ISSN 1808-8546 (ONLINE) 1808-3765 (CD-ROM)

CRESCIMENTO DE CULTIVARES DE PALMA FORRAGEIRA IRRIGADA SOB DIFERENTES NÍVEIS DE SALINIDADE EM REGIÃO SEMIÁRIDA

MÁRCIA CRISTINA DE ARAÚJO PEREIRA[1]; CARLOS ALBERTO VIEIRA DE AZEVEDO [2]; JOSÉ DANTAS NETO [3]; MARIANA DE OLIVEIRA PEREIRA [4]; JAILTON GARCIA RAMOS [5] E BEATRIZ DE ARAÚJO TOMAZ [6]

[1] Programa de Pós-Graduação em Engenharia Agrícola, Universidade Federal de Campina Grande, Rua Aprígio Veloso, 882, Bairro Universitário, 58428-830, Campina Grande, Paraíba, Brasil. E-mail: marciacristina794@gmail.com.
[2] Programa de Pós-Graduação em Engenharia Agrícola, Universidade Federal de Campina Grande, Rua Aprígio Veloso, 882, Bairro Universitário,58428-830, Campina Grande, Paraíba, Brasil. E-mail: cvieiradeazevedo@gmail.com.
[3] Programa de Pós-Graduação em Engenharia Agrícola, Universidade Federal de Campina Grande, Rua Aprígio Veloso, 882- Bairro Universitário,58428-830, Campina Grande, Paraíba, Brasil. E-mail: zedantas1955@gmail.com.
[4] Pós-doutoranda em Engenharia Agrícola, Rua Aprígio Veloso, 882 -Universitário, Campina Grande -PB, Brasil. 58428-830, E-mail: marianapereira.agri@gmail.com
[5] Programa de Pós-Graduação em Engenharia Agrícola, Universidade Federal de Campina Grande, Rua Aprígio Veloso, 882, Bairro Universitário,58428-830, Campina Grande, Paraíba, Brasil. E-mail: jailtonbiossistemas@gmail.com.
[6] Unidade Acadêmica de Engenharia Agrícola, Universidade Federal de Campina Grande, Rua Aprígio Veloso, 882, Bairro Universitário, 58428-830, Campina Grande, Paraíba, Brasil. E-mail: beatrizatomaz2@gmail.com

1 RESUMO

A palma forrageira se destaca por ser uma cultura bem adaptada às condições edafoclimáticas do semiárido brasileiro, pois apresenta características anatômicas, morfofisiológicas e químicas que possibilitam seu desenvolvimento. Objetivou-se nesse trabalho avaliar o efeito de diferentes níveis de salinidade da água de irrigação, no crescimento de cultivares de palma forrageira na região do semiárido. O delineamento experimental foi em blocos casualizados em esquema fatorial 4 x 3, com quatro níveis salinos (0,2; 2,0; 3,8 e 5,6 dS m^{-1}) e três cultivares (Miúda, Orelha de Elefante Mexicana e IPA-Sertânia), quatro repetições. Foram avaliadas as variáveis altura de planta, largura de planta, comprimento, largura, perímetro e espessura dos cladódios primários. As variáveis foram submetidas a análise de variância pelo teste F ao nível de 1 e 5% de probabilidade, quando significativo foram submetidos à análise de regressão linear e quadrática para variáveis quantitativas e teste de Tukey ($p < 0,05$) para a variável qualitativa. O desenvolvimento da palma forrageira irrigada com diferentes níveis salinos foi influenciado com o aumento da salinidade, sendo que a melhor condição para a cultivar Miúda foi a salinidade de 3,8 dS m^{-1}, já para Baiana e Orelha de Elefante Mexicana foi a salinidade de 2,0 dS m^{-1}.

Palavras-chave: *Opuntias*, *Napolea*, Águas Salinas, Semiárido.

Recebido em 16/09/2021 e aprovado para publicação em 20/10/2021
DOI: http://dx.doi.org/10.15809/irriga.2021v26n4p814-826

PEREIRA, M. C. de A.; AZEVEDO, C. A. V. de; DANTAS NETO, J.; PEREIRA, M. de O.; RAMOS, J. G.; TOMAZ, B. de A.

GROWTH OF IRRIGATED FORAGE PALM CULTIVARS UNDER DIFFERENT SALINITY LEVELS IN A SEMI-ARID REGION

2 ABSTRACT

The forage palm stands out for being a crop well adapted to the edaphoclimatic conditions of the Brazilian semiarid region, for it presents anatomical, morphophysiological, and chemical characteristics that enable its development. This work aimed to evaluate the effect of different levels of salinity of irrigation water on the growth of forage palm cultivars in the semiarid region. The experimental design was in randomized blocks in a 4 x 3 factorial scheme, with four salt levels (0.2; 2.0; 3.8 and 5.6 dS m^{-1}) and three cultivars (Miúda, Mexican Orelha de Elefante, and IPA-Sertânia), four repetitions. The variables of plant height, plant width, length, width, perimeter and thickness of the primary cladodes were evaluated. The variables were subjected to analysis of variance by the F test at the level of 1 and 5% probability, when significant were subjected to linear and quadratic regression analysis for quantitative variables and Tukey test ($p < 0.05$) for the qualitative variable. The development of the forage palm irrigated with different saline levels was influenced with increasing salinity, and the best condition for the cultivar Miúda was a salinity of 3.8 dS m^{-1}, and for Baiana and Mexican Elephant's Ear was salinity of 2.0 dS m^{-1}.

