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Effect of saline water and shading on dragon fruit ('pitaya') seedling growth[1]

Efeito da água salina e sombreamento no crescimento de mudas de 'pitaya'

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HIGHLIGHTS:

The protected environment under 50% shade with black net is an alternative for the production of 'pitaya' seedlings.
The full sun environment mitigated the salt stress on the biomass of the aerial part of 'pitaya' seedlings.
Saline stress affected plant height, number of secondary shoots and root length of 'pitaya' seedling.

ABSTRACT: 'Pitaya' (*Hylocereus undatus*) is a fruit-bearing, climbing cactus with great food potential for the semiarid region. This study aimed to evaluate the production of 'pitaya' seedlings irrigated with low and high salinity water and grown in different light intensities. The experiment was conducted in a completely randomized design, in a 2 × 2 factorial arrangement, with two electrical conductivities of irrigation water: S_1 - 0.3 dS m^{-1} (low salinity) and S_2 - 5.0 dS m^{-1} (moderate salinity) in two environments: A_1 - black net with 50% shading, and A_2 - full sun, with ten replicates. The variables evaluated were plant height, main cladode diameter, above-ground biomass, root biomass, total plant biomass, number of secondary cladodes, root length, and length of secondary cladodes. The 50% shading (black net) promoted higher plant height, number of secondary shoots, and root length of the 'pitaya' plants. The irrigation with moderate saline water (5.0 dS m^{-1}) reduced the number of secondary cladodes, length of root, and length of secondary cladodes. The 'pitaya' seedlings grown under 50% shading (black net) showed greater root dry biomass when irrigated with low-salinity water. Greater values of diameter of the primary cladode, above-ground dry biomass, and total dry biomass were observed under full sunlight and elevated saline stress.

Key words: *Hylocereus undatus*, salinity, protected environment

RESUMO: Pitaya' (*Hylocereus undatus*) é um cacto trepador, frutífera com grande potencial de alimento para região semiárida. Objetivou-se avaliar a produção de mudas de 'pitaya' irrigadas com água de baixa e alta salinidade e cultivadas em diferentes tipos de ambientes. O experimento foi conduzido em delineamento experimental inteiramente casualizado, em esquema fatorial 2 × 2, sendo duas condutividades elétricas da água de irrigação: S_1 - 0,3 dS m^{-1} (baixa salinidade) e S_2 - 5,0 dS m^{-1} (salinidade moderada), em dois ambientes: A_1 - telado preto com 50% de sombreamento e A_2 - pleno sol, com 10 repetições. As variáveis analisadas foram: altura da planta, diâmetro do caule principal, massa seca da parte aérea, massa seca da raiz, massa seca total da planta, número de brotos secundários, comprimento de raiz e comprimento dos brotos secundários. O telado preto com 50% de sombreamento proporcionou maior altura de planta, número de brotos secundários e comprimento de raiz de plantas de 'pitaya'. A irrigação com água de salinidade moderada (5,0 dS m_{-1}) reduz o número de brotos secundários, e comprimento da raiz e dos cladódios secundários. As mudas de 'pitaya' cultivadas sob 50% de sombreamento (telado preto) apresentaram maior biomassa seca de raiz quando irrigadas com água de baixa salinidade. Foram observados maiores valores do diâmetro do cladódio primário, da biomassa seca acima do solo e da biomassa seca total sob luz plena do sol e elevado estresse salino.

Palavras-chave: *Hylocereus undatus*, salinidade, ambiente protegido

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Introduction

'Pitaya' (*Hylocereus undatus*) is a fruit-bearing climbing cactus, originally from the Americas, and is considered promising for cultivation due to the fruit having an exotic appearance, sweet, and smooth flavor and it has presented an increasing acceptance in consumer markets (Moreira et al., 2011; Cordeiro et al., 2015). However, there is still variation in fruit yield and the physic-chemical characteristics of the fruits (Lima et al., 2013). Besides, there is a scarcity of studies on both growth and the appropriate agricultural environment for 'pitaya'.

In Brazil, the plant was introduced due to its great food, nutritional, and commercial potential; however, it has not been widely studied. Additional studies may provide practical and technological information to increase 'pitaya' production (Cavalcante et al., 2011).

The water used for irrigation in the semiarid region generally has high salt concentration. Thus, it is necessary to use low-quality water to meet the water requirement of the crops (Silva et al., 2014). This water resource is difficult for plants to absorb, increases the salt concentration in the soil, and causes toxicity to plants, reducing vegetative growth and development (Dias et al., 2016).

