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REUSE OF WASTEWATER FROM MILKING IN CACTUS PEAR UNDER DIFFERENT IRRIGATION AND FERTILIZATION FREQUENCIES

Clarice da Silva Santos[1*], Jéssica Lavinea Aragão Mota[2], Evandro Oliveira de Jesus[3], Lígia Maria Gomes Barreto[2], Nailson Lima Santos Lemos[2]

[1]Núcleo de Graduação em Zootecnia, Universidade Federal de Sergipe – UFS, Sergipe, Brasil, E-mail: clarice.santos0888@gmail.com
[2]Graduando em Engenharia Agronômica, Universidade Federal de Sergipe – UFS, Sergipe, Brasil.
Autor para correspondência: Clarice da Silva Santos, clarice.santos0888@gmail.com

ABSTRACT: The aim of this study was to evaluate the performance of cactus pear cv. 'Miúda' (*Nopalea cochenillifera* Salm Dyck) in dense cultivation under different fertilization and irrigation frequencies with reuse water in the semiarid region of Sergipe. The design was in split plots, with three replicates of four irrigation plots (7, 14, 21 and 28) and one control (no irrigation) and four fertilizations: organic fertilization levels 1 (35t bovine manure ha^{-1}), organic fertilization 2 (35t sheep manure ha^{-1}), chemical fertilization (150 kg N ha^{-1}) and fertigation (wastewater). Growth variables (Height, TCV-Vertical Growth Rate; TCH-Horizontal Growth Rate; TApC- Cladode Appearance Rate) showed no differences in relation to irrigation frequency with control; NCT- Total Cladode Number, CC- Cladode Length, EC- Cladode Thickness, VT- Total Volume and EUA- Water Use Efficiency, were similar among treatments and LC-Cladode width was inversely proportional; irrigation frequencies of 7 and 14 days were similar and greater than 21 and 28 days. In the control treatment (rainfed), yield was 23.84 t DM ha^{-1}, the lowest obtained when compared to the highest yield of the 14-day irrigation frequency, which was 30.11 t DM ha^{-1}. Irrigation frequency of 7 days promoted better morphological results in cactus pear. It could be inferred that, at 18 months of age, if the water factor is not limiting, cactus pear cv. 'Miúda' can reach its maximum growth point, which is when the 5th order of appearance of cladodes is reached.

KEYWORDS: Morphogenetic characteristics; Cladode; *Nopalea cochenillifera*; semiarid

REUTILIZAÇÃO DA ÁGUA RESIDUÁRIA DA ORDENHA NA PALMA SOB DIFERENTES FREQUÊNCIAS DE IRRIGAÇÃO E ADUBAÇÃO

RESUMO: Objetivou–se avaliar o desempenho da palma miúda (*Nopalea cochenillifera* Salm Dyck), em cultivo adensado sob diferentes frequências de fertilização e irrigação com água de reuso no semiárido sergipano. O delineamento foi em parcelas subdivididas, com três repetições de quatro parcelas de irrigação (7, 14, 21 e 28) e um controle (sem irrigação) e quatro níveis de fertilização: adubação orgânica 1 (35t esterco bovino ha-1), adubação orgânica 2 (35t esterco ovino ha^{-1}), química (150 kg de N ha^{-1}) e fertirrigação (água residuária). Onde as variáveis de crescimento (Altura, TCV-Taxa de Crescimento Vertical; TCH-Taxa de Crescimento Horizontal; TApC-Taxa de Aparecimento de Cladódio) não demonstraram diferenças em relação a frequencia de irrigação com o controle; os NCT-Números de Cladódios Totais, o CC-Comprimento do Cladódio, EC- Espessura do Cladódio, VT- Volume Total e a EUA- Eficiência de Uso da Água, foram semelhantes entre os tratamentos e a LC-Largura do cladódio foi inversamente proporcional; frequências de irrigação de 7 e 14 dias foram semelhantes e maiores que 21 e 28 dias. No tratamento controle (sequeiro) obteve - se produtividade de 23,84 t MS ha^{-1}, sendo a menor obtida quando comparada a maior produtividade da frequência de irrigação de 14 dias, que foi de 30,11 t MS ha^{-1}. A frequência de irrigação de 7 dias promoveu melhores resultados morfológicos na palma. Podendo inferir que, aos 18 meses de idade, se o fator água não for limitante, a palma miúda pode atingir o ponto máximo de crescimento, sendo este, quando atingida a 5ª ordem de aparecimento de cladódios.