Keywords: Opuntias, Napolea, Saline Water, Semi-arid.

3 INTRODUCTION

The semiarid region of Brazil is characterized by the occurrence of irregularly distributed rainfall concentrated in a short rainy period, followed by a long dry period, which is the main limiting factor in agricultural production in this region. Therefore, it is important to apply specific strategies to obtain greater yields in forage production (Perazzo et al., 2013).

In this scenario, forage cactus pear appears to be one of the main sources of feed for animals in this region, especially during dry periods, enabling farmers to meet the reduced food supply during this period and reducing production costs (Rego et al., 2014). Compared with other forage species, it is a species that stands out in the semiarid region of Brazil, as its cladodes contain, on average, 90% water, which represents a valuable contribution to the animal water supply (Pereira et al., 2021). Furthermore, it constitutes an important forage resource, meeting food demand during dry periods due to its hardiness, high production potential, and high energy value compared with many native vegetation species (Bezerra et al., 2015).

On the other hand, although forage species are adapted to this region, soil and climate conditions can significantly influence crop development. Thus, irrigation becomes essential for plant development and adequate productivity (Braz, 2018).

However, in areas that encompass the semiarid region of Brazil, water resources generally undergo changes throughout the year, both in quantity and quality, which often present high saline levels (Ferreira, 2018). However, the use of these types of water can cause serious problems for crop development and productivity, interfering with the quality of agricultural products (Leite et al., 2007; Abrantes, 2015). The use of lower-quality water is becoming increasingly necessary, especially water from wells located in regions with crystalline rocks, as well as from surface reservoirs, which are affected by the transport and leaching of salts present in soils from higher elevations (Queiroz et al., 2016).

Given this information, research focused on the constitution of plant species production is of fundamental importance to better define their use (Ramos et al., 2015). The study of saline and brackish water resources is possible for minimizing water scarcity (Fonseca, 2017), considering that the incorporation of lower-quality water into the production system can become a fundamental alternative to meet the needs of agricultural production (SILVA et al., 2014). Lima et al. (2015), when using saline water in the irrigation of forage cactus, which has an electrical conductivity greater than 5 dS m^{-1}, achieved satisfactory results.

Therefore, studies analyzing the use of saline water for irrigation in semiarid regions are valuable, as much of the water available in these regions comes from underground wells. Therefore, the aim of this study was to evaluate the effects of different irrigation water salinity levels on the growth of forage cactus cultivars.

4 MATERIALS AND METHODS

The study was conducted under field conditions, from November 2016 to July 2017, at the Center for Technology and Natural Resources - CTRN of the Federal University of Campina Grande - UFCG, Campina Grande, Paraíba - PB, at geographic coordinates of 7° 15 '18" S latitude, 35° 52 '28" W longitude and an altitude of 550 m. According to the Koppen classification (1948), the predominant climate is AS', a semiarid region of Northeast China, with a long dry period, which is hot and humid, with a maximum annual temperature of 28.6 °C and a minimum of 19.5 °C, with an average annual precipitation of 765 mm. The period between planting and growth assessment had an accumulated precipitation of 512.7 mm, with maximum and minimum temperatures and average relative humidities of 29.35 °C, 20.08 °C and 78.57%, respectively.

The experimental design adopted was a randomized complete block design (DBC) in a 4 × 3 factorial scheme, with a total of 48 experimental units. The treatments consisted of four salinity levels (S1 = 0.2; S2 = 2.0; S3 = 3.8 and S4 = 5.6 dS m^{-1}) of irrigation water and three palm cultivars (Miúda or Doce (*Nopalea cochenillifera Salmon* Dyck), Mexican elephant ear (*Opuntia stricta Haw*), Baiana or IPA-Sertânia (*Nopalea cochenillifera* Salmon Dyck)) with 4 replicates, which were chosen because they are resistant to the carmine mealybug and because they adapt well to the climatic conditions of the semiarid region.

To prepare the treatments, commercial sodium chloride (without iodine), calcium chloride and magnesium chloride were added to the local water supply (EC = 1.7 dS m^{-1}) in proportions of 7:2:1, adjusting them to the concentrations of the available water supply to increase the electrical conductivity of the water, according to the methodology proposed by Richards (1954). The dilutions were carried out in four polyethylene boxes (500 L), where each box corresponded to a salinity level.