Furthermore, for seedling production, factors that provide adequate climatic conditions contributing to plant growth must be studied. 'Pitaya' production is sensitive to light intensity, as a 50% reduction in the direct incidence of the sun allowed the highest growth of plants (Cavalcante et al., 2011). Lone et al. (2018) evaluated 'pitaya' root cuttings under different shading levels and showed that partial shading (between 23 and 42%) increased the cladodes percentage.

This study aimed to evaluate the production of 'pitaya' seedlings irrigated with low and high salinity water in two light intensities.

Material and Methods

The experiment was conducted from July to August 2019, at the Auroras Seedling Production Unit (UPMA), at the University for International Integration of the Afro-Brazilian Lusophony (UNILAB) in Redenção, CE, Brazil, (05° 31' 87.7" S and 95° 33' 74.8" W), at an altitude of 317 m.

According to the Köppen classification, the climate of the region is Aw-type, tropical with dry winter. 'Pitaya' cuttings came from seedlings at 120 days of age, grown under 50% luminosity in (UPMA-UNILAB), sexually propagated from seeds obtained from a 'pitaya' variety with a red-skinned fruit with white flesh. Cuttings were standardized. The cladodes (two) were planted in perforated polyethylene bags, with 3 L capacity, containing substrate produced with cattle manure + sand + 'arisco' in the proportion of 2:1:1, respectively (Table 1).

The experimental design was completely randomized (CRD), in a 2 × 2 factorial scheme, with two electrical conductivities of irrigation water: S_1 - 0.3 dS m^{-1} (low salinity) and S_2 - 5.0 dS m^{-1} (moderate salinity) in two environments: A_1 - black net with 50% shading, and A_2 - full sun, with ten repetitions (Table 2).

The moderate-salinity water (5.0 dS m^{-1}) was prepared by the following method: salts of NaCl, $CaCl_2.2H_2O$, and $MgCl_2.6H_2O$ were used in the equivalent proportion of 7:2:1, respectively, obeying the relationship between ECw and its concentration (mmol$_c$ L^{-1} = EC x 10) (Rhoades et al., 2000). Low-salinity water (0.3 dS m^{-1}) was obtained from the municipal supply. Irrigation was manual and carried out daily, applying a leaching fraction of 0.15 until drainage at the bottom was started, according to the method described in Bernardo et al. (2019).

After 50 days from the initiation of the experiment, the following variables were evaluated: plant height (PH), main cladode diameter (MCD), above-ground dry biomass (AGDB), below-ground dry biomass (BGDB), total plant dry biomass (TPDB), number of secondary cladodes (NSC), root length (RL), and length of secondary cladodes (LSC).

The plants were kept in a forced air oven at 65 °C for 48 hours in the Laboratory of Plant Physiology of UNILAB, to determine AGDB, BGDB, and TPDB and weighed on a precision scale of 0.01 g.

The results were submitted to the analysis of variance (ANOVA) and the Tukey test at $p \leq 0.05$, using Assistat software version 7.7 (Silva & Azevedo, 2016).

Table 2. Mean values of temperature and relative air humidity of the environments (full sun and black net with 50% shading), during the experiment

Environments	Temperature (°C)		Relative humidity (%)	
	Max	Min	Max	Min
Full sun	33.7	32.6	58	45.9
Black net with 50% shading	34.5	33.8	52	45.7

Max - maximum; Min - Minimum

Results and Discussion

According to the summary of the analysis of variance (Table 3), there was an isolated effect for both salinity and light intensity on plant height (PH) at $p \leq 0.01$. There was a significant interaction $p \leq 0.01$ and $p \leq 0.05$ between the light intensity and the salinity of irrigation water for the following variables: main cladode diameter (MCD), above-ground dry biomass (AGDB), below-ground dry biomass (BGDB), and total plant dry biomass (TPDB). The number of secondary cladodes (NSC), root length (RL), and length of secondary cladodes (LSC) revealed an isolated effect for the salinity factor. About the dry root mass, there was no significant effect between the factors studied (Table 3).