PALAVRAS CHAVE: Características morfogênicas; Cladódio; *Nopalea cochenillifera*; Semiárido

INTRODUCTION

Regions with semiarid conditions are characterized by low precipitation, irregular rainfall and high temperatures. According to IBGE, this area covers 60% of the northeastern region of Brazil, where rainfall is irregular and scarce, with great torrential potential due to the fact that rainfall is concentrated in short seasonal periods that generally lasts from 3 to 5 months. Among agricultural activities developed in these regions, milk production stands out (Ferreira, 2009), which is directly affected by the availability of food for animal production (Marques, 2017).

This activity also generates large amounts of waste. A dairy cow (average weight of 400 kg) produces, daily, excreta equivalent of 28 – 32 kg of feces, being the production of feces and urine in the range of 38 – 50 kg. These residues can become an opportunity for farmers if properly handled. In Brazil, water has already been reused for agricultural purposes in certain regions (Otenio, 2017).

Dantas (2019) reports that, given the scenario that livestock represents for the semiarid region of Brazil and the morphophysiological characteristics of forage cactus pear, the cultivation of this plant is undoubtedly used to meet part of the food demand of bovine, goat and sheep herds, and combined with high water use efficiency, puts forage cactus pear in prominence in semiarid regions (Barbera, 1995).

Silva et al. (2017) concluded that the successful implementation of an irrigation system can increase forage cactus pear productivity, promoting higher gains for producers and contributing to the faster modernization of the rural environment in the Brazilian semiarid region.

The water availability in the northeastern semiarid region is low, and for this reason, alternatives such as the use of wastewater can be adopted to reduce the consumption of drinking water, making water use rational (Brazão and Silva, 2016).

Among cactus pear cultivars cultivated in the semiarid region of Brazil, the 'Miúda' cultivar (*Nopalea cochenillifera* Salm Dyck) stands out for its high yield potential and resistance to carmine cochineal (*Dactylopius* sp), with production being influenced by plant density, harvest frequency, cutting intensity, fertilization, rainfall, among others (Menor, 2018).

In view of the above, this study aimed to evaluate the performance of cactus pear 'Miúda' cultivar (*Nopalea cochenillifera* Salm Dyck) in dense cultivation under different fertilization and irrigation strategies with reuse water in the semiarid region of Sergipe.

MATERIAL AND METHODS

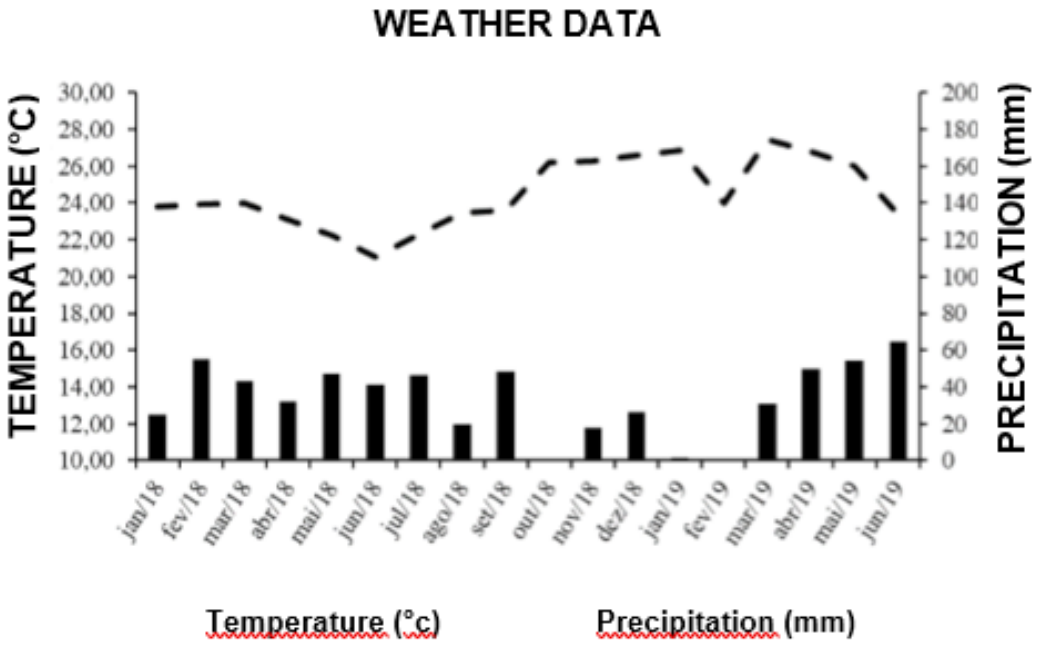
The experiment was carried out at the Technological Reference Unit (URT) of the "Forrageiras para o Semiárido" project, of the Rural Learning System - SENAR, located in the municipality of Nossa Senhora da Glória-SE (10º 12'18" S and 37º 19'39" W and altitude of 294 m a.s.l), semiarid region of the state of Sergipe. According to Koppen Geiger's classification, the municipality has Aw type climate (Tropical with dry season).