The cultivars were grown in 120-L pots under field conditions in an area of 148.2 m^{2}, spaced 1.50 m between rows and 1.00 m between plants, with one plant per pot. The pots were adapted as drainage lysimeters to quantify the drained volume. The pots were filled with a layer of No. 1 gravel covered with textile fabric, a layer of coarse sand, and 0.120 m^3 of soil.

The soil used was from the Poço de Pedra Farm, Highway PB-233 – Rural Area, Santa Luzia – PB. The physical–chemical analysis of the soil was carried out by the Irrigation and Salinity Laboratory (LIS) of UFCG, and the physical, chemical and water values of the soil were determined according to the methodology proposed by Teixeira et al. (2017): Ca^{2+} = 5.49 cmolc dm^{-3}; Mg^{2+} = 11.41 cmolc dm^{-3}; Na^{+} = 0.14 cmolc dm^{-3}; K^{+} = 1.86 cmolc dm^{-3}; $Al^{3+} + H^{+}$ = 0 cmolc dm^{-3}; pH in H_2O (1:2.5) = 6.97; pH (saturation extract) = 6.90. ECes (dS m^{-1}) = 0.64; organic matter (%) = 1.2; sand (%) = 91.34, silt (%) = 7.1 and clay (%) = 1.56; bulk density (g cm^{-3}) = 1.42; moisture (%) = 0.49 and available water (%) = 6.37; sodium adsorption ratio = 0.26; salinity = nonsaline; and soil classification = normal.

The cladodes of the three palm cultivars used in the experiment also came from the Poço de Pedra Farm. The cultivars were identified as V1 - Miúda or Doce; V2 - Orelha de Elefante Mexicana (OEM); and V3 - Baiana or IPA-Sertânia. After the rackets were cut at the farm, they remained in the shade for 15 days to lose excess moisture, thus allowing the healing of injuries caused during cutting and reducing the possibility of disease incidence. After curing, the rackets were half-buried to promote root system development (GAVA; LOPES, 2012).

Planting was carried out by placing one racket per hole at an inclination of 45° in the predominant direction of the wind to reduce plant toppling (Silva et al., 2010). Fertilization was carried out monthly, with 8.5 g per pot of MAP, 1.26 g per pot of urea and 3.54 g per pot of potassium chloride (KCl), as recommended by NOVAIS (NEVES; BARROS 1991).

After the pots were filled, the soil moisture was increased to field capacity and maintained throughout the study period, with a 10-day irrigation schedule, via manual irrigation via graduated containers. The applied volume was estimated by a water balance: the volume of water applied minus the volume of water drained from the previous irrigation. Water with varying saline levels was applied 100 days after transplanting (DAT), that is, after the emergence of primary cladodes.

At 234 days after the start of treatment, the following growth variables were analyzed: plant height (AP), measured from the soil level to the highest cladode; plant width (LP), which is based on the most distant points between the ends of the plants; length of primary (CCP) and secondary (CCS) cladodes; width of primary (LCP) and secondary (LCS) cladodes; thickness of primary (ECP) and secondary (ECS) cladodes; and perimeter of primary (PCP) and secondary (PCS) cladodes. A tape measure with 1 mm precision was used, according to the methodology proposed by Borges et al. (2015).

The data obtained were subjected to analysis of variance via the F test at the 0.05 and 0.01 probability levels. Under the condition of a significant effect, linear and quadratic polynomial regression analyses were performed for the salinity factor. For the cultivar factor, the Tukey test was applied, with 5% significance for comparison of means. For the statistical analyses, SISVAR software, version 5.6 (Ferreira, 2011), was used.

5 RESULTS AND DISCUSSION

Text results and discussion Significant effects were observed ($p \leq 0.01$) for the variables plant width, length, width, thickness and perimeter of primary cladodes of forage cactus cultivars and for the source of variation in the salinity of the irrigation water, only for plant width. The interaction effect was also significant ($p \leq 0.01$ and 0.05), with no significant effect observed for the variables plant height and width of primary cladodes.

Table 1. Summary of the analysis of variance for the studied variables of the cultivars Miúda, Orelha de Elefante Mexicana and Baiana.

Source of variation	GL	Mean squares (MS)					
		AP	**LP**	**CCP**	**LCP**	**ECP**	**PCP**
Cultivar (C)	2	28.38 ns	618.34 *	460.67 *	412.62 *	145.79 *	624.56 *
Salinity (S)	3	12.18 ns	488.69 *	4.05 ns	0.54 ns	0.53 ns	41.03 ns
C*S	6	40.61 ns	269.84 **	14.56 **	1.42 ns	8.31 *	180.32 *
Block	3	42.6 ns	105.29 ns	10.46 ns	3.02 ns	5.79 ns	66.97 ns
Error	3	27.27	97.38	4.78	1.07	2.43	37.46
CV (%)	-	8.05	10.09	6.9	6.62	9.94	8.27
Overall average	-	64.88	97.85	31.69	15.65	15.69	73.99

