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DESEMPENHO DE VARIEDADES DE PALMA FORRAGEIRA SUBMETIDAS A DIFERENTES NÍVEIS DE SALINIDADE

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1 RESUMO

Objetivou-se avaliar o desenvolvimento de variedades de palma forrageira resistentes a Cochonilha do Carmim irrigada com água salina. O experimento foi desenvolvido na estação experimental do Instituto Nacional do Semiárido – INSA, em Campina Grande, Paraíba, Brasil. Foi conduzido em sistema irrigado, com as variedades Orelha de Elefante mexicana, Baiana e Miúda e 4 níveis de salinidade com turno de rega de 7 dias, corrigido a cada irrigação, com base na lisimetria de drenagem. Utilizou-se um fatorial 3 x 2 x 4, com delineamento em blocos casualizados, com 6 repetições. As avaliações ocorreram 365 dias após o início dos tratamentos para produção de massa fresca (PMF) e massa seca (PMS). A variedade Orelha de Elefante Mexicana (OEM) apresentou uma menor variação dentro dos níveis de salinidade, contudo a variedade Baiana apresentou o maior PMF com 1,7 kg por planta e para PMS a Miúda apresentou a maior produção com 180,2 g por planta. A variedade OEM destacou-se como a mais tolerante a irrigação com água salinizada.

Palavras-chave: estresse salino, condutividade elétrica, cactáceas, irrigação, tolerância.

FELIX, E. S.; ARAÚJO, J. S.; LIMA, W. D.; LIRA, E. C.; OLIVEIRA FILHO, T. J.; SOUZA, J. T. A.
PERFORMANCE OF FORAGE CACTUS VARIETIES SUBJECTED TO DIFFERENT LEVELS OF SALINITY

2 ABSTRACT

The objective was to evaluate the development of forage palm varieties resistant to Cochonilha do Carmim irrigated with saline water. The experiment was carried out at the INSA

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experimental station in Campina Grande, Paraíba, Brazil. It was conducted in an irrigated system, with the OEM, Baiana and Miúda varieties and 4 salinity levels with a 7-day irrigation shift, corrected for each irrigation, based on drainage lysimetry. A factorial 3 x 2 x 4 with a randomized block design with 6 repetitions was used. The evaluations occurred 365 days after the beginning of treatments for PMF and PMS. At 365 days of treatment, it was found that the OEM variety showed a smaller variation within the salinity levels, however the Baiana variety showed the highest PMF with 1.7 kg per plant and for MS the Miúda presented the highest production with 180.2 g per plant. The OEM variety stood out as the most tolerant to irrigation with saline water.

Keywords: saline stress, electric conductivity, cactaceae, irrigation, tolerance.

3 INTRODUCTION

Over the years, livestock farming has demonstrated socioeconomic importance in the semiarid region of Brazil, with a particular emphasis on sheep and goat farming. However, regions with semiarid conditions are characterized by low precipitation, irregular rainfall, and high temperatures, which directly affect the availability of food for livestock production. Vegetation is characterized by small trees and shrubs, most of which are thorny and deciduous, characterized by the loss of their leaves at the beginning of the dry season (SANTOS et al., 2010).

Cultivating forage species that best adapt to these conditions is essential to avoid production and financial losses in ruminant production systems. In this sense, forage cactus (*Opuntia* sp.) appears to be an important food source (MARQUES et al., 2017), where it is considered an economically viable nutritional alternative (DANTAS; LIMA; MOTA, 2017) because of its drought resistance and high productivity. Even though it is tolerant to water deficit, studies have shown increased productivity with the use of irrigation in this crop (LEMOS et al., 2021).

The use of irrigation to produce food, whether for animal or human use, involves the problem of water availability in adequate quantity and quality, since low-salt, high-quality water sources are scarce and prioritized primarily for human consumption. In addition to the problem of rainfall scarcity and its uneven distribution during the rainy season, most drilled artesian wells are not of adequate quality for agricultural use and human consumption because of high electrical conductivity rates resulting from the salinity levels encountered (NEVES et al., 2017). Therefore, it is necessary to adopt practices aimed at mitigating these effects to ensure year-round forage production.

