

ASPECTOS MORFOLÓGICOS DE CULTIVARES DE PALMA FORRAGEIRA SOB ESTRATÉGIAS HÍDRICAS

DJALMA CORDEIRO DOS SANTOS¹; LARA CAROLINI LIMA TENÓRIO DE BARROS²; DANIELA ROSARIO DE MELLO³; DIEGO DE LIMA COELHO⁴; PHILIP MOAB DUARTE DE AMORIM⁵ E SÉRVULO MERCIER SIQUEIRA E SILVA⁶

¹Pesquisador Mestre do Instituto Agrônomo de Pernambuco; Brasil, djalma.cordeiro@ipa.br; <http://orcid.org/0000-0002-1194-300X>

²Mestranda do Programa de Pós-graduação em Alimentação Animal e Pastagens, Universidade Federal do Agreste de Pernambuco; Brasil, laracltbarros@gmail.com; <http://orcid.org/0009-0005-5583-8219>

³Doutoranda no Programa de Pós-graduação em Agronomia, Universidade Federal da Paraíba; Brasil, danielamello07@hotmail.com; <http://orcid.org/0009-0007-9097-2602>

⁴Doutor, Bolsista BFT FACEPE, Instituto Agrônomo de Pernambuco; Brasil, diegolcoelho@gmail.com; <https://orcid.org/0000-0003-4436-7165>

⁵Doutorando do Programa de Pós-graduação em Forragicultura, Universidade Federal Rural de Pernambuco; Brasil, philipmoab@gmail.com; <https://orcid.org/0000-0002-0482-7713>

⁶Pesquisador Doutor do Instituto Agrônomo de Pernambuco; Brasil, servulo.siqueira@ipa.br; <https://orcid.org/0000-0001-9980-7258>

1 RESUMO

A busca pelo aumento da produção da palma forrageira nas áreas semiáridas é um dos pontos mais discutidos na atualidade e a pesquisa com estratégias de irrigação pode auxiliar nesse desafio. A partir disto, foi conduzida uma pesquisa no Instituto Agrônomo de Pernambuco (IPA) - Estação Experimental de Ibimirim, Ibimirim, PE, Brasil, entre os anos de 2019 e 2023. O delineamento experimental utilizado foi em blocos ao acaso com parcelas subdivididas, em arranjo 2 x 4 x 3, com três repetições. As parcelas foram dois horários de irrigação (HI₁ = irrigação diurna e HI₂ = irrigação noturna), as subparcelas foram quatro turnos de rega (TR₁ = 0, TR₂ = 14 TR₃ = 28 e TR₄ = 56 dias), aplicados em três subsubparcelas que foram as cultivares de palma forrageira IPA-Sertânia, Miúda e Orelha de Elefante Mexicana. Não houve diferença significativa ($p > 0,05$) entre os horários de irrigação e nem entre os turnos de rega 14, 28 e 56 dias para os volumes de água determinados nos ciclos. De modo geral, a palma Orelha de Elefante Mexicana apresentou melhores resultados quantos às variáveis morfológicas estudadas para as condições do semiárido pernambucano.

Palavras-chave: complementação hídrica, cactáceas, semiárido

SANTOS, D. C. dos; BARROS, L. C. L. T. de; MELLO, D. R. de; COELHO, D. de L.; AMORIM, P. M. D. de; SIQUEIRA e SILVA, S. M.
MORPHOLOGICAL ASPECTS OF FORAGE CACTUS CULTIVARS UNDER WATER STRATEGIES

2 ABSTRACT

The search for increasing forage cactus production in semiarid areas is currently among the most discussed topics today, and research into irrigation strategies can help meet this challenge. From this perspective, research was conducted at the Agronomic Institute of Pernambuco (IPA) - Experimental Station of Ibimirim, Ibimirim, PE, Brazil, between 2019 and 2023. A randomized block split-split plot design was used, in scheme $2 \times 4 \times 3$, with three replications. The plots included two irrigation schedules (IS_1 = daytime irrigation and IS_2 = nighttime irrigation), and the subplots included four irrigation intervals ($II_1 = 0$, $II_2 = 14$, $II_3 = 28$ and $II_4 = 56$ days), which were applied to three subplots, which were the cultivars of forage cactus IPA-Sertânia, Miúda, and Mexican Elephant Ear. There was no significant difference ($p > 0.05$) between the irrigation schedules or between the irrigation intervals of 14, 28, and 56 days for the water volumes determined during the cycles. Overall, the morphological variables studied for the semiarid conditions of Pernambuco state were better for the Mexican elephant ear forage cactus.