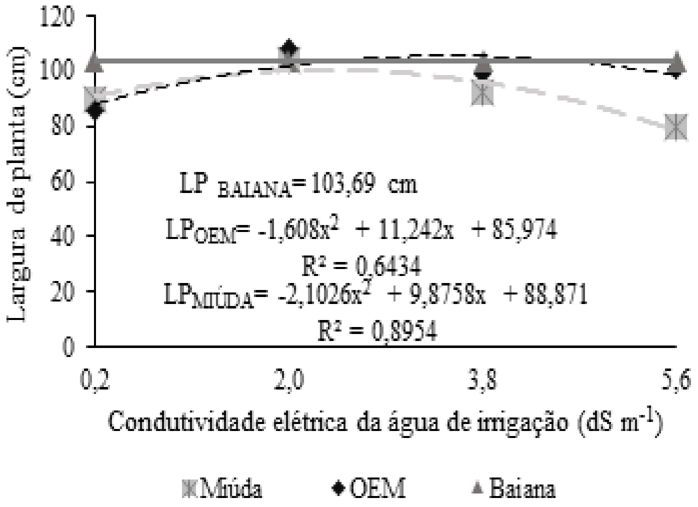
ns Not significant at the 0.05 probability level according to the F test; *, ** Significant at the 0.01 and 0.05 probability levels according to the F test.
AP= plant height (cm); LP= plant width (cm), CCP= length of primary cladodes (cm); LCP= width of primary cladodes (cm); ECP= thickness of primary cladodes (mm) and PCP= perimeter of primary cladodes (cm).

The different salinity levels of the irrigation water did not significantly affect the plant height for any of the cultivars studied. However, they presented average heights of 64.11 cm for the cultivar Miúda, 66.42 cm for the cultivar Orelha de Elefante Mexicana, and 64.12 cm for the cultivar Baiana. In a study by Pereira (2020), which aimed to study the agronomic performance of the forage cactus pear Orelha de Elefante Mexicana at different irrigation depths and salinity levels, no significant effects on plant height were observed, thus obtaining a lower average height than that of this study.

Freire (2012), when evaluating different clones of forage palm (*Opuntia* and *Napolea*) irrigated with saline water, reported a significant effect of salinity level on the cladode width variable in the Miúda cultivar, with responses inversely proportional to the salinity level.

For the variable plant width, its interaction (Cult. x Sal.) was significant at the 5% probability level for the cultivars Miúda and Orelha de Elefante Mexicana, at the different salinity levels of the irrigation water, promoting a quadratic effect, but it did not demonstrate significance for the cultivar Baiana, with an average width of 103.69 cm, for the adjustment equation of $y = -1.9375x^2 + 3.9125x + 108.44$, with the occurrence of the maximum point for Baiana for the saline level of 1.0 dS m^{-1}, with an average width of 110.41 cm. For the Miúda cultivar, the largest average plant width occurred for the salinity level of 2.35 dS m^{-1}, with a width of 100.47 cm, and for the Orelha de Elefante Mexicana cultivar, at the salinity level of 3.50 dS m^{-1}, with an average yield of 105.62 cm. With increasing salinity, the width of the Miúda cultivar decreased by 11.17%, that of the Orelha de Elefante Mexicana decreased by 14.56%, and that of Baiana decreased by 17.48% (Figure 1).

Figure 1. LP width as a function of salinity breakdown within each cultivar



Even though the width of the plant was irrigated with saline water, it did not completely affect its growth over time. Each of the cultivars behaved according to its distinct characteristics. For Amorim (2015), these results are related to the growth characteristics of each cultivar in isolation.

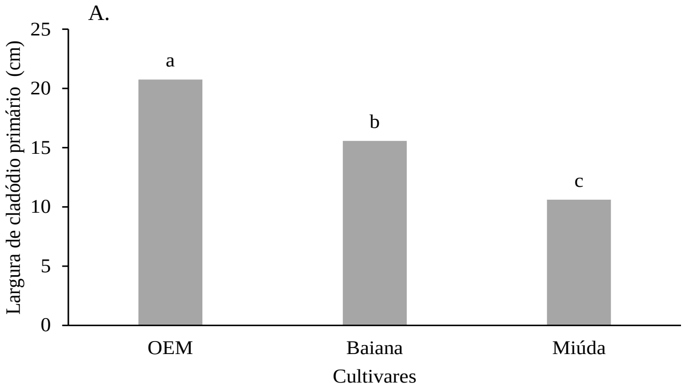
In a study carried out by Félix et al. (2018), who evaluated the cultivation of the Mexican elephant ear forage palm (*Opuntia Stricta Haw*) irrigated with salinized water, higher average values for the variable plant width of 3.0 dS m^{-1} at 90 DAP, which surpassed 1.5 dS m^{-1} from 120 DAP onward, thus showing that the higher concentration of salts can affect the development of the plant, with values lower than those reported in the present study.