With the increasing scarcity of high-quality water resources for irrigation, the use of water sources that present high saline concentrations has become an important alternative for the development of irrigated agriculture, according to Fonseca (2017).

The use of saline water in agricultural production is a challenge that has already been successfully overcome in several parts of the world, owing to the use of tolerant species and the adoption of appropriate crop, soil, and water management practices (RHOADES; KANDIAH; MASHALI, 2000). Forage cactus has shown satisfactory development when irrigated with saline water, but its productivity decreases with increasing salt concentration (FELIX et al., 2018).

In view of the above, there is a need to use saline water in a rational and controlled manner for irrigation, as its incorrect use can lead to a reduction in crop growth and productivity, making it impossible to use the soil for subsequent crops.

In this context, the present work aimed to identify the variety of forage cactus resistant to Carmine Scale that is most tolerant to saline stress.

4 MATERIALS AND METHODS

The research was carried out from May 2017 to August 2018 in drainage lysimeters under field conditions at the Ignácio Salcedo Experimental Station of the National Institute of Semi-Arid - INSA, located in the municipality of Campina Grande, PB, at geographic coordinates 07°16'41” S, 35°57'59” W and an average altitude of 470 m.

A randomized block design was used in a 3 × 2 × 4 factorial arrangement, whose treatments resulted from the combination of three factors: three palm varieties (Mexican elephant ear, Baiana and Miúda), two leaching fractions (15 and 30% above field capacity) and four levels of electrical conductivity of irrigation water (ECa) (S1 = 1.5; S2 = 3.0; S3 = 4.5 and S4 = 6.00 dS m^{-1}). The combined factors resulted in 24 treatments, with six replicates and one racket per pot.

Drainage lysimeters with a capacity of 40 L were used in the research; these lysimeters were filled with 2 kg of gravel (n° 2), which covered the base of the pot, followed by 15 kg of soil material (planosol), which was collected at a depth of 0–20 cm, properly broken down and came from the experimental station, whose chemical characteristics (Table 1) were obtained according to methodologies described by Teixeira et al. (2017).

Table 1. Chemical characteristics of the soil used in the experiment before application of the treatments.

Layer	pH	CE	P	Al	H + Al	He re	Mg	In the	K	SB	T	t	V	m
	H_2O	mS cm^{-1}	mg kg^{-1}				cmol $_c$ kg^{-1}						%	
0-20 cm	6.2	130	4.76	0.1	1.5	4.4	0.6	0.5	0.4	5.9	7.4	6.0	79.7	1.7

pH – hydrogen potential, EC – electrical conductivity, SB – sum of bases, T – potential CTC, t – effective CTC, V – base saturation, m – aluminum saturation.

The seed rackets used, which were also from the experimental station, were collected and left in a ventilated place in the shade for 12 days, which was the time necessary for the cut to heal. They were then immersed in a Bordeaux mixture for approximately 30 s and planted the following day.

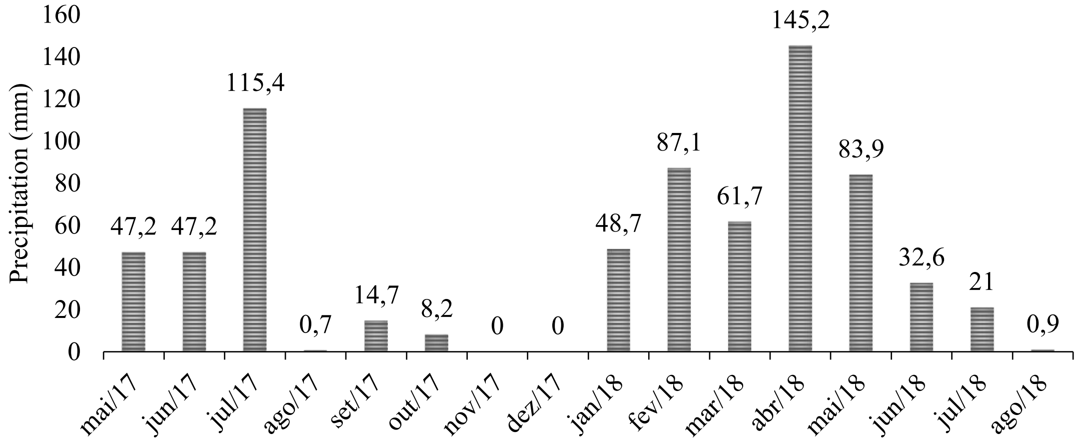
The palm was initially irrigated with rainwater, with 1 liter per plant applied every 7 days. At 90 days after planting (DAP), the first morphometric evaluation was performed, in which the following variables were measured: plant height (AP), plant width (LP), total cladode number (TCN), and the length, width, perimeter, and thickness of the cladodes. Saline water was subsequently applied to the samples, which were obtained by diluting sodium chloride (NaCl) in rainwater and storing it in 1,000-liter boxes.

