16	76.25	0.01	1.21	0.00003
Salinity - S	1	562.50*	0.21**	7.68*	0.00013*
Residue - S	16	91.87	0.01	1.19	0.00003
A x S	3	147.50^{ns}	0.10**	1.30*	0.00003^{ns}
Total	39	-	-	-	-
CV - A (%)	-	18.78	19.97	7.26	7.55
CV - S (%)	-	20.61	20.88	7.19	7.72

DF - Degrees of freedom; CV - Coefficient of variation; *; **, ns - Significant at $p \leq 0.05$ and $p \leq 0.01$, and not significant, respectively, by F test

The use of shading screens provided a better percentage of emergence, especially in the environment covered with black screen (59%), compared to full sun with lower rates, showing a reduction of 30% (Figure 2A).

The higher electrical conductivity of irrigation water (3.0 dS m^{-1}) reduced the percentage by 7% in comparison with water of 0.3 dS m^{-1} (Figure 2B).

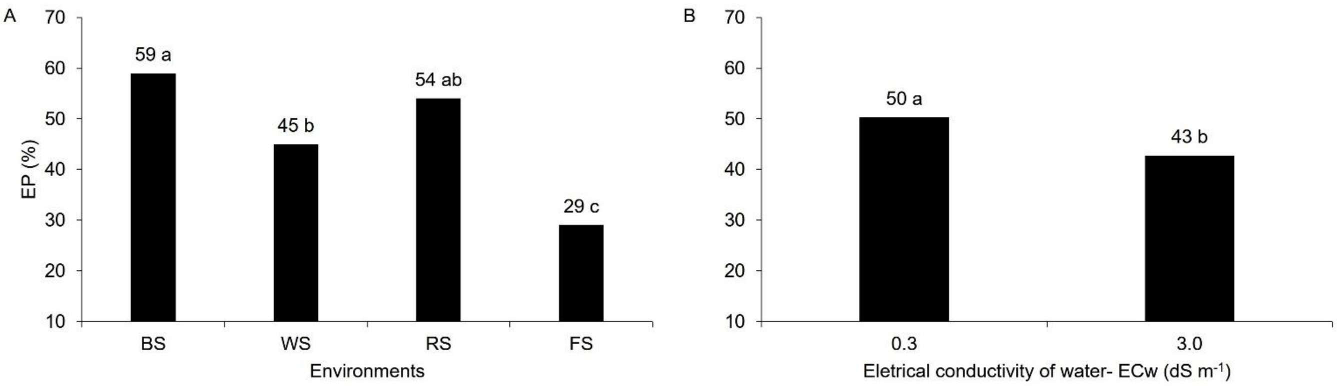

Figure 2. Emergence percentage - EP of passion-fruit culture under different environments. (A) and irrigated with low and high electrical conductivity water (B). BS - black screen; WS - white screen; RS - red screen; FS - full sun. Means followed by the same letter do not differ by Tukey test at $p \leq 0.05$.

The present result (Figure 2A) may be related to the ability of the environments to favor a reduction of adverse environmental variations related to high luminosity, especially in the environment with black screen with greater ability to reduce the incidence of direct radiation (Goes et al., 2019; Silva et al., 2020).

Higher percentage of emergence was obtained by Silva et. al., (2020) when using black shading screen in species of phialis (*Physalis angulata*, *P. peruviana* and *P. pubescens*). Freitas et al. (2015) obtained better emergence in full sun in passion fruit culture.

The germination process of yellow passion-fruit seeds follows a three-phase pattern, with rapid water uptake in phases one and three (Phase 1: rapid increase in moisture demand at the beginning of emergence; Phase 3: speed of uptake enhanced with the emission of the radicle), being of great importance the water maintenance in these periods, but salt stress tends to reduce the water potential, hindering the uptake of water resulting in a lower rate of emergence as shown in Figure 2B (Bezerra et al., 2014).

Ribeiro et. al., (2016) obtained similar results, i.e., a decline in emergence after irrigation with saline water (1 to 5 dS m^{-1}) in passion fruit culture. Bezerra et al. (2014) also observed reductions in the percentage of emergence of passion-fruit with increasing electrical conductivity of irrigation water (0.3 to 4 dS m^{-1}).