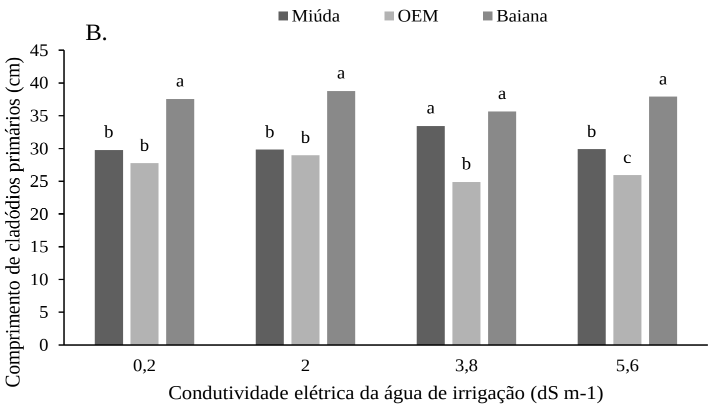
However, lower values were reported by Pereira et al. (2015), who, when studying the morphogenesis of drip-irrigated forage cactus, identified values of 49.8 cm for IPA-Sertânia, 48.8 cm for Miúda and 59.8 cm for Orelha de Elefante Mexicana.

In terms of the variable width of primary cladodes according to the data presented in Table 1, the cultivar Orelha de Elefanta Mexicana presented the largest width, with an average value of 20.76 cm, followed by Baiana with 15.57 cm and Miúda, which obtained the lowest average width value of 10.61 cm, with only the characteristics related to each cultivar being evaluated (Figure 2A).

With respect to the interaction between the cultivar and salinity factors, there was a significant effect ($p \leq 0.05$) for the cultivar split within each of the salinity levels for the variable cladode length; however, there were significant differences between the cultivars and the different salinity levels studied. The cultivar Baiana presented the greatest length of primary cladodes at 38.77 cm for a water salinity of 2.0 dS $m^{-1;}$ for Miúda, the greatest value was 33.44 cm for a salinity of 3.8 dS $m^{-1;}$ and for the cultivar Orelha de Elefante Mexicana, the average value was 28.95 cm (Figure 2B).

Figure 2. Width of primary cladodes - LCP for the forage cactus cultivars studied in isolation (A), Length of primary cladodes - CCP as a function of the interaction of the cultivars with the different salinity levels through the breakdown of cultivars within each salinity level (B).





Freire (2012), when evaluating different clones of forage cactus, specifically Miúda, irrigated with saline water (3.6 dS m $^{-1}$), reported that with increasing salinity of the irrigation water, the width of the cladodes decreased.

These values were lower than those reported by Dantas (2015), who studied the length of the cladodes of the Miúda palm at 12 months of regrowth as a function of different saline water depths (5.25 dS m $^{-1}$) and reported a greater length of cladodes for the greatest irrigation depth, with an average length of 23.68 cm. Fonseca (2017), when investigating the strategy of using saline water in the cultivation of 'giant' forage palm with 3.6 dS m $^{-1}$ saline water, reported that in the first cycle, it had a cladode length of 24.26 cm in relation to the different depths and irrigation shifts in comparison to those without irrigation, with an average value of 22.03 cm. In the second cycle, the authors reported values of 27.91 cm for the different depths and irrigation shifts and without irrigation 24.84 cm, which implies that the larger the irrigation depth is, the greater the length of irrigation.

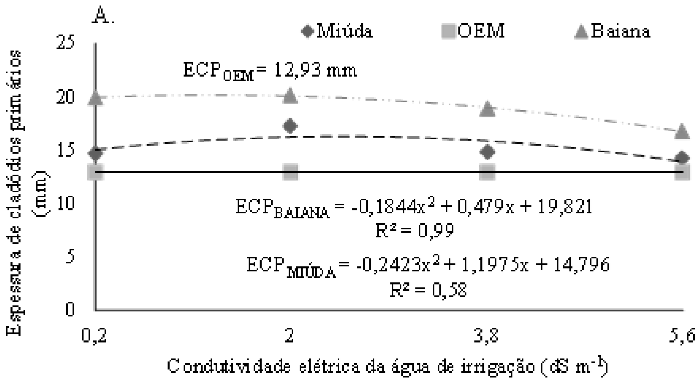
For the variable thickness of primary cladodes, significance was observed at the 1% probability level for the interaction factor and effect of the unfolding of salinity within each cultivar, in addition to being significant at the 5% probability level for the cultivars Miúda and Baiana, in which the adjustment equation that best suited both cultivars was the quadratic polynomial, with maximum points for the cultivar Miúda of 2.47 dS m $^{-1}$, with an average thickness of 16.27 mm, with a decrease of 14.56% in relation to the highest salinity level, and for the cultivar Baiana of 1.30 dS m $^{-1}$, with an average thickness of 20.13 mm.