The irrigations, with a 7-day watering shift, were carried out in the late afternoon, and each saline treatment received its own irrigation volume, corrected at each irrigation, on the basis of drainage lysimetry. At the end of the afternoon, to avoid losses due to evapotranspiration, a known quantity of water was placed in pots that had five holes in the base to allow drainage, and below them, plastic bottles were used to monitor the volume of water drained and estimate the water consumption of the plant.

Early in the morning of the following day, the drained water was collected, and the leached volume was measured with a volumetric cylinder, and the electrical conductivity was measured with a portable conductivity meter. In the late afternoon of the same day, irrigation was applied, considering the difference between the applied water and the drained water from the last irrigation event (field capacity - CC). Every two months, 15% or 30% more CC was applied to promote leaching in the root zone.

Figure 1 shows the rainfall that occurred during the experimental period.

Figure 1. Rainfall during the experimental period



Cultural treatments were carried out according to the emergence of invasive plants through manual weeding between the pots and inside them using only the hands.

At 365 days after the start of treatment, fresh mass production (FMP) was determined in g plant $^{-1}$ by order of emergence, where the harvested rackets were weighed on a precision scale still in the field, and dry mass (DMS) was determined by the dry matter content (DMT). For this purpose, the rackets were cut into smaller fragments, predried in a dry and ventilated environment and then placed in an oven at 65 °C until a constant weight was obtained. The DMS was calculated by multiplying the FMP by the DMT content and dividing by 100 (RODRIGUES, 2010).

The results were subjected to analysis of variance via the F test. The means for the leaching levels were compared via the F test ($P \leq 0.05$), which is conclusive for one degree of freedom. Those for the irrigation water salinity levels were adjusted via regression. SISVAR statistical software version 5.6 (FERREIRA, 2019) was used for data processing.

5 RESULTS AND DISCUSSION

The results of the analysis of variance (Table 2) revealed that there was a significant difference ($p<0.01$) between the varieties and salinity levels studied for all the variables, as did the interaction between variety and salinity for all the variables, except for the dry mass of the tertiary cladodes.

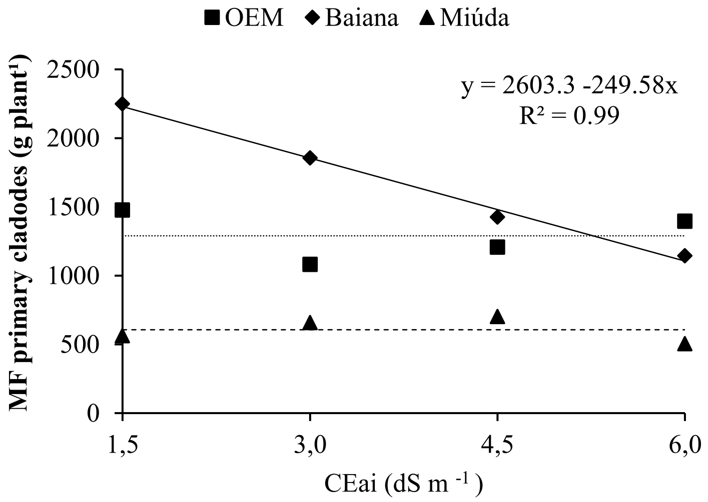
Table 2. Summary of variance analyses, referring to fresh and dry masses of primary, secondary and tertiary cladodes.