The area was established in January 2018 with cactus pear 'Miúda' cultivar densified and fertilized during planting with 750 kg of P2O5 ha^{-1} (simple superphosphate source) arranged in spacing of 1.4 x 0.1 m, with density of 70 thousand plants ha^{-1}.

During the experimental period, temperatures ranged from 21.07 °C to 27.44 °C. Rainfall during the experimental period was 617 mm (Figure 1).

The experimental design used was in subdivided plots, with four irrigation frequency plots in intervals of 7 – 14 – 21 - 28 days plus a control plot (no irrigation) and four fertilization plots as follows: organic fertilizer 1 (35 t bovine manure ha^{-1}), organic fertilization 2 (35 t sheep manure ha^{-1}), chemical fertilization (150 kg of N ha^{-1}) and fertigation (wastewater), with three replicates.

Figure 1. Climatic data referring to the experimental period.



Wastewater from the daily washing of the milking room at the Riacho Grande farm was applied by dripping and filtered according to five steps, as follows: 1. Grease box – 2. Three decantation boxes – 3. Decanted water reception tank – 4. Filter tank (6-layer filter: larger pebbles, smaller pebbles, larger gravel, smaller gravel, pebble and washed sand) – 5. Water distribution tank for irrigation between intervals mentioned above.

Evaluations of the morphogenic characteristics were performed by the marking of three plants/plot and identified with metallic threads of different ~~colors (orange,~~ yellow and blue), and carried out frequently every week and/or a few days. Measurements were performed with the aid of a measuring tape and a caliper measuring the following components: plant height (vertical distance between the highest cladode and ground level), plant width (horizontal distance between end cladodes), total number of cladodes, cladode thickness (EC), cladode width (LC), cladode length (CC) and cladode volume (VC = EC x AC).

Cladode area (AC) was estimated according to equations proposed by Miranda et al (2011), who calibrated the linear model for cactus pear, represented by the equation: AC=0.7327x+3.3339;

Where:

"x" corresponds to the product between cladode length and width (CC x LC).

This information was used to calculate the following variables:

- Cladode Appearance Rate (cladode/plant/month): number of cladodes per plant divided by the number of months of the evaluation period;

- Vertical Growth Rate (cm/plant/month): difference between initial and final plant height divided by the evaluation period;

- Horizontal Growth Rate (cm/plant/month): difference between initial and final plant width divided by the evaluation period;

- Total cladode area per plant (cm2/plant): sum of the area of cladodes per plant evaluated;

- Total cladode volume per plant (cm3/plant): sum of the volume of cladodes per plant evaluated.

Cladode Area (CA) values were used to calculate the Cladode Area Index (IAC), which is the area occupied in each m2 of soil, through the following equation:

$$IAC = \frac{\sum_{n}^{i=1} AC}{10000 \times E1 \times E2)}$$

where:

IAC = is the observed cladode area index, in m^2. m^{-2};

10,000 = is the conversion factor from cm^2 to m^2;

E1 × E2 = is the spacing between rows and plants in m.

Yield evaluation was carried out 18 months after planting, discarding the end rows and the first two and last two plants in the central row, thus considering useful plot of 20 plants. Subsequently, all plants in the useful plot were cut and weighed, keeping the basal cladode. A representative plant, per experimental plot, was removed, fragmented and weighed to obtain fresh weight. The plant was placed in Styrofoam tray and kept in forced circulation oven at 55 ºC until the dry weight remained constant in order to determine the dry matter content.