Keywords: water supplementation, cacti, semi-arid

3 INTRODUCTION

Water scarcity represents a significant obstacle for conventional agriculture in the Brazilian semiarid region, making rainfed farming a challenging undertaking (Ramos, 2018).

Some crops can be grown under these conditions, such as the forage cactus, which stands out as a prominent choice because of its remarkable ability to adapt to the region's characteristic climate. This plant, despite being a forage crop with low dry matter, fiber, and crude protein contents, has high digestibility and a high quantity of soluble carbohydrates, in addition to being a source of water for animals (Araújo Júnior *et al.*, 2021).

Although the cactus is adapted to the aforementioned climatic conditions, the adoption of effective irrigation systems, such as drip irrigation, can be an alternative for increasing the production of this forage crop. According to Amorim *et al.* (2017) and Araújo Júnior *et al.* (2021), the application of supplemental irrigation, in addition to enhancing the yield of the forage cactus, can significantly modify the expression and duration of the phenological phases of the

crop, promoting earlier harvesting compared with rainfed cultivation. Furthermore, the combination of other water strategies, such as irrigation schedules and watering shifts, especially during the hottest and driest months of the year, allows for improved use, distribution, and conservation of water resources, ensuring the sustainability and efficiency of the agricultural system (Alves *et al.*, 2021).

Adopting specific irrigation schedules can minimize losses due to evaporation and optimize water absorption by plants. The irrigation interval refers to the time between water application to the soil to meet the plants' water needs. Appropriate irrigation intervals aim to identify the best period for irrigation, allowing the plant to utilize the available water to carry out its physiological activities (Santos *et al.*, 2017; Miranda *et al.*, 2023).

Given the above, the objective of this study was to analyze some of the morphological aspects of the forage palm cultivars IPA-Sertânia, Miúda, and Orelha de Elefante Mexicana, which were subjected to supplemental irrigation at different times and irrigation shifts during the dry season in

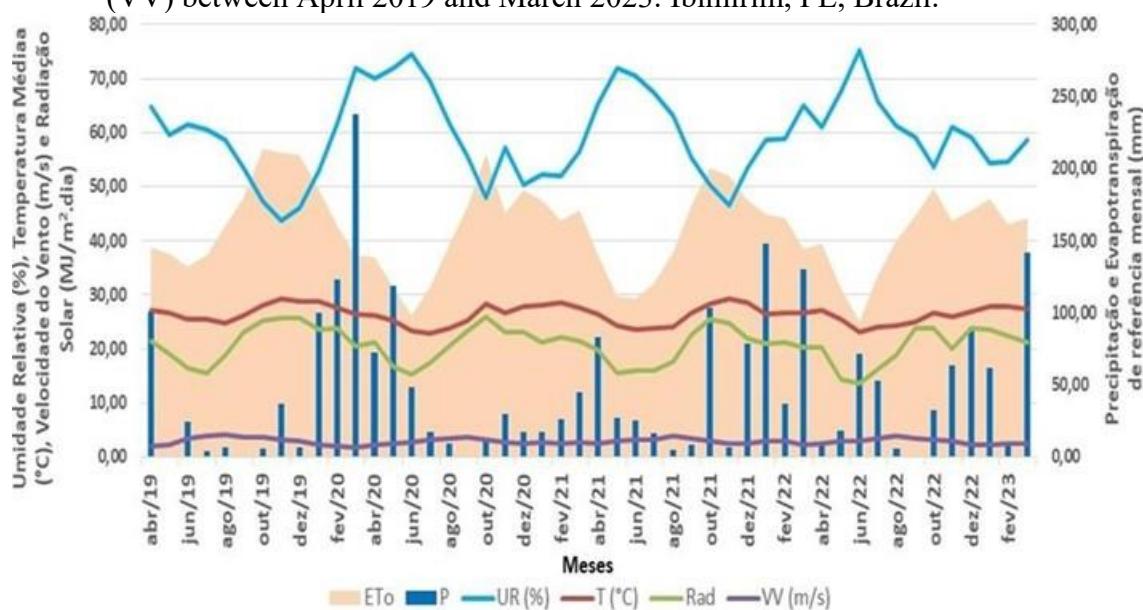
the semiarid region of Pernambuco over four production cycles.