FV	GL	F Test					
		MFP	**MFS**	**MFT**	**MSP**	**MSS**	**MST**
Variety (A)	2	**	**	**	**	**	**
Leaching (B)	1	ns	ns	ns	ns	ns	ns
Salinity (C)	3	**	**	**	**	**	**
A x B		ns	ns	ns	ns	ns	ns
A x C		**	**	*	**	*	ns
B x C		ns	ns	ns	ns	ns	ns
A x B x C		ns	ns	ns	ns	ns	ns
CV%		43.45	51.94	28.61	39.04	54.16	29.63

MFP - fresh mass of primary cladode; MFS - fresh mass of secondary cladode; MFT - fresh mass of tertiary cladode; MSP - dry mass of primary cladode; MSS - dry mass of secondary cladode; MST - dry mass of tertiary cladode.
** - 1%; * - 5%, ns – not significant

The salinity level of the irrigation water negatively influenced the fresh mass of primary cladodes of the Baiana variety, as the highest production was obtained at the lowest level (1.5 dS m $^{-1}$). Productivity gradually decreased as the salinity level increased, with the lowest productivity (1250 g of primary cladodes/plant) occurring at the highest salinity level (6.0 dS m $^{-1}$). The Miúda and Orelha de Elefante Mexicana varieties did not significantly differ, with only a reduction in the average absolute values (Figure 2). Lima et al. (2022), studying the production of OEMs irrigated with four levels of water salinization in three soil types in the semiarid region, reported that the fresh mass of primary cladodes was not affected by the salinity level, corroborating the results of this study for the same variety but contradicting what occurred with the Baiana variety.

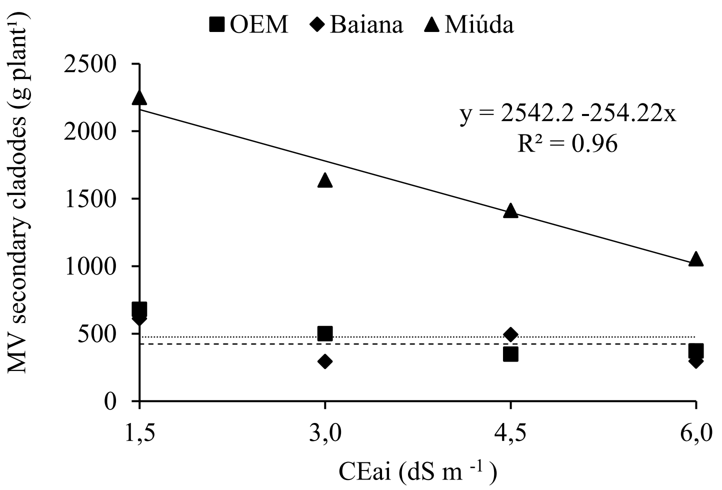
Figure 2. Fresh mass of primary cladodes (g plant $^{-1}$) as a function of irrigation water salinity level



The Mexican elephant ear variety performed best at the lowest salinity, decreasing productivity at levels 3 and 4.5 dS m $^{-1}$ and increasing again at the lowest level of 6 dS m $^{-1}$, as shown in Figure 3. However, there was little variation between the highest and lowest averages, with no significant difference between the treatments. The Miúda variety, on the other hand, showed little variation in primary cladodes within the salinity levels studied, with the highest production found precisely at the lowest salinity (1.5 dS m $^{-1}$). These results demonstrate a certain tolerance of these varieties to saline stress, at least for cladodes of this order, contradicting the results of Pereira et al. (2021), who, by applying four levels of irrigation water salinity to three forage cactus varieties, identified morphological changes in each of the varieties affected by increasing salinity.

In terms of secondary cladodes, the Miúda variety differed statistically from the other varieties, obtaining the highest PMF, 2,250 g/plant, at the lowest salinity level, which decreased inversely proportional to the increase in salinity concentration, whereas the lowest PMF (1,055 g/plant) was obtained when the highest level was applied (6.0 dS m $^{-1}$) (Figure 3). This behavior corroborates Freire (2012), who, working with different levels of saltwater up to 3.6 dS m $^{-1}$ in Miúda palm, identified a reduction in the width of the cladodes inversely proportional to the salinity level and associated it with the dehydration that occurred in the variety, as observed from the increase in the dry mass content in the cladodes.