The rate of speed of emergence was positively influenced by the shading screens compared to the full sun environment, regardless of the irrigation water. However, the highest values were obtained with the black screen cloth under irrigation water of 0.3 dS m^{-1} (0.86 seedlings day^{-1}), and the lowest values were obtained by the association of full sun and irrigation water of 3.0 dS m^{-1}, (0.26 seedlings day^{-1}) (Table 3).

Table 3. Emergence velocity index (EVI) of passion-fruit culture under different environments irrigated with low and high electrical conductivity water.

Environments	EVI (seedlings day^{-1})	
	0.3 dS m^{-1}	3.0 dS m^{-1}
Black Screen	0.86 aA	0.72 aA
White Screen	0.68 bA	0.59 aA
Red Screen	0.80 aA	0.69 aA
Full Sun	0.51 bA	0.26 bB

Means followed by the same lowercase letters in the same salinity level or uppercase in the same environment, do not differ significantly from each other by Tukey test ($p \leq 0.05$)

A possible answer for these results is linked to the high evaporation caused by the full sun environment, resulting in a greater loss of water keeping the salts present in the substrate used, intensifying adjustments in the matrix potential and reducing the water absorption by seeds. The presence of shading screens, on the other hand, helps in the relative maintenance and hinders ventilation, thus reducing the loss of water from the substrate and allowing greater soaking of the seeds under these conditions, accelerating germination (Guimarães et al., 2013; Silva et al., 2020).

Guimarães et al. (2013) obtained reductions in EVI in mulungu (*Erythrina velutina* Willd.) from irrigation with saline water of 2.5 dS m^{-1}. Moura et al. (2015) obtained higher rates of EVI when using 50% shade cloth compared to treatments without protection.

The average time of emergence was delayed with the use of saline water, so the seeds took longer to emerge, with an increase of 5.97% (Figure 3A).

Possibly this delay is related to the increased concentration of soluble salts in the substrate, consequently reducing its osmotic potential and directly interfering with water availability and decreasing water uptake by the seeds (Freire et. al., 2018; Ceita et. al., 2020). Ribeiro et al., (2016) reaffirm that it is important to evaluate the mean time of emergence to classify the vigor of seeds, these same authors working with the culture of passion fruit obtained higher ATE under salt stress (4.5 dS m^{-1}).

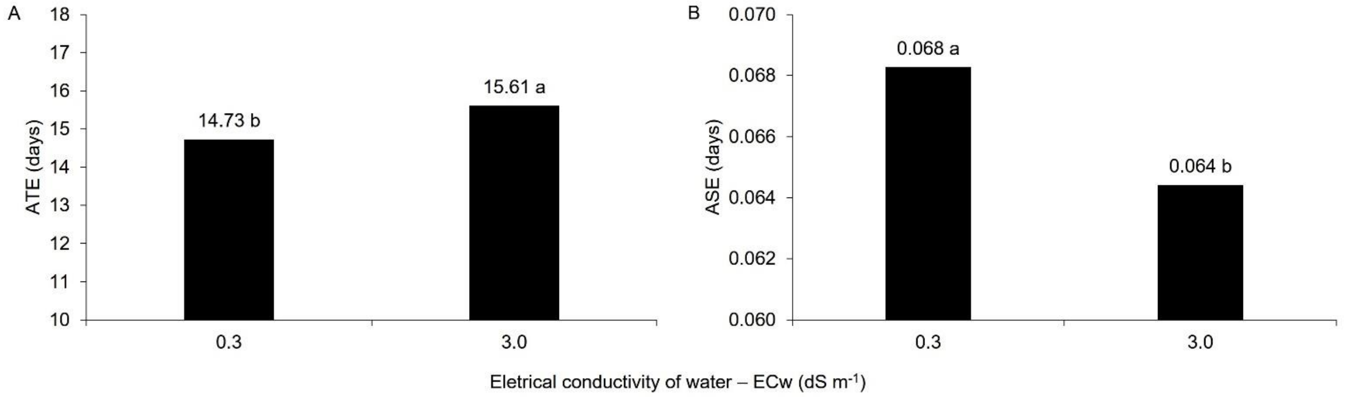

Figure 3. Average time of emergence - ATE (A) and average speed of emergence - ASE (B) of passion-fruit culture irrigated with low and high electrical conductivity water. Means followed by the same letter do not differ by Tukey test at $p \leq 0.05$.