4 MATERIALS AND METHODS

The study was conducted at the Ibimirim Experimental Station, Ibimirim, PE, Brazil, belonging to the Agronomic Institute of Pernambuco (IPA), during four

production cycles. Work began in April and continued until March of the following year, between 2019 and 2023. The area is located at a latitude of 8° 32' 26.46" S, a longitude of 37° 40' 39.12" WGr and an altitude of 407 m. The region's climate is classified as BSh, hot semiarid dry, according to the Köppen classification. The climatogram for the study period is shown in Figure 1.

Figure 1. Monthly average data for reference evapotranspiration (ET₀), precipitation (P), relative humidity (RH), average temperature (T), solar radiation (R_{ad}), and wind speed (VV) between April 2019 and March 2023. Ibimirim, PE, Brazil.



Source: Ibimirim Automatic Station, PE (A349) – INMET.

A randomized block design with split-split plots was used in a $2 \times 4 \times 3$ factorial combination with three replications. The plots were formed by the combination of two irrigation schedules (HI₁ = daytime irrigation and HI₂ = nighttime irrigation), and the subplots were composed of four irrigation shifts (TR₁ = 0, TR₂ = 14, TR₃ = 28 and TR₄ = 56 days), applied to three subsubplots, which were the forage palm cultivars IPA-200205/IPA-Sertânia (IPA), IPA-100004/Miúda (MIU), both (*Nopalea cochenillifera* (L.) Salm-Dyck) and IPA-200016/Orelha de Elefante Mexicana (OEM) (*Opuntia stricta* (Haw.) Haw.). TR₁ = 0 refers to the control

treatment, i.e., without receiving supplemental fluids.

Each experimental plot consisted of three planting rows that were 5 m long. The spacing per plant was 1.5 m × 0.2 m for the MIU and 1.5 m × 0.4 m for the IPA and OEM. The central row was used as the usable area, except for 0.40 m at the ends of this row, totaling 6.3 m². Before the experimental area was installed, soil samples were collected at depths of 0–20 cm for physical and chemical analyses, the results of which are shown in Tables 1 and 2. The soil texture was sandy loam and classified as a fluvisol.

Table 1. Physical characteristics of the soil in the experimental area. Ibimirim, PE, Brazil.

Depth (cm)	Dap		Dr			Texture (%)		Humidity		AD
	(g.cm ⁻³)		(g.cm ⁻³)					(cm ⁻³ .cm ⁻³)		
-	-		-			Sand Silt Clay		0.33 15		mm.cm
0-20	1.26		2.51			49 29 22		FAN 17.91 9.72		1.03

Notice: Dap = Density apparent; Dr = Density real; FA = Franco sandy; AD = Water available.

Source: Soil Fertility Laboratory – IPA.

Table 2. Chemical features of the soil from the experimental area. Ibimirim, PE, Brazil.

pH	P	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Al ³⁺	H ⁺
-	mg.dm ⁻³	-----cmol _c .dm ⁻³ -----					
0	111	9.30	3.15	0.70	0.80	0.00	3.13

Note: pH = hydrogen ion potential; P = phosphorus; Ca²⁺ = calcium ions; Mg²⁺ = magnesium ions; Na⁺ = sodium ions; K⁺ = potassium ions; Al³⁺ = aluminum ions; H⁺ = hydrogen ions.

Source: Soil Fertility Laboratory – IPA.

One cladode was planted per hole and buried 50% of the soil. Throughout the experiment, organic fertilization was carried out, with approximately 10 Mg.ha⁻¹ of manure based on dry matter, during the rainy season, and mineral fertilization with 100 kg.ha⁻¹ of N, the source of which was urea, was always applied at the beginning of the water supplementation. Cultural and

phytosanitary practices were carried out whenever necessary.