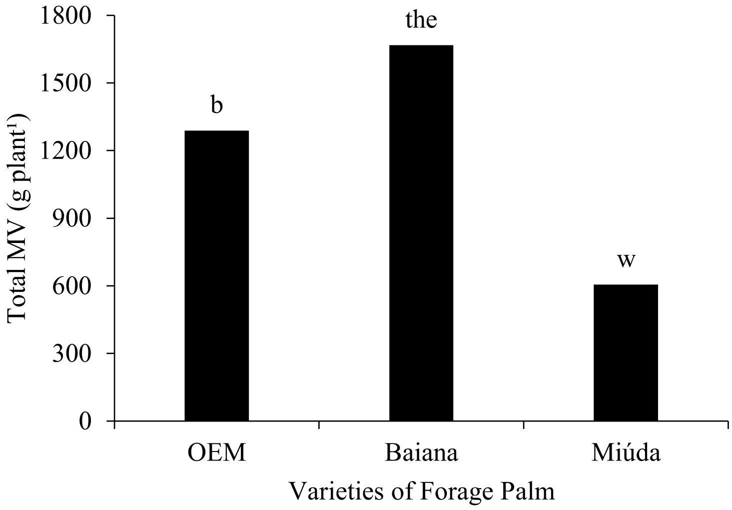
Figure 3. Fresh mass of secondary cladodes (g plant $^{-1}$) as a function of irrigation water salinity level



The OEA and Baiana varieties did not significantly differ between the treatments applied, with only absolute average values with little variation between the salinity levels applied, indicating tolerance to irrigation with saltwater.

In terms of total fresh mass (Figure 4), the Baiana variety presented the highest productivity, with 1667.4 g/plant, which differed statistically from those of the other varieties. The OEM had the second highest productivity, with 1289.3 g plant $^{-1}$. These results differ from those reported by Silva et al. (2014), who, when working with the same forage cactus varieties under rainfed conditions, obtained the highest results for fresh mass in the OEM variety, with 5216 g plant $^{-1}$. Notably, the harvest was carried out two years after planting, which may have contributed to the increased production.

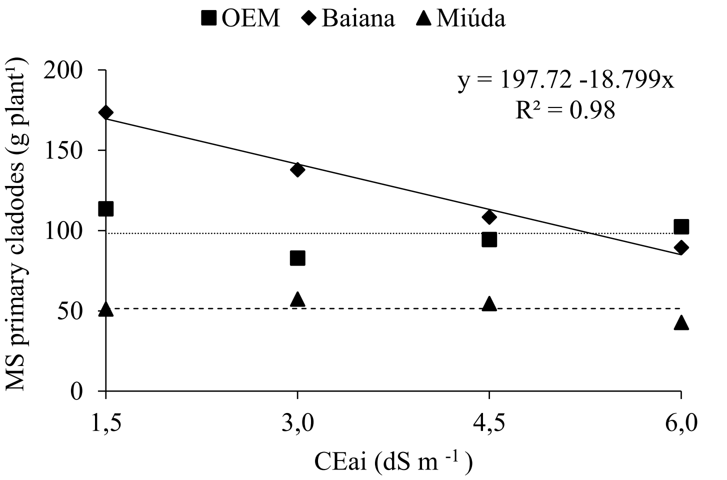
Figure 4. Fresh mass productivity of the forage palm varieties Orelha de Elefante Mexicana, Baiana and Miúda



The M. iúda variety had the lowest productivity among the varieties studied (606.3 g plant $^{-1}$), which may be related to the size of the plant, since the rackets of this variety are small. These results are similar to those reported by Cavalcante et al. (2014), who, when working with the Redonda, Gigante and Miúda varieties at different planting densities, reported the lowest productivity for the Miúda variety.

The dry mass productivity of the Baiana variety, for the primary cladodes, was the most influenced by the salinity level, so the lowest level of 1.5 (dS m $^{-1}$) promoted a productivity of 173.5 g plant $^{-1}$, which decreased with increasing salinity concentration, with 89.4 g dry mass per plant at the highest level (6.0 dS m $^{-1}$) (Figure 5).