Table 1. Chemical characteristics and salinity of the growing substrate composed of 2:1:1 (mass basis) of cattle manure + sand + 'arisco', respectively

O.M.	N	P	Mg	K	Ca	Na	pH	PES	ECw
(g kg^{-1})		(mg kg^{-1})	(cmol$_c$ dm^{-3})					(%)	(dS m^{-1})
4.34	0.26	65	1.2	0.65	1.2	0.33	6.2	7.0	1.19

O.M. - Organic matter; PES - Percentage of exchangeable sodium; ECw - Water electrical conductivity

Table 3. Summary of analysis of variance[1] for plant height (PH), main cladode diameter (MCD), above-ground dry biomass (AGDB), below-ground dry biomass (BGDB), and total plant dry biomass (TPDB), number of secondary cladodes (NSC), root length (RL), length of secondary cladodes (LSC) under different levels of salinity and cultivation environment

SV	Mean square								
	DF	PH	MCD	AGDB	BGDB	TPDB	NSC	RL	LSC
Saline waters (S)	1	1.71**	1.08 **	0.24 **	0.004ns	0.26**	3.75*	0.67 **	1.55 **
Environments (A)	1	0.94**	0.0001ns	0.0001ns	0.01ns	0.008ns	4.31ns	0.03ns	0.42ns
Interaction (S x A)	1	0.04ns	0.48**	0.11**	0.006ns	0.14**	0.32ns	0.24ns	0.02ns
Treatments	3	2.70**	0.52**	0.12**	0.07**	1.40**	0.32*	0.04*	0.66ns
Residue	36	0.88	0.03	0.007	0.01	0.1	0.07	4.29	0.03
Total	39	-	-	-	-	-	-	-	-
CV (%)	-	6.79	7.70	9.61	6.78	11.62	19.72	10.16	6.0

[1]Statistical analysis performed after transforming data into ln (y + 1); SV - Source of variation; DF - Degrees of freedom; CV - Coefficient of variation; **, *, ns - Significant at $p \leq 0.01$ and $p \leq 0.05$ and not significant by F test, respectively

The highest plant height values were obtained with the use of moderate-salinity water (Figure 1A). Saline stress provided plant height of 18.26 cm, and water with low salinity was 12.14 cm; that is, there was a reduction of 33.51%. It should be noted that 'pitaya' plants have adaptations to salt stress, that is, adjusting osmotically and avoiding less plant growth induced by salinity.

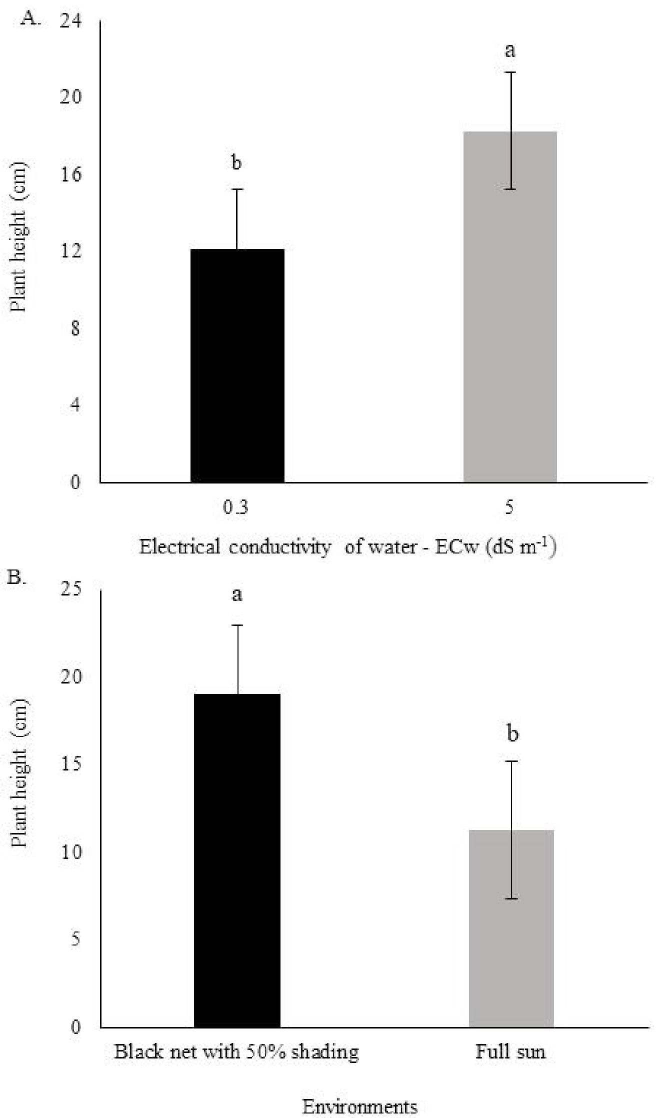

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Figure 1. Plant height depending on electrical conductivity of irrigation water (A) and agricultural environment (B)

The opposite result of this study was reported by Cavalcante et al. (2008), studying the salinity of irrigation water in 'pitaya'; they observed a reduction in plant height. Additionally, Nascimento et al. (2017) and Bonifácio et al. (2018) observed reduced plant growth in yellow passion fruit seedlings and guava plants, respectively.