The water used for supplemental water supply came from a tubular well with a depth of 168 m and a flow rate of 17 m³.h⁻¹, which was classified as C₁S₁, according to Richards (1954), with the aforementioned chemical characteristics shown in Table 3.

Table 3. Featured chemicals from the water used in the experimental area. Ibimirim, PE, Brazil.

pH	RAS	CEa	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	CO ₃	HCO ₃	Cl ⁻
-	meq . L ⁻¹	dS . m ⁻¹	-----meq . L ⁻¹ -----						
7.90	0.73	0.15	1.72	0.80	0.82	0.24	3.66	1.80	1.21

Note: pH = Hydrogen ion potential; SAR = Sodium adsorption ratio; EC_w = Electrical conductivity of water; Ca²⁺ = Calcium ion; Mg²⁺ = Magnesium ion; Na⁺ = Sodium ion; K⁺ = Potassium ion; CO₃ = Carbonate; HCO₃ = Bicarbonate; Cl⁻ = Chloride.

Source: Plant, Feed and Water Analysis Laboratory – IPA.

The localized irrigation system used in the experiment was drip irrigation, where one line of the system was used for each planting row. The drip tape used was a Netafim® with a nominal diameter of 16 mm, a wall thickness of 10 mil (254 microns), a spacing of 20 cm between emitters, and a dripper flow rate of 1.6 L h⁻¹. The values of the system's water application intensity were determined, as well as the

Christiansen uniformity coefficient (CUC), which yielded excellent results, with CUC > 95%.

The water depths required for the plants were calculated using reference evapotranspiration (ET₀). ET₀ values were calculated according to the Penman–Monteith method (Eq. 1) and parameterized by the Food and Agriculture Organization (FAO) of the United Nations (Allen *et al.*,

1998). The data were obtained from an Automatic Weather Observation Station belonging to the National Institute of Meteorology (INMET), which is installed 200 m from the experimental site.

$$ET_0 = \frac{0,408\Delta(Rn-G) + \gamma \frac{900}{T+273} \mu_2 (es-ea)}{\Delta + \gamma (1+0,34 \mu_2)} \quad (1)$$

where ET_0 = reference evapotranspiration, (mm d^{-1}); Δ = slope of the saturation vapor pressure curve, ($\text{kPa}^\circ\text{C}^{-1}$); G = soil heat flux, ($\text{MJ m}^{-2} \text{d}^{-1}$); Rn = net radiation balance, ($\text{MJ m}^{-2} \text{d}^{-1}$); γ = psychrometric constant, ($\text{kPa } ^\circ\text{C}^{-1}$); T = average daily air temperature at two meters height, ($^\circ\text{C}$); μ_2 = wind speed at two meters height, (ms^{-1}); es = saturation vapor pressure, (kPa); ea = actual vapor pressure of the air, (kPa); and $es-ea$ = vapor pressure deficit, (kPa).

In the estimation of crop evapotranspiration (ET_c), the daily rate was set at 50% of ET_0 , and this value was multiplied by one coefficient of initial cultivation, Initial $K_c = 0.30$ monthly, which increased to 0.02 to the final K_c limit = 0.52 for forage palm (Queiroz *et al.*, 2016). A value referring to the adjustment coefficient for localized irrigation (K_L) was also included in the calculations. In this study, K_L was based on the percentage of shaded area (PAS) by the plants in relation to the total plant area (Eq. 2). Finally, with the resulting daily ET_c value (Eq. 3), the days were summed and applied for each irrigation shift treatment of 14, 28 and 56 days.

$$PAS = \frac{AS}{AT} \quad (2)$$

where PAS = percentage of shaded area; AS = area shaded by the plant (m^2); and AT = total area of the plant (m^2).

$$ET_c = 0.5 \times ET_0 \times K_c \times K_L \quad (3)$$

where ET_c = crop evapotranspiration,

(mm); ET_0 = reference evapotranspiration, (mm); K_c = crop coefficient; and K_L = adjustment coefficient for localized irrigation.