Yield data were estimated from plant dry matter data, the green weight of the experimental plot and the number of plants per hectare, in tons of dry matter (DM) per hectare.

Data were submitted to analysis of variance and means compared by the Dunnett's test. When there was a degree of relationship with the control treatment, irrigation frequencies were analyzed using the Tukey test at 10% significance level using the SAS 9.0 statistical package.

RESULTS AND DISCUSSION

Among interactions at level of P>0.01, there was no effect of fertilization strategies on height values, as well as on irrigation frequencies compared to control. The mean height value was 58.81 cm, a value higher than that found by Pereira et al. (2015), which was 47.5 cm for cactus pear cv. 'Miúda', working with irrigation frequency of 7, 14 and 28 days (Table 1).

Table 1. Height (cm), Vertical Growth Rate (TCV - cm/plant/month), Horizontal Growth Rate (TCH - cm/plant/month) and Cladode Appearance Rate (TApC - cladode/plant/month) values at different irrigation frequencies and fertilization strategies.

	Height 1	TCV1	TCH1	TApC1
Rainfed (control)	58.91	2.31	2.76	0.90
7	57.34	2.20	2.96	1.15
14	60.90	2.38	2.75	0.93
21	58.59	2.26	2.95	0.87
28	58.30	2.28	2.82	0.88
Gray water	57.34	2.21	2.72	0.90
Chemical	57.65	2.23	2.81	0.97
Bovine	60.64	2.38	3.04	0.97
Sheep	59.59	2.32	2.82	0.95
Mean	58.81	2.29	2.85	0.95
CV%	11.55	15.53	18.38	31.33

(1) no significant differences at 10% probability when submitted to the Dunnett's test.

In plants, Vertical Growth Rate (TCV) and Horizontal Growth Rate (TCH) values were not different (Table 1). Cunha (2012), did not find significant differences for the same variables, but reported that, in absolute values, the Cladode Appearance Rate (TApC - cladode/day) increases according to nitrogen availability.

Total cladode number (NCT), cladode length (CC) and cladode thickness (EC) values were similar to control treatment at different irrigation frequencies and among fertilization strategies, resulting in mean values of 17 cladodes with 17.60 cm and 14.34 cm, respectively (Table 2).

Campos (2018) evaluated the use of rainfed-cultivated cactus pear and found mean NCT values of 10.5 cladodes at 330 days after planting and 11.5 cladodes at 445 days, a result similar to that obtained by Oliveira Júnior et al. (2009) and Ramos et al. (2011), which values are lower when compared to those found in this experiment, allowing inferring that both the conditions offered to the plant and the environment in which it was introduced somehow interfered in its performance during the project.

Cladode width (LC) values were inversely proportional to irrigation frequencies, since irrigation