It was observed (Figure 1B) that the plants are grown under 50% shading (black screen) presented plant height values (19.1 cm) statistically higher than those of plants grown under the full sun (11.3 cm). This result may be related to the mitigation that the environment might provide, as an example, to reduce the adverse effects of excessive rain, high radiation levels, and the extremes of air temperature (Reis et al., 2012).

Similar tendencies have been described by Cavalcante et al. (2011); when cultivating 'pitaya' in a protected environment, they verified a good performance in plant height. Likewise, Hirata et al. (2017) evaluated the chives crop 49 days after transplanting and found higher plant height in a protected environment of 50% shading than in full sunlight.

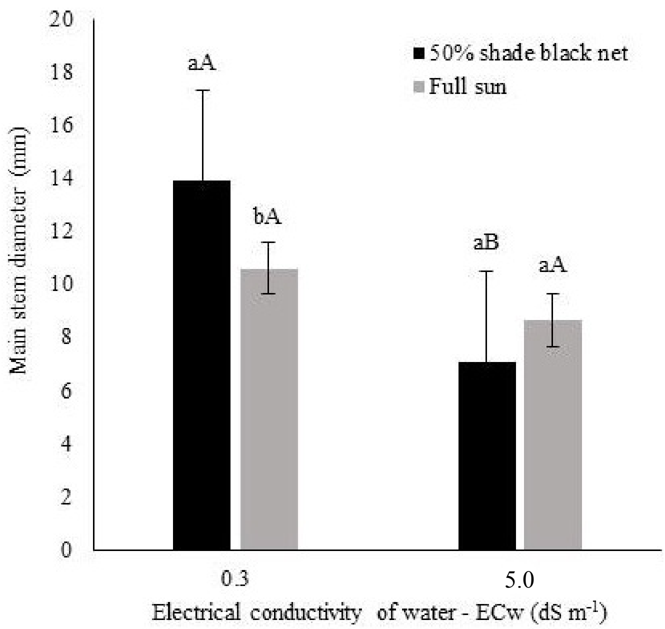

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Figure 2. Stem diameter of the main cladode as a function of electrical conductivity of irrigation water and agricultural environment

Regarding the interaction among environment and low and moderate-salinity water, plants irrigated with low salinity water had a higher diameter of the primary cladode under the 50% shading (black screen) (13.9 cm) than the full sun (10.61 cm), corresponding to losses of 23.66%. Plants irrigated with high salinity water showed better performance in full sun (8.65 cm) concerning the protected environment (7.07 cm) with a reduction of 18.26%.

In agreement with this study, Cavalcante et al. (2008) irrigated the 'pitaya' crop with high-salinity water and found a smaller cladode diameter in a greenhouse. However, Goes et al. (2019), evaluating the influence of saline stress on okra seedlings grown in different environments (structure with 50% shading and full sunlight), did not observe any significant effect for this variable.

Plants cultivated under black net with 50% shading and irrigated with low-salinity water presented superior results compared to plants irrigated with high-salinity water. In full sunlight, there was no significant difference (Figure 3). Plants irrigated with low salinity water and grown under black net with 50% shading had higher mean values (0.90 g) than those under the full sun (0.54 g), obtaining a 40% reduction. Plants irrigated with high salinity water showed higher mean values under the full sun (0.34 g) than those under 50% shading (0.20 g), corresponding to a reduction of 41.17%.

The effect of salts on shaded crops is decreased evapotranspiration according to the increased soil salinity and decreased leaf area. It should be noted that salt stress causes disturbances in the absorption and/or distribution of nutrients and early senescence, reflecting in the reduction of AGDB.

The results found are similar to those verified by Cavalcante et al. (2008), who studied 'pitaya' plants grown in a greenhouse (50% shading) and irrigated with saline water. The reduction of the shoot dry matter was also reported by Mesquita et al. (2014) when irrigating papaya seedlings in a screened environment under different salinity levels.