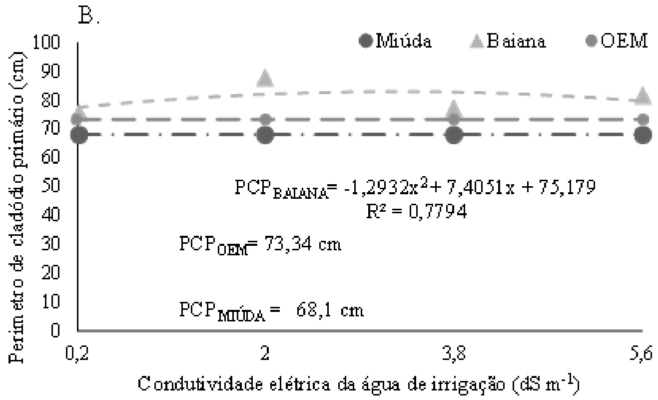
With respect to the cultivar Orelha de Elefante Mexicana, the results were not impressive, with the average thickness value, referring to all the salinity levels, being y = 12.93 mm, for the adjustment equation of $y = -0.16x^2 + 0.764x + 12.22$; however, its maximum point occurred at a salinity of 2.39 dS m $^{-1}$, with an average thickness of 13.13 mm (Figure 3A).

The perimeter of the primary cladodes was significant at the 1% probability level for the S × C interaction factor. In the analysis of the breakdown of saline levels within each cultivar studied, there was significance for the Miúda cultivar, but there was no model adjustment, with the average value for the perimeter of primary cladodes referring to all salinity levels of y = 68.10 cm, for the adjustment equation of $y = -3.4475x^2 + 18.941x + 46.602$, with its maximum point at the salinity level of 2.75 dS m $^{-1}$, with the average perimeter for this salinity of 72.61 cm.

In Baiana, the mathematical model that was best fitted was the quadratic model, with maximum points for an irrigation water salinity of 2.87 dS m $^{-1}$ and a perimeter of 85.78 cm, representing a decrease of 11.29%. In relation to the cultivar Orelha de Elefante Mexicana, there was no significant difference, with an average perimeter for the four salinity levels of y = 73.34 cm and a fitting equation of $y = 0.585x^2 - 4.993x + 81.44$, with a maximum salinity of 4.27 dS m $^{-1}$ and an average perimeter of 70.78 cm (Figure 3B).

Figure 3. Thickness of primary cladodes - ECP (A) and perimeter of primary cladodes - PCP (2), as a function of the interaction of cultivars with different salinity levels through the breakdown of the cultivar within each salinity level.





The continuous use of saline water during irrigation may have affected the turgidity of the plant, since, in addition to the increase in the salinity of the irrigation water and the 10-day watering shift, it may have caused water stress and thus influenced the thickness of the cladodes.

In a study carried out by Freire (2012) on the evaluation of forage palm clones (*Opuntia and Napolea*) under four irrigation frequencies (7, 14, 21 and 28 days) and salinities (0.3 dS m $^{-1}$, 0.5 dS m $^{-1}$, 1.5 dS m $^{-1}$ and 3.6 dS m $^{-1}$), the thickness of primary cladodes decreased as a function of the soil type and the increase in the salinity of the irrigation water, which was related to the amount of water present in the cladodes. For Freire et al. (2018), lower irrigation frequencies are most often caused by larger amounts of applied water and, as a consequence, may lead to a greater disposition of ions in the soil, affecting crop development.

Similar behavior was observed by Silva (2017), who studied the growth of forage cactus irrigated with saline water and reported a decrease in cladode thickness. Similar results were reported by Dantas (2015) for the Miúda adensada cultivar, who, when studying saline water depths and organic fertilizer doses in cactus production in the semiarid region, observed a quadratic effect for cladode thickness in relation to irrigation depth, in which he reported that the greatest thickness was for the deepest saline water depth (30 mm/month), with a thickness of 16.97 mm, and even irrigation with saltwater resulted in greater thickness.

For Morais et al. (2017), when studying the hydrodynamic changes in the soil–palm interface, effective real evapotranspiration and water efficiency under irrigation of the three cultivars studied in the present work, despite being from different genera (*Opuntia and Napolea*), the forage cactus clones subjected to irrigation do not have different behaviors in relation to water consumption; however, the palms of the genus *Opuntia* presented a lower capacity for water accumulation in their cladodes.

A lower value than that in the current study for the thickness of the Miúda cultivar was reported by Xavier Junior (2018). In his study on biofertilization and organic fertilization in forage palm clones irrigated with saltwater with an electrical conductivity of 1.62 dS m $^{-1}$, he reported a value of 9.6 mm in thickness.

Dantas (2015) reported lower values than those reported in the present study for the cultivar Miúda when studying saline water depth and organic fertilizer dose in the production of densely packed palm in a semiarid region and reported the highest average value for a perimeter of 56.62 cm for an electrical conductivity of 5.25 dS m $^{-1}$, with an applied irrigation depth of 30 mm month $^{-1}$.