At the end of the first, second, third, and fourth growing cycles, the rainfall volumes recorded were 844.1, 470.4, 670.7, and 525.9 mm, respectively. Supplemental irrigation was carried out between September and December, the hottest and driest period for the region, or until the return of rainfall, with values of 50.2, 54.8, 18.5, and 45.4 mm for the aforementioned cycles. The irrigation depths applied were the same for the 14-, 28-, and 56-day treatments.

At the end of each cycle, the precipitated volumes were added to the water supplements, which represented the water input into the system, totaling 894.3, 525.2, 689.2, and 571.3 mm from the first cycle to the fourth cycle.

The following morphological variables were determined: plant height (PH), plant width (PW), and total number of cladodes (TNC) at the end of each cycle and jointly.

On the basis of the data obtained, analysis of variance and the F test were performed. The mean values of the variables with significant effects were compared using Tukey's test ($p \leq 0.05$) for the different irrigation systems, irrigation schedules, and cultivars. All the statistical analyses were performed using the SISVAR® Computer Program (Ferreira, 2019).

5 RESULTS AND DISCUSSION

According to the data presented in Table 4, there was no significant difference in the irrigation times (daytime and nighttime) between the four crop cycles or overall plant height, plant width, or total number of cladodes ($p > 0.05$).

In terms of the changes in irrigation for the LP and NCT variables, there was also

no difference between treatments ($p > 0.05$). However, for AP in the 2019/20 cycle, there was a significant effect, where the control was inferior to the treatments of 14, 28, and 56 days, on average, at 9.69%, 5.91%, and 8.82%, respectively. This condition was repeated in the combined analysis, although with lower percentages. This effect may have been due to the application of supplemental water in TR₂, TR₃, and TR₄ to the detriment of the plants in TR₁ (Table 5).

For the forage palm cultivars, the values are shown in Table 6; for AP in the 2019/20 and 2020/21 cycles, there was no significant effect ($p > 0.05$), whereas in the 2021/22 and 2022/23 cycles, the MIU variety was inferior to the IPA variety and inferior to the OEM variety, with these behaviors being similar in the joint analysis. Similar results, where OEM > IPA > MIU palm for AP, were also obtained by Pereira *et al.* (2021).

With respect to the width of the cladodes, the width of the OEM cultivar was the widest ($p \leq 0.05$), whereas that of the IPA and MIU cultivars did not differ significantly from each other. In the 2021/22 cycle, the OEM was 41.54% superior to the IPA and 33.65% superior to the MIU, and in the combined analysis, the same trend occurred, with superiorities of 32.53% and 28.06%, respectively. This behavior may

have occurred because of the morphology of OEMs, reinforcing the findings of some studies that indicate that forage palm cultivars respond differently to management with supplemental irrigation, mainly in relation to cladode width (Queiroz *et al.*, 2015; Pereira *et al.*, 2021).

An analysis of the NCT (Nutrient Count of the Palm) revealed that in the 2019/20 production cycle, the MIU variety was the palm with the greatest number of total cladodes, followed by the OEM and IPA, in that order. These values corroborate those determined by Araújo Júnior *et al.* (2021), in which the water regime favored a greater emission of cladodes from the small variety.

However, in subsequent cycles, this pattern changed, with the OEM having the greatest number of cladodes, averaging 37.56 for the three growing cycles, followed by the MIU and IPA. According to Araujo *et al.* (2024), this may be due to the efficiency of supplemental water use by the OEM cultivar, resulting in better performance. In this sense, compared with the other cultivars, the IPA variety always performed worse, as observed in the joint analysis. In part, this may also be caused by the plant's own architectural structure, according to Felix *et al.* (2022).

Table 4. Average values for the height of the plant (AP), width of the plant (LP) and number of cladodes totals (NCT) at different irrigation times for the palm forage for the 1st cycle productive (2019/2020), 2nd cycle productive (2020/21), 3rd cycle productive (2021/22), and 4th cycle productive (2022/23) and analysis joint of the period. Ibimirim, PE, Brazil.