Figure 3B shows that low electrical conductivity water provided a higher average speed of emergence (0.068 days) compared to high electrical conductivity water (0.064 days).

The results reflect the statement of Demontiêzo et al. (2016), that is, the addition of NaCl in irrigation water can contribute to the delay in seedling emergence, thus consequently being a determining factor in the lower average speed of emergence observed under the salt stress situation.

Similar results were observed by Ceita et al. (2020), when irrigating four bean cultivars with water of increasing salinity (0 to 4 dS m^{-1}).

Seedling height (SH) and stem diameter (SD) were influenced by both factors (environment and salinity) in isolation. The number of leaves (NL) and radicle length (RL) were influenced only by the salinity factor. The interaction between factors was observed only in the shoot dry mass (SDM) (Table 4).

Table 4. Summary of variance analysis for seedling height (SH), number of leaves (NL), stem diameter (SD), radicle length (RL) and shoot dry mass (SDM) in passion-fruit seedlings under different environments irrigated with low and high salinity water

Source of variation	DF	Mean Square				
		SH	NL	SD	RL	SDM
Environments - A	3	2.10**	1.29**	0.29**	2.14**	0.004**
Residue - A	16	0.03	0.10	0.02	0.14	0.00005
Salinity - S	1	0.49**	0.02^{ns}	0.09*	0.39^{ns}	0.004**
Residue - S	16	0.05	0.10	0.01	0.12	0.00008
A x S	3	0.06^{ns}	0.29^{ns}	0.01^{ns}	0.02^{ns}	0.0005**
Total	39	-	-	-	-	
CV - A (%)	-	5.66	13.90	13.41	13.08	8.97
CV - S (%)	-	7.68	13.90	10.81	11.98	11.25

DF - Degrees of freedom; CV - Coefficient of variation; *; **, ns - Significant at $p \leq 0.05$ and $p \leq 0.01$, and not significant, respectively, by F test

Seedling height (SH) and stem diameter (SD) were positively influenced by the protected environments, especially under the black screen with values of 3.71 cm and 1.24 mm, respectively, in comparison with the full sun environment, with a reduction of approximately 30% in both variables (Figure 4A and 4B).