Figure 5. Dry mass of primary cladodes (g plant $^{-1}$) as a function of irrigation water salinity level

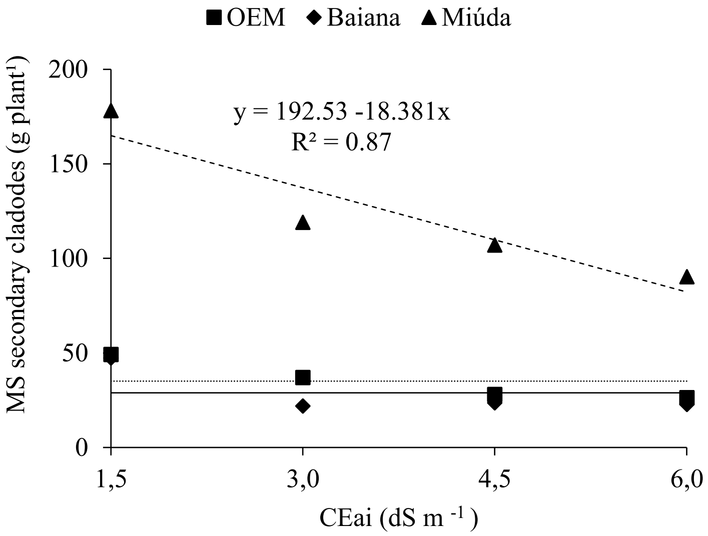


For the OEM and Miúda varieties, there was no great variation; however, the highest dry mass production for the OEM was at the lowest salinity level, whereas for

Miúda, there was practically no variation within the levels. However, the productivity decreased slightly at a concentration of 6.0 dS m $^{-1}$. These results corroborated those obtained by Freire et al. (2018), who, when evaluating the performance of Miúda palm in a controlled environment using four salinity levels, with the highest value being 3.6 dS m $^{-1}$, concluded that this variety is sensitive to salinity, affecting productive performance.

For secondary cladodes, the Miúda variety again showed lower tolerance to saline stress (Figure 6), with production decreasing as the salinity level increased. The variety presented a secondary cladode productivity of 178.8 g/plant at the lowest salinity concentration and 90.2 g plant $^{-1}$ when the irrigation water level was 6.0 dS m $^{-1}$.

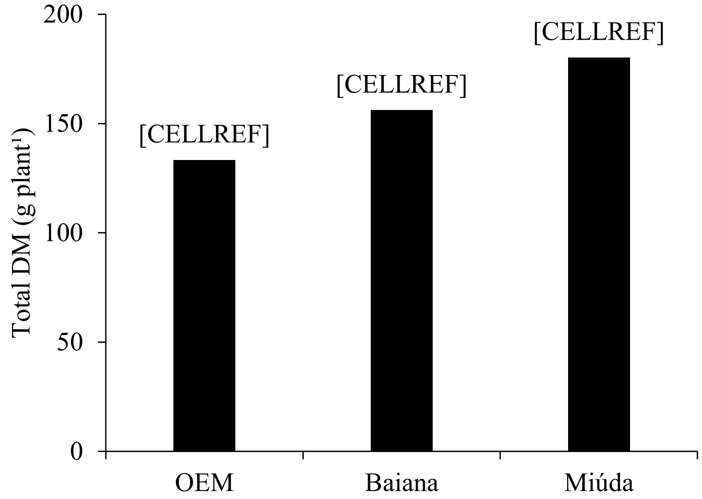
Figure 6. Dry mass of secondary cladodes (g plant $^{-1}$) as a function of irrigation water salinity level



The OEM and Baiana varieties presented nonsignificant results for the salinity levels applied in the irrigation water, which shows a small variation in productivity between treatments, which can be considered a positive characteristic of these varieties when subjected to salinity stress.

The total dry mass production differed significantly among the studied varieties, with the highest productivity occurring in the Miúda variety (180.2 g plant $^{-1}$). This is due to the size of this variety, which has small cladodes but in large quantities, reducing the water concentration and consequently increasing the dry mass content (Figure 7).