PLANT HEIGHT (cm)		
Schedules	Daytime	Night
2019/20	84.80 a	83.25 a
2020/21	87.17 a	85.50 a
2021/22	101.69 a	102.44 a
2022/23	97.75 a	97.00 a
Joint	92.85 a	92.05 a
PLANT WIDTH (cm)		
2019/20	106.78 a	99.17 a
2020/21	94.89 a	93.58 a
2021/22	118.44 a	117.14 a
2022/23	97.86 a	96.42 a
Joint	104.49 a	101.58 a
NUMBER OF TOTAL CLADOSES (units)		
2019/20	22.47 a	23.72 a
2020/21	22.69 a	21.03 a
2021/22	34.61 a	34.33 a
2022/23	34.44 a	31.19 a
Joint	28.56 a	27.57 a

Note: The average values followed by the same letter are not significantly different for the Tukey test ($p > 0.05$).

Table 5. Average values for the height of the plant (AP), width of the plant (LP) and number of cladodes totals (NCT) for different shifts in the 1st cycle of productive palm forage—2019/2020 2nd cycle productive—2020/21, 3rd cycle productive—2021/22, and 4th cycle productive—2022/23—and analysis joint of period. Ibimirim, PE, Brazil.

HEIGHT OF PLANT (cm)				
TR (days)	0	14	28	56
2019/20	78.77 b	87.22 a	83.72 ab	86.39a
2020/21	81.33 a	87.72 a	85.89 a	90.39 a
2021/22	100.22 a	104.89 a	102.28 a	100.89 a
2022/23	93.00 a	99.83 a	97.27 a	95.39 a
Joint	88.33 b	94.92 a	92.29 ab	93.26 ab
WIDTH OF PLANT (cm)				
2019/20	113.00 the	100.67 a	96.44 a	101.78 a
2020/21	96.22 a	92.78 a	91.56 a	96.39 a
2021/22	118.89 a	120.50 a	117.61 a	114.17 a
2022/23	105.00 a	97.33 a	95.17 a	93.06 a
Joint	108.28 a	102.82 a	100.19 a	101.35 a
NUMBER OF CLADODES TOTALS (units)				
2019/20	25.44 a	22.33 a	20.56 a	24.06 a
2020/21	18.56 a	21.44 a	22.83	24.61 a
2021/22	34.33 a	37.06 a	32.28 a	34.22 a
2022/23	36.00 a	36.33 a	31.00 a	27.94 a
Joint	28.58 a	29.29 a	26.67 a	27.71 a

Note: The average values followed by the same letter are not significantly different for the Tukey test ($p > 0.05$).

Table 6. Average values for the height of the plant (AP), width of the plant (LP) and number of cladodes totals (NCT) in cultivars of palm forage for the 1st cycle productive (2019/2020), 2nd cycle productive (2020/21), 3rd cycle productive (2021/22), and 4th cycle productive (2022/23) and analysis of the period together. Ibimirim, PE, Brazil.

PLANT HEIGHT (cm)			
Cultivars	IPA	MIU	OEM
2019/20	84.75 a	80.87 a	86.46 a
2020/21	91.50 a	84.50 a	83.00 a
2021/22	102.25 b	93.29 c	110.67 a
2022/23	95.63 b	88.58 c	104.92 a
Joint	93.53 a	86.81 b	96.26 a
PLANT WIDTH (cm)			
2019/20	91.17 b	95.92 b	121.83 a
2020/21	81.79 b	89.12 b	106.79 a
2021/22	101.71 b	107.71 b	143.96 a
2022/23	88.75 b	88.50 b	115.67 a
Joint	90.86 b	95.31 b	122.06 a
NUMBER OF TOTAL CLADODES (units)			
2019/20	13.42 c	32.67 a	23.21 b
2020/21	16.67 b	22.42 a	26.50 a
2021/22	22.42 b	38.75 a	42.25 a
2022/23	20.46 c	34.08 b	43.92 a
Joint	18.24 b	31.98 a	33.97 a

Note: The average values followed by the same letter are not significantly different for the Tukey test ($p > 0.05$).

6 CONCLUSION

Under the edaphoclimatic conditions of Ibimirim-PE, the Mexican Elephant Ear forage cactus obtained the best morphological responses for plant height, plant width, and total number of cladodes. There was no difference between the application of supplemental irrigation during the day or at night, nor was there any difference between the use of the 14, 28, and 56-day irrigation schedules during the crop cycles.