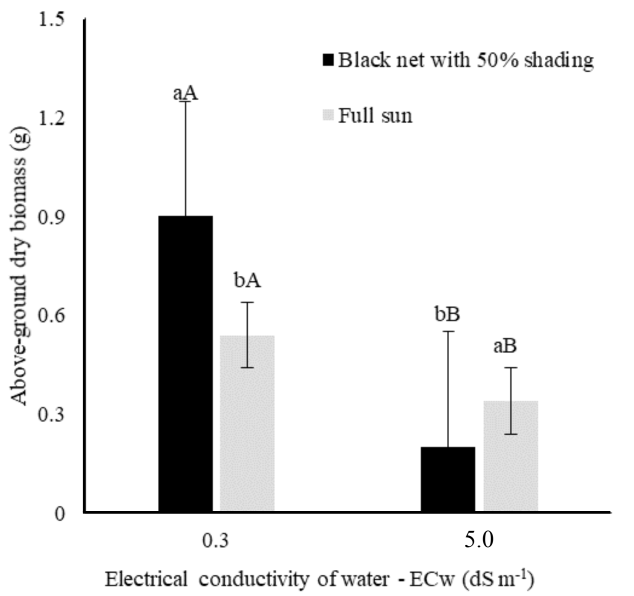

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Figure 3. Above-ground dry biomass as a function of electrical conductivity of irrigation water and agricultural environment

As shown in Figure 4, plants irrigated with low-salinity water exhibited a better performance of dry matter production of plants when cultivated under 50% shading (black screen) compared to plants irrigated with moderate-salinity water. Irrigation with low salinity water and the cultivation under a protected environment obtained higher mean values (1.16 g) concerning the full sun (0.61 g), obtaining a reduction of 47.41%. Plants irrigated with higher salinity water at the full sun (0.43 g) had higher values than those under 50% shading (0.32 g), corresponding to a 23.80% reduction.

This result reflects the similarity between shoot dry matter and root dry matter; that is, plants irrigated with low salinity water in a protected environment evidence a greater accumulation of photoassimilates in the upper part of the plant because, in this environment, there is a better transmittance and light absorption, consequently better efficiency in photosynthesis and higher biomass performance.

Furthermore, similar results were verified by Souto et al. (2016) in noni (*Morinda citrifolia* L.), irrigated with moderate-saline water, and grown under 50% shading. Likewise, Melo Filho et al. (2017) also found reductions in the total dry matter of pitomba (*Talisia esculenta*) seedlings.

It can be seen in Figure 5 that plants irrigated with low-salinity water obtained higher numbers of secondary shoots. That is, low salinity water provided a greater number of secondary shoots (four) than high salinity water (one). This result corroborates with Moreira et al. (2017), who asserted that the formation of shoots and roots in plants cultivated with low-salinity water is influenced by the higher cutting length, which has elevated nutritional reserves, above all carbohydrate.

Regarding the effect of saline stress, the lower number of shoots in plants may be explained, due to the increase in the NaCl concentration in the root system, affecting the decrease and

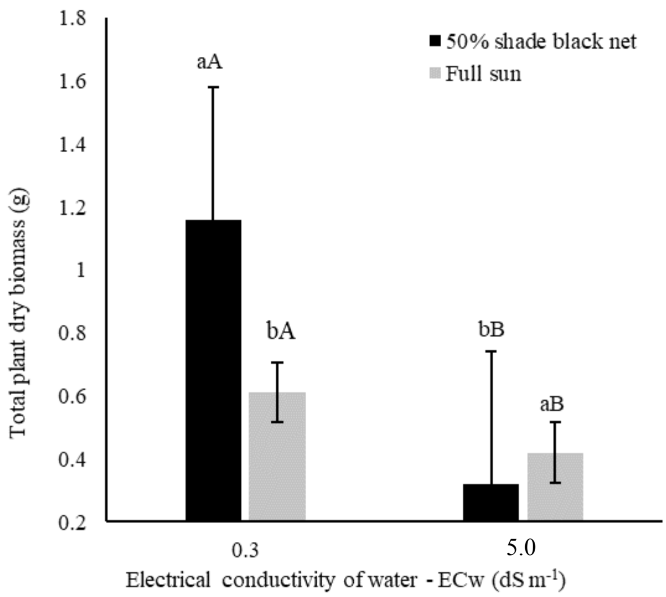

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Figure 4. Total plant dry biomass as a function of electrical conductivity of irrigation water and agricultural environment