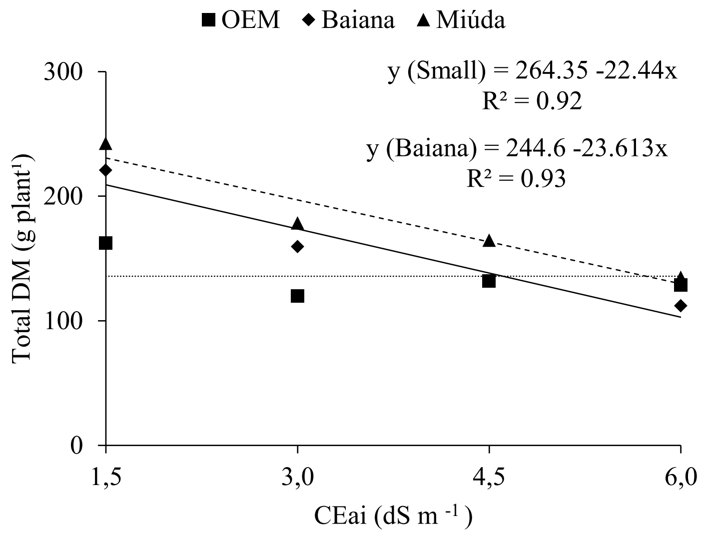
Figure 7. Dry mass productivity of the forage palm varieties Orelha de Elefante Mexicana, Baiana and Miúda



The Mexican elephant ear variety had the lowest production, with 133.3 g plant $^{-1}$ DM, which was explained by Santos et al. (2006), who, when working with forage cactus pear clones, reported that the Miúda variety of the *Nopalea genus*, despite having lower fresh mass production, commonly has higher average dry mass contents than clones of the *Opuntia genus*. These values were much higher than those reported by Dubeux Júnior et al. (2010), who, when working with the IPA 20 clone of the same genus in a controlled environment, in a pot and fertilized with doses of 4.25 g pot $^{-1}$ P_2O_5 and 4.05 g pot $^{-1}$ K2O, reported a productivity of 86.25 g plant $^{-1}$.

Salinity levels in irrigation water promoted a decreasing effect, especially in varieties of the genus *Nopalea*. The Miúda variety presented a value of 230.69 g plant $^{-1}$ in the lowest salinity treatment of 1.5 dS m $^{-1}$, reaching 129.71 g plant $^{-1}$ when subjected to the salinity treatment of 6.0 dS m $^{-1}$, causing a decrease in production of 43.77% with increasing salinity. The Baiana variety presented a similar behavior to Miúda but with lower values, which indicates a lower tolerance to saline stress (Figure 8).

Figure 8. Total dry mass (g plant $^{-1}$) as a function of the irrigation water salinity.



The OEM variety showed little variation within the treatments, demonstrating greater tolerance to saline stress than the other varieties studied. These results demonstrate the feasibility of using saline water in forage cactus cultivation, as demonstrated by Silva (2017). When evaluating the impact of salinity stress and irrigation frequency on the growth physiology of forage cactus of the genera *Opuntia* and *Nopalea* grown in the semiarid region of Chapada do Apodi, in Limoeiro do Norte, CE, Silva demonstrated that salinized water is viable as long as the electrical conductivity does not exceed 4.78 dS m-^{1}, with a 7-day irrigation cycle.

These results were superior to those reported by Dubeux Júnior et al. (2010), who, when working with the IPA-20 clone, in a controlled, irrigated and fertilized environment, reported a maximum production of 100 g/pot dry mass when doses of 200 and 800 kg/ha phosphate and potassium fertilizers were used.

The leaching fraction used was ineffective in reducing the effects of soil salts on forage cactus. This may be related to the precipitation that occurred during the experiment, in which monthly rainfall of up to 140 mm was observed during the data collection period (Figure 1), which may have leached salts from the soil. Consistent with this finding, Fonseca (2017), who studied the production of the Gigante variety with irrigation depths of salinized water and irrigation shifts, reported that rainfall between crop cycles interfered with soil electrical conductivity, explained by the leaching of salts from the root zone.

6 CONCLUSION

Among the varieties resistant to the Carmine scale studied in this research, Mexican elephant ear presented greater tolerance to saline stress when irrigated with water for up to 6 dSm $^{-1}$ without affecting the production of primary and secondary cladodes.

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