7 ACKNOWLEDGEMENTS

THE Foundation for the Support of Science and Technology of the State of Pernambuco (FACEPE) - APQ-0468-5.03/18 for financial support, to the IPA by

facilities and to the *dryGrow Foundation* for their support in conducting the study and for their partnership.

8 REFERENCES

- ALLEN, R. G.; PEREIRA, L. S.; RAES, D.; SMITH, M. **Crop and vapotranspiration** : Guidelines for computing crop water requirements . Rome: FAO, 1998. 300 p. (FAO Irrigation and Drainage Paper , 56). Available at: <http://www.fao.org/3/x0490e/x0490e00.htm>. Accessed on: May 12, 2025.
- ALVES, W. P.; CIRINO JUNIOR, B.; ROCK, THE. K. P.; VIEIRA, D. S. M. M.; EUGENIO, D. S.; LEITE, M. L. M. V. Answers morphophysiological of plants forage plants under management of

Cultivation and grazing: A review.

Research, Society and Development, Vargem Grande Paulista, v. 10, n. 6, p. e10610615405, 2021. DOI:

<https://doi.org/10.33448/rsd-v10i6.15405>.

Available at:

<https://rsdjournal.org/index.php/rsd/article/view/15405>. Accessed on: May 10, 2025.

AMORIM, D. M.; SILVA, T. G. F.; PEREIRA, P. W.; SOUZA, L. S. B.; MINUZZI, R. B.

Phenophases and cutting team of forage cactus under irrigation and cropping systems. **Tropical Agricultural Research**, Goiânia, v. 47, n. 1, p. 62-71, 2017. DOI:

[https://doi.org/10.1590/1983-](https://doi.org/10.1590/1983-40632016v4742746)

40632016v4742746. Available at:

<https://www.scielo.br/j/pat/a/JkXgjHs48KsPkb5rKgVyHcp/?lang=en>. Accessed on: May 8, 2025.

ARAUJO, J. F. N.; SANTOS, J. P. THE. S.; SOUZA, L. S. B.; SOUZA, W. THE. THE.; ALVES, W. P.;

GARDEN, THE. M. R. F.; EUGENIO, D. S.; SOUZA, L. F.; MORAIS, J. AND. F.; SANTOS, W. R.; GOIS, G. W.; FIELDS, F. S.; SILVA, M. V.; MONTENEGRO, THE. THE. THE.; SILVA, T. G. F. Effect

of different irrigation programs on structural characteristics, productivity and water use and efficiency of *Opuntia* and *Nopalea* forage cactus clones. **Grasses**, Basel, vol. 3, n. 4, p. 307-319, 2024. DOI: <https://doi.org/10.3390/grasses3040023>. Available at: <https://www.mdpi.com/2813-3463/3/4/23>. Accessed on: May 12, 2025.

ARAUJO JUNIOR, GN; SILVA, TG F.;

SOUZA, L. SB; ARAÚJO, G. G. L.;

MOURA,

M. S. B.; ALVES, W. P.; SAVIOR, K. R.

S.; SOUZA, W. THE. THE.;

MONTENEGRO, THE. THE.

THE.; SILVA, MJ Phenophases, morphophysiological indices and cutting time in clone of the forage cacti under

controlled water regimes in a semiarid environment. **Journal of Arid Environments**, Amsterdam, v. 190, article 104510, 2021. DOI:

<https://doi.org/10.1016/j.jaridenv.2021.104510>. Available at:

<https://www.sciencedirect.com/science/article/abs/pii/S0140196321000768?via%3Dihub>. Accessed on: May 10, 2025.

FELIX, ES; ARAÚJO, JS; LIMA, WB; LIRA, EC; OLIVEIRA FILHO, TJ;

SOUZA, JTA. Performance of forage palm varieties subjected to different salinity levels. **Irriga**, Botucatu, v. 27, n. 4, p. 729-741, 2022.

DOI:<https://doi.org/10.15809/irriga.2022v27n4p729-741>. Available at:

<https://irriga.fca.unesp.br/index.php/irriga/article/view/4385>. Accessed on : May 10, 2025

FERREIRA, D. F. SISVAR: the computer analysis system to fixed effects split-plot type designs.