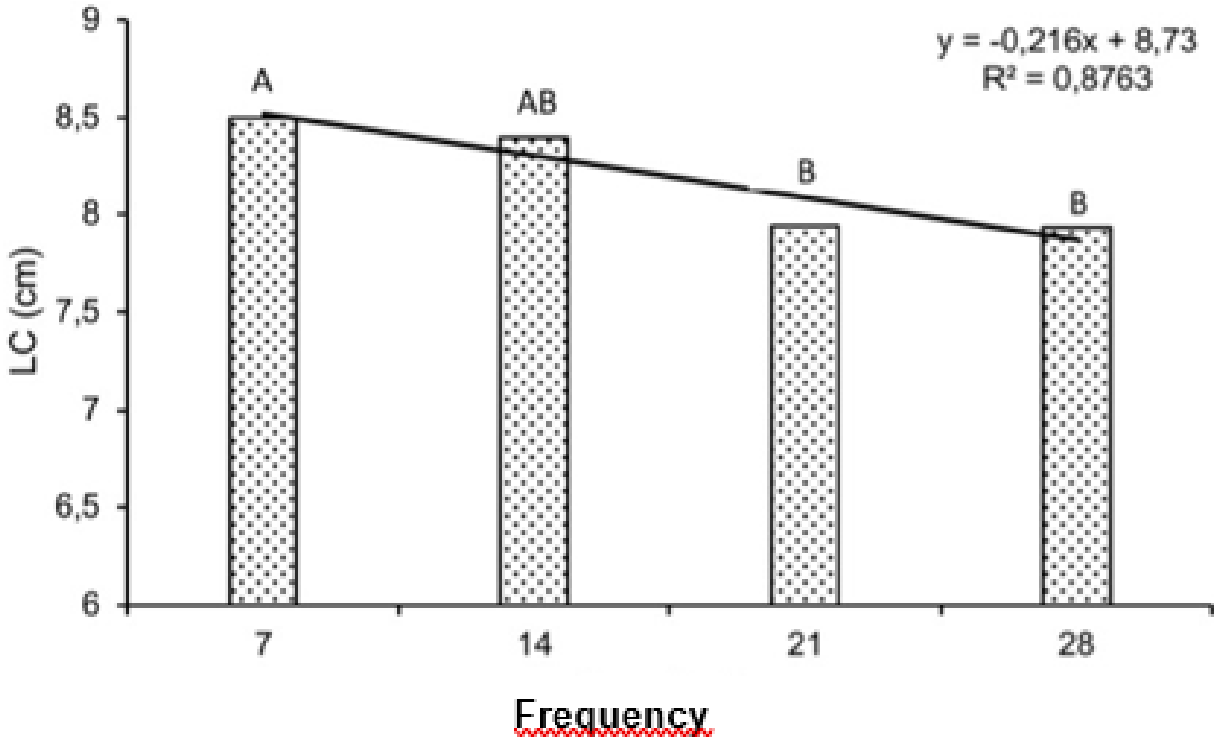
frequencies of 7 and 14 days were similar and higher than irrigation frequencies of 21 and 28 days (Figure 2). This factor was emphasized by Sales et al. (2013), where in addition to plant genetics, climatic fluctuations influence cladode width and length, thus affecting crop production.

Table 2. Total cladode number (NCT), cladode length (CC), cladode width (LC) and cladode thickness (EC) at different irrigation frequencies and fertilization strategies.

	NCT	CC (cm)[1]	LC (cm)	EC (mm)[1]
Rainfed (control)	16	17.21	7.88	15.55
7	21	17.74	8.50*	14.40
14	17	17.96	8.39*	13.23
21	16	17.82	7.94	13.95
28	16	17.27	7.93	14.57
Gray water	16	17.45	8.05	14.16
Chemical	18	17.53	8.10	14.16
Bovine	18	17.71	8.36	14.94
Sheep	17	17.71	8.00	14.09
Mean	17	17.60	8.13	14.34
CV%	31.37	6.71	6.46	22.01

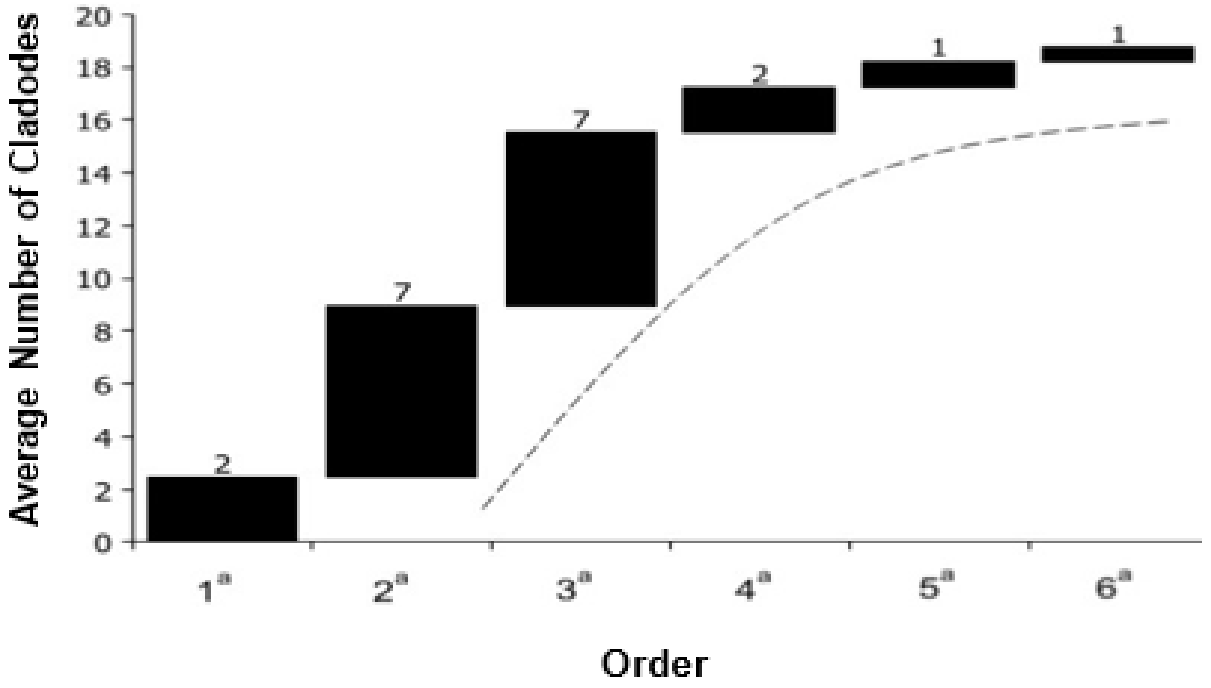
(1) no differences at 10% probability level, by the Dunnett's test. Differ from control treatment (rainfed) by the Dunnett's test, at 10% probability level.