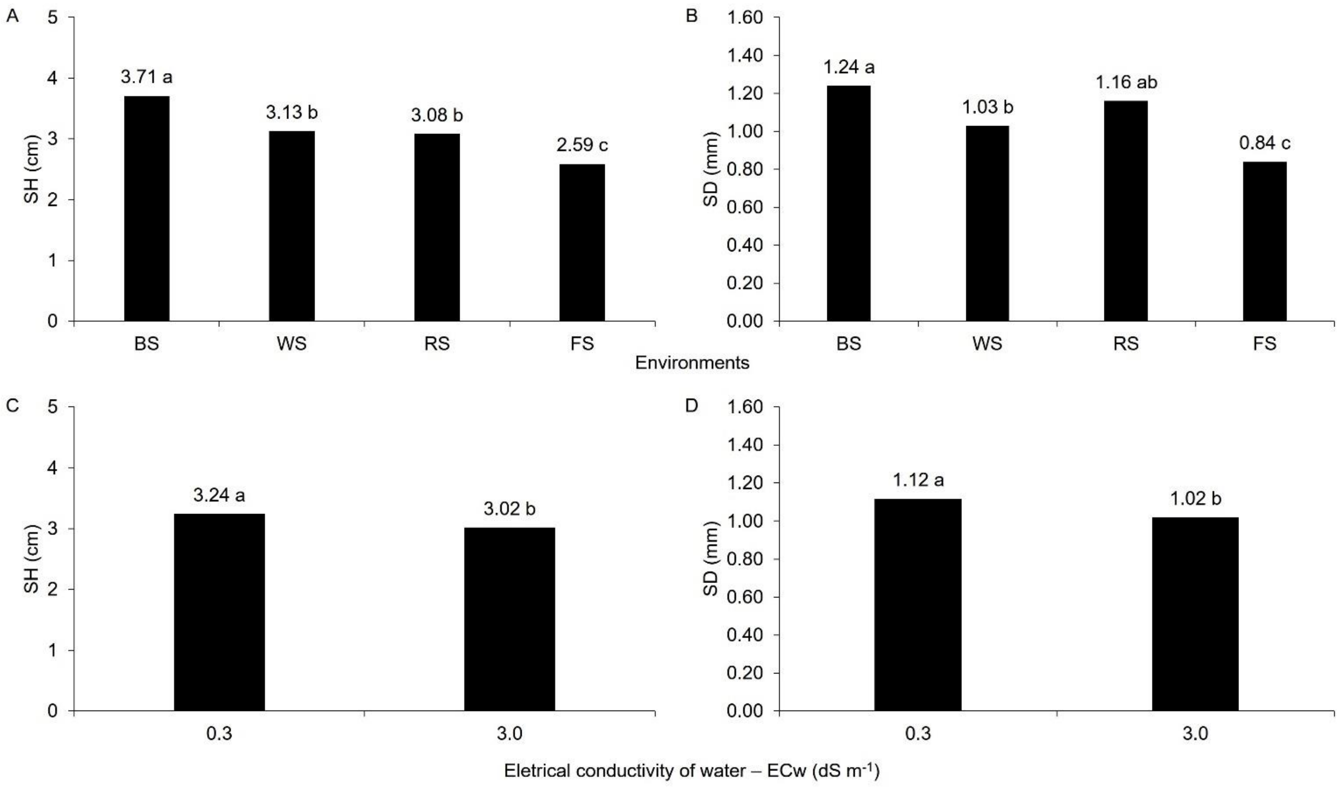

Figure 4. Seedling height (A and C) and stem diameter (B and D) of passion-fruit culture under different environments and irrigated with low and high electrical conductivity water. BS - black screen; WS - white screen; RS - red screen; FS - full sun. Means followed by the same letter do not differ by Tukey test at $p \leq 0.05$.

The present result is justified as a reduction in energy expenditure of plants submitted to 50% black mesh, due to favorable conditions provided as greater thermal comfort and less variation on evapotranspiration, compared to the absence of shading screen, thus enabling greater growth (Taiz et. al., 2017; Silva et. al., 2019).

Goes et al. (2019) obtained higher values of height and stem diameter in okra seedlings under 50% black shading screen compared to full sun environment.

Increasing the electrical conductivity of irrigation water provided reductions under the variables seedling height (SH) and stem diameter (SD) of 7% and 9% respectively (Figure 4C and 4D).

Irrigation with water of high electrical conductivity causes a reduction in the osmotic potential of the soil, causing lower water availability for seedlings subjected to these conditions, which results in lower uptake and turgor pressure, and the toxic ions present (Na^+ and Cl^-) have a proven negative effect on elongation and cell division (Sousa et. al., 2021; Taiz et. al., 2017). Reduction in initial growth (height and stem diameter) in yellow passion fruit culture was also obtained by Ribeiro et al. (2013) with increasing salinity of irrigation water.

The number of leaves was negatively affected by the cultivation in full sun, suffering a reduction of 40% when compared to the environment with a black screen that provided statistically higher values than all environments (Figure 5A).

According to Figure 5B, the radicle length was greater under the protection of the black shading mesh (3.59 cm), and the lowest value was obtained in the absence of solar protection, causing a reduction of 1.53 cm.