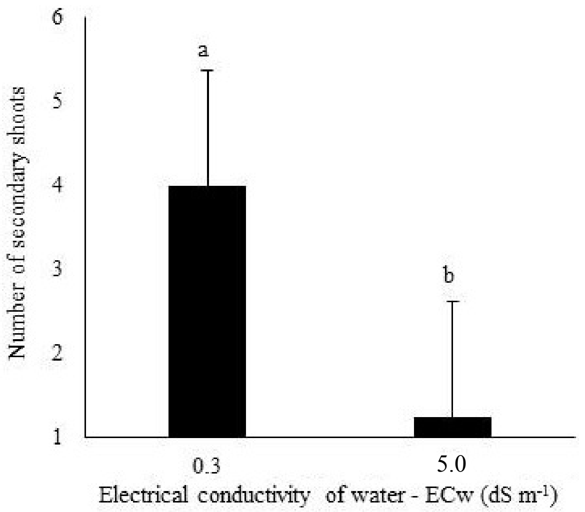

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Figure 5. Number of secondary shoots depending on irrigation water salinity

formation of new organs (Franco-Salazar & Véliz, 2008). Studies that address a reduction in this vegetative part due to saline stress were found by Santos et al. (2020) in red 'pitaya' seedlings.

As shown in Figure 6, low salinity water provided a longer root length (2.28 cm), being statistically higher than high salinity water, obtaining 1.97 cm, revealing a 13.59% reduction. Saline stress causes a reduction in osmotic potential, consequently in the growth of the root zone, affecting the absorption of water and nutrients.

Similar results were observed by Melo Filho et al. (2017) in pitombeira seedlings (*Talisia esculenta* (A. St.-Hil.) Radlk) irrigated with saline water.

The increase in the irrigation water salinity also caused a decline in the length of the secondary cladodes (Figure 7), causing a reduction of 32.24% concerning low salinity water. Saline stress reduces the osmotic potential of the soil solution, causing water stress and nutritional disorders and consequently the productive aspects (Rodrigues et al., 2020; Sousa et al., 2012).

Similar results to this study were reported by Bezerra et al. (2020), who observed reductions in the productive branches of the yellow passion fruit irrigated with high salinity water.

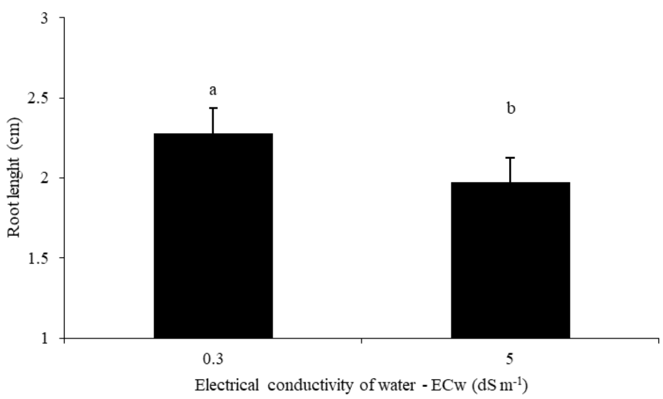

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Figure 6. Root length depending on electrical conductivity of irrigation water

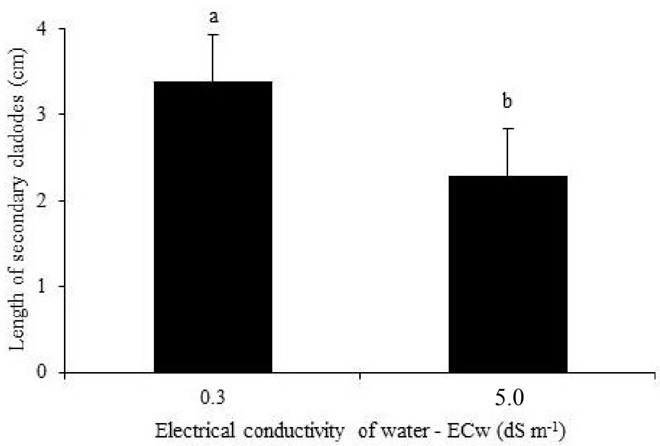

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Figure 7. Length of secondary cladodes depending on electrical conductivity of irrigation water

Conclusions

1. The 50% shading (black screen) promotes higher plant height, number of secondary shoots, and root length of the 'pitaya' plants.

2. The irrigation with moderate saline water (5.0 dS m^{-1}) reduced the number of secondary cladodes and length of root and secondary cladodes.

3. The 'pitaya' seedling grown under 50% shading (black net) showed greater root dry biomass when irrigated with low-salinity water. Under full sunlight and elevated saline stress, a larger diameter of the primary cladode, greater above-ground dry biomass, and total dry biomass were observed.

Acknowledgments

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