Magazine Brazilian of Biometrics, Lavras, v. 37, n. 4, p. 529-535, 2019. DOI: <https://doi.org/10.28951/rbb.v37i4.450>.

Available at:

<https://biometria.ufla.br/index.php/BBJ/article/view/450>. Accessed on: May 14, 2025.

MIRANDA, J. R.; STEALTH, D. THE.;

SILVA, V. W.; DANTAS NETO, J.;

SOUZA, J. T. THE.; ARAÚJO, JS

Physiology of the forage cactus cultivate *Opuntia Haw. stricta* under different irrigation frequencies in the Semiarid region. **Revista Ceres**, Viçosa, v. 70, n. 1, p. 24-31, 2023. DOI:

[https://doi.org/10.1590/0034-](https://doi.org/10.1590/0034-737X202370010003)

737X202370010003. Available at:

<https://www.scielo.br/j/rceres/a/TgFMRMDgRDnnhFqspmm5T9S/?lang=en>. Accessed on: May 10, 2025.

PEREIRA, M. W. THE.; AZEVEDO, W.

THE. V.; DANTAS NETO, J.;

PEREIRA, M. THE.; RAMOS, J. G.;

THOMAS, B. THE. Growth of cultivars of palm forage irrigated under different Salinity levels in a semiarid region. **Irriga**, Botucatu, v. 26, n. 4, p. 814-826, 2021.

DOI:

<https://doi.org/10.15809/irriga.2021v26n4p814-826>. Available at:

<https://revistas.fca.unesp.br/index.php/irriga/article/view/4399>. Accessed on: May 8, 2025.

QUEIROZ, M. G.; SILVA, T. G. F.; ZOLNIER, S.; SILVA, S. M. S.; FILE, L. R.; ALVES,

Morphophysiological characteristics and productivity of forage palm in different planting depths of irrigation. **Magazine Brazilian of Engineering Agricultural and Environmental**, Campina Grande, v. 19, n. 10, pp. 931-938, 2015. DOI:

<https://doi.org/10.1590/1807-1929/agriambi.v19n10p931-938>. Available at:

<https://www.scielo.br/j/rbeaa/a/n6d3mqmPtyGv9MCwXtJgLhx/?lang=pt>. Accessed on: May 11, 2025.

QUEIROZ, M. G.; SILVA, T. G. F.; ZOLNIER, S.; SILVA, S. M. S.; SOUZA, W. THE. THE.;

OAK, H. F. S. Relations water-economic from the palm forage cultivated in an environment semiarid.

Irriga, Botucatu, v. 1, n. 1, pp. 141-154 2016. DOI:

<https://doi.org/10.15809/irriga.2016v1n01p141-154>. Available at:

<https://revistas.fca.unesp.br/index.php/irriga/article/view/1814>. Accessed on: May 9, 2025.

RAMOS, CHS. Agroecological backyards conquer the Brazilian Semi-Arid region: Food security for the most vulnerable through the use of the land's power. *In*: TECHNICAL CENTRE FOR AGRICULTURAL AND RURAL COOPERATION (org.). **Capitalizing on experiences**: Lessons for development in Mozambique and Brazil. v. 2.

Wageningen: CTA Experience Capitalization Series, 2018. pp. 16-21.

Available at:

<https://hdl.handle.net/10568/97722>.

Accessed on: May 13, 2025.

RICHARDS, LA **Diagnosis and improvement of saline and alkali soils**.

Washington: USDA, 1954. (Handbook, 60). Available From:

<https://www.ars.usda.gov/ARUserFiles/20360500/hb60.pdf>. Accessed on: May 12, 2025.

SANTOS, M. R.; SILVA, THE. J. P.; FONSECA, V. THE.; FIELDS, THE. R. F.; LISBON, M. A.

Irrigation in forage palm. Informe Agropecuário, Belo Horizonte, v. 38, n. 296, p. 00-00, 2017. Available at:

https://www.researchgate.net/publication/323943111_Irrigacao_na_palma_forrageira.

Accessed on: May 15, 2025.