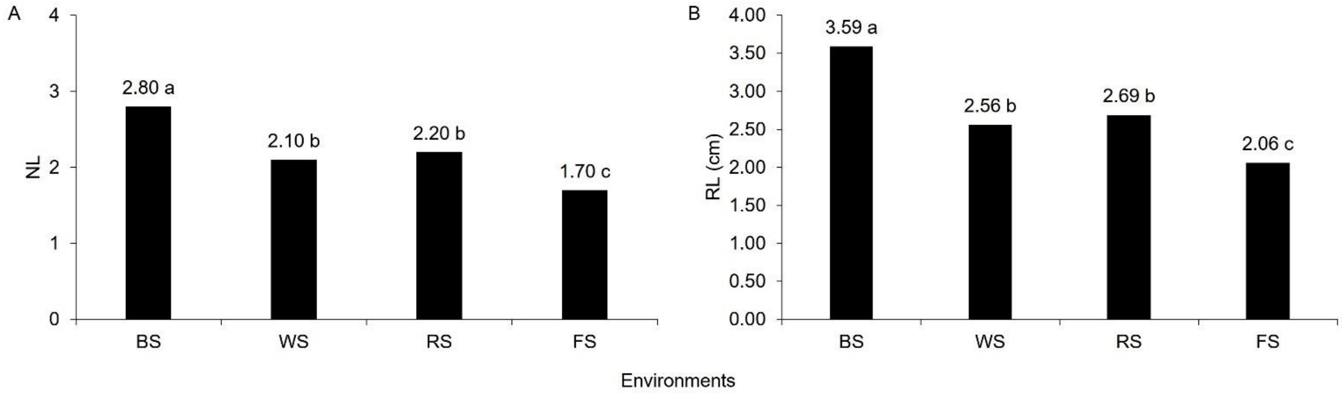

Figure 5. Number of leaves - NL (A) and radicle length - RL (B) of passion fruit seedlings under different environments. BS - black screen; WS - white screen; RS - red screen; FS - full sun. Means followed by the same letter do not differ by Tukey test at $p \leq 0.05$.

Associating the present result with plant metabolism refers to the statement of some authors who relate high temperatures with higher photosynthetic activity, consequently, greater production of organic compounds that contribute to a greater number of leaves (Mezzalira et. al., 2012; Taiz et. al., 2017).

Silva Junior et al. (2020) working with the culture of watermelon, obtained a greater number of leaves under black screen with 50% shading compared to an unprotected environment.

The greater length of the radicle system obtained (Figure 5B) may be directly related to the greater values obtained in the morphological parameters of the aerial part (AP, DC, and NF) with the use of the black screen, through the source-drain relationship between the aerial part and the root, consequently attributing greater length of the root system (Taiz, et. al., 2017).

Similar results were obtained by Goes et al. (2019) working with agricultural ambience on okra seedlings, where the largest root system was obtained under black shading screen.

The interaction between black shading screen and irrigation water of low conductivity (0.3 dS m^{-1}) provided the highest values of shoot dry mass (0.12 g) whereas the full sun environment associated with water of higher electrical conductivity (3.0 dS m^{-1}) affected negatively causing the lowest values (0.03 g) (Table 5).

The biomass of the aerial part is directly proportional to the growth of the plant, that is, the lower its growth parameters, consequently the lower its biomass will be, thus according to the results of the present study the decrease is justified since the full sun environment provided less development of the part area, intensified by the presence of salts in the irrigation water that inhibit the translocation and synthesis of essential hormones for plant growth consequently decreasing the production of biomass (Freire, et. al., 2018; Silva, et, al., 2020).

Table 5. Shoot dry mass (SDM) of passion-fruit seedlings under different environments irrigated with low and high electrical conductivity water.

Environments	SDM (g)	
	0.3 dS m^{-1}	3.0 dS m^{-1}
Black Screen	0.12 aA	0.09 aB
White Screen	0.08 bA	0.07 bA
Red Screen	0.09 bA	0.08 bA
Full Sun	0.07 bA	0.03 cB

Means followed by the same lowercase letters in the same salinity level or uppercase in the same environment, do not differ significantly from each other by Tukey test ($p \leq 0.05$)

Silva Junior et al. (2020) working with watermelon seedlings in two environments (full sun and black screen) obtained contrasting results to the present study, where higher MSPA values were obtained in full sun. Moura et al. (2015) observed greater production of aboveground biomass in cupuaçu seedlings when grown under 50% shade.

Reductions in SDM in yellow passion fruit were also reported by Ribeiro et al. (2013), studying the initial growth of the culture under irrigation with water of different conductivities (0, 2, 4 and 6 dS m^{-1}).

Conclusions

The protected environment with black shading screen 50% provided better emergence percentage, seedling height, stem diameter, number of leaves and radicle length in yellow passion fruit.

The deleterious effects of salts on the rate of emergence and shoot dry matter were reduced when the 50% black shading screen was used.

Irrigation with water of higher conductivity (3.0 dS m^{-1}) caused reductions in the percentage and average speed of emergence, average time of emergence of the passion-fruit culture. Besides negatively affecting the height and dry matter of the aerial part of the seedlings.

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