With respect to the perimeter of secondary cladodes, Silva et al. (2015) reported values of 71.59 cm for Orelha de Elefante Mexicana, 55.94 cm for IPA-Sertânia and 41.02 cm for Miúda. Pereira et al. (2015) reported values of 44.1 cm for the Baiana cultivar, 27.3 cm for Orelha de Elefante Mexicana and 39 cm for Miúda, diverging from the results obtained in the present study, since the Miúda cultivar presented a smaller perimeter.

6 CONCLUSION

The development of primary cladodes was affected by increasing salinity, according to the morphological behavior of each cultivar.

The Miúda palm has better performance in relation to the change in the water salinity level of 3.8 dS m -1, whereas Baiana and the Mexican elephant ear perform better at a salinity of 2.0 dS m^{-1}.

7 ACKNOWLEDGMENTS

We thank the National Council for Scientific and Technological Development (CNPq) and CAPES for granting scholarships and the Federal University of Campina Grande (UFCG) for their support.

8 REFERENCES

ABRANTES, DS de. **Interaction between salinized waters and nitrogen fertilization in the production of grafted guava seedlings.** 2015 **.** Dissertation (Master's in Agroindustrial Systems). Federal University of Campina Grande, Pombal, 2015.

AMORIM, S. O de. **Morphological and productive characteristics of forage cactus cv. Mexican elephant ear subjected to different planting densities and cutting intensities in the semiarid region of Pernambuco** . 2015. Dissertation (Animal Science). Federal Rural University of Pernambuco, Recife, 2015.
water demand of Forage Cactus in future climate change scenarios in the State of Pernambuco. Brazilian **Journal of Physical Geography** , v.8, n.06, p.1628-1643,2015.

BORGES, VE; MATOS, RM; SILVA, PF; DANTAS NETO, J.; SOBRINO, TG Growth analysis of three forage cactus cultivars. **Higher Agricultural Education** , v.30, p. 7-14, 2015. Doi : 10.12722/0101-756X.v30 n02a07.

BRAZ, R DOS S **. Effects of nitrogen fertilization on corn crops under saline stress in two soils.** 2018. Thesis (Doctorate in Soil Science. Federal University of Ceará, Fortaleza, 2018.

DANTAS, FDG **Saline water depths and organic fertilizer doses in the production of small and dense palm in the semiarid region.** 2015. Dissertation (Animal Production). Universidade Federal do Rio Grande do Norte, Macaíba, 2015.

FÉLIX, E. dos. S.; LIMA, W. B de.; SILVA, CT da.; ARAÚJO, JS; PEREIRA, DD; LIRA, EC de. Cultivation of forage palm (Opuntia Stricta) irrigated with saline water. **Brazilian Applied Science review** , Curitiba, v. 2, n. 6 (Special Edition), p. 1869-1875, 2018.

FERREIRA, AA **Production of forage cactus cultivars under water salinity levels and organic fertilization.** 2018. Dissertation (Master's in Agroindustrial Systems). Federal University of Campina Grande, Pombal, 2018.

FERREIRA, DF **Sisvar : a computer statistical analysis system** . Science and Agrotechnology (UFLA), v. 35, n.6, p. 1039-1042, 2011.

FONSECA, V. A **. Strategy for using saline water in the cultivation of 'giant' forage palm.** 2017. Dissertation (Plant Production in the Semi-Arid Region). Instituto Federal Baiano, Guanambi, 2017.

FREIRE, J. of L.; SANTOS, MVF dos.; DUBEUX JUNIOR, JCB; NETO, EB; LIRA, M. of A.; CUNHA, MV da.; SANTOS, DC dos.; AMORIM, SO de.; MELLO, ACL de. Growth of cactus pear cv. Miúda under different salinity levels and irrigation frequencies . **Annals of the Brazilian Academy of Sciences,** v. 90, p. 3893-3900, 2018.

FREIRE, JL de. **Evaluation of forage palm clones (*Opuntia* and *Nopalea)* under irrigation and salinity.** 2012. Thesis (Integrated Doctorate in Animal Science), Federal Rural University of Pernambuco, Recife, 2012.

GAVA, CAT; LOPES, EB Production of forage cactus seedlings using cladode fragments. **Embrapa Semiárido - Technical Communication 101 (INFOTECA-E)** , 2012.

KOPPEN W. Climatology. Translated by Pedro R. H. Perez. Buenos Aires: Printing Panamericana , 1948.

LEITE, EM; CAVALCANTE, LF; DINIZ, AA; SANTOS, RV; ALVES, GS; CAVALCANTE, IHL Correction of sodicity of two irrigated soils in response to the application of agricultural gypsum. **Irriga** , Botucatu, v.12, p.168-176, 2007.

LIMA, G.F. DA C.; WANDERLEY, A. DE M.; GUEDES, FX; REGO, MMT; DANTAS, FDG; SILVA, J.G. M. DA; NOVAES, L. P; AGUIAR, E. M. DE. Irrigated and densified forage cactus: a strategic forage reserve for the Potiguar Semi-Arid Region. EMPARN, Parnamirim, Rio Grande do Norte, 2015. **Embrapa Semi-Arid (Document 45).**

MORAIS, J. E. de.; SILVA, T. G. F. da.; QUEIROZ, M. G. de.; ARAÚJO, G. G. de.; MOURA, M. S.; ARAÚJO JUNIOR, G. do N. Hydrodynamic changes of the soilcactus interface, effective current evapotranspiration and its water efficiency under irrigation . **Brazilian Journal of Agricultural and Environmental Engineering** , Campina Grande, v.21, n.4, p.273-278, 2017.

NOVAIS, RF; NEVES, JCL; BARROS, NF Essay in environment controlled . In: Oliveira, AJ (ed.). **Soil fertility research methods** , Brasília: Embrapa SEA. P. 189-253, 1991.

PERAZZO, AF, SANTOS, EM, PINHO, RM, CAMPOS, FS, RAMOS, JP, AQUINO, MM; BEZERRA, HF Agronomic characteristics and rain-use efficiency in sorghum cultivars in the semiarid region. **Ciência Rural** , Santa Maria, v.43, n.10 , p. 1771-1776, 2013.

PEREIRA, MCA de.; AZEVEDO, CAV de.; DANTAS NETO, J. PEREIRA, M. de O.; RAMOS, JG; NUNES, KG; LYRA, GB; SABOYA, LMF Production of forage palm cultivars (Mexican Elephant Ear, IPA-Sertânia and Miúda) under different salinity levels in irrigation water . **Australian Journal of Crop Science** , v. 15, no. 7, p. 977-982 (2021).

PEREIRA, M. de O **. Agronomic performance of forage cactus under irrigation depths and water salinity levels** . 2020. Thesis (Doctorate in Agricultural Engineering). Federal University of Campina Grande, Campina Grande, 2020.

PEREIRA, PC; SILVA, TGF; ZOLNIER, S.; MORAIS, JEF; SANTOS, DC Morphogenesis of drip-irrigated forage cactus. **Caatinga Journal** , Mossoró, v. 28, p. 184-195, 2015.

QUEIROZ, JE; GONÇALVES, ACA; SOUTO, JS; FOLEGATTI, MV; SOUSA, ER de.; BARROS, M. de FC Assessment and monitoring of soil salinity using geostatistical tools . In: GHEYI, RH; DIAS, NS; LACERDA, CFR **Salinity Management in Agriculture: Basic and Applied Studies** . 2nd. ed. Fortaleza: INCTSal , 2016.

RAMOS, J. P de F; SANTOS, EM; PINHO, RM A; BEZERRA, HFC; PEREIRA, GA BELTRÃO, GR; OLIVEIRA, JS Growth of forage cactus as a function of organic fertilization. **REDVET. Electronic Veterinary Journal** , v. 16, n. 12, p. 1-11, 2015.

REGO, MMT do.; LIMA, GF da C.; SILVA, JGM da.; GUEDES, FX; DANTAS, FDG; LÔBO, RNB Morphology and Biomass Yield of Irrigated Cactus Under Organic Fertilizer Doses and Cutting Intensities. **Embrapa Goats and Sheep-Article in an indexed journal (ALICE)** , 2014.

RICHARDS, LA Diagnosis and improvement of saline and alkali soils . **Washington: US Department of Agriculture** , 1954. 160 p. USDA. Agricultural Handbook , 60.

SILVA, JLA; MEDEIROS, JF de.; ALVES, SSV; OLIVEIRA, FA de.; SILVA JUNIOR, MJ da.; NASCIMENTO, IB do. Use of saline water as an alternative in irrigation and forage production in the semiarid Northeast region. **Brazilian Journal of Agricultural and Environmental Engineering.** Campina Grande, PB, v.18, (Supplement), p.S66–S72, 2014.

SILVA, NGM; LIRA, MA; SANTOS, MVF; DUBEUX JR., JCB; MELLO, ACL; SILVA, MC Relationship between morphological and productive characteristics of forage cactus clones. **Brazilian Journal of Biotechnology Journal of Animal Science** , vol. 39, p. 2389-2397, 2010.

SILVA, PF da. **Growth and productivity of forage cactus under different irrigation depths and nitrogen fertilization** . 2017. Thesis (Doctorate in Agricultural Engineering) – Federal University of Campina Grande, Campina Grande, 2017.

SILVA, TGF da.; ARAÚJO PRIMO, JT; MORAIS, JEF de.; DINIZ, WJ da S.; SOUZA, CAA de.; SILVA, M. da C. Growth and productivity of forage palm clones in the semiarid region and relationships with meteorological variables. **Caatinga Journal** , Mossoró, v. 28, n. 2, p. 10 – 18, 2015.

XAVIER JUNIOR, OS Liquid **biofertilizer on the agronomic performance of forage palm clones.** 2018. Dissertation (Plant Production), Federal Rural University of Pernambuco, Serra Talhada, 2018.