Figure 2. Cladode width (CL), in centimeters at different irrigation frequencies. Means followed by the same letter do not differ from each other by the Tukey's test at 10% probability level.



Based on the order of appearance of cladodes among treatments (irrigation and fertilization), it was observed that cactus pear cv. 'Miúda' has the lowest number of 1st, 4th, 5th and 6th order cladodes, releasing the highest number of cladodes in the 2nd and 3rd order, which shows slow initial growth, followed by high growth phase and subsequent growth reduction, with tendency to stabilize, according to the growth curve for forage plants proposed by Brougham (1956) (Figure 3).

Figure 3. Average cladode number of 'Miúda' cactus pear classified by order of appearance in the municipality of Nossa Senhora da Glória-SE.



First-order cladodes are supplied solely by the basal cladode, and under this condition, sprouting was not influenced by the higher water content. However, second-order cladodes, as they are young structures, require more water for their intense functioning, and may be influenced by soil moisture (Dantas, 2019).

Cunha et al. (2012) studied the morphometry and biomass accumulation in cactus pear cv. 'Miúda' and reported that nitrogen positively favors the number of cladodes. In this work, the authors obtained average of 36.08 cladodes per plant.

Variables IAC and total cladode area per plant presented values in the irrigation frequency of 7 days higher than the control, of 1.71 and 2396.9 cm^2/plant, respectively (Table 3). As a strategy, Lira et al. (2006) suggests increasing the IAC through plant densification. This concern with smaller spacing between plants and the direct relationship with IAC is due to light. The luminosity factor is important due to the growth architecture of this plant, as the almost perpendicular arrangement of cladodes in relation to the soil impairs light interception on the plant structure (Farias et al. 2005).

In Figure 4, the IAC values of irrigation frequencies reduced with the increase in the irrigation frequency due to the reduction in LC (Figure 2) and total cladode area, which decreased with the increase in the irrigation frequency (Figure 5).

IAC is a measure that helps to estimate the photosynthetic capacity of the plant and can be used as a variable to measure vegetative growth, thus allowing evaluating the effects of agronomic crop management (Oliveira Júnior et al., 2009).

Menor (2018) emphasizes that the low cladode area index (IAC) can limit growth and favor the incidence of invasive plants. Dantas (2019) compared different forage cactus cultivars and found IAC values in 'Orelha

Table 3. Cladode Area Index (IAC), Total cladode area per plant (cm 2 / plant), total cladode volume per plant (liters / plant), water use efficiency (EUA - kg DM / mm of water) and cactus pear yield (t DM / ha) values at different irrigation frequencies and fertilization strategies.

	IAC	Total Area	Total Volume [1]	EUA[1]	Yield
Rainfed (control)	1.26	1769.8	2.99	34.90	23.84
7	1.71*	2396.9*	3.51	38.15	26.06
14	1.46	2051.9	2.78	44.09	30.11
21	1.49	1867.4	2.73	39.14	26.73
28	1.14	1596.1	2.36	44.01	30.06
Gray water	1.27	1782.5	2.62	39.14	26.73
Chemical	1.47	1997.9	2.93	38.38	26.21
Bovine	1.37	1922.5	2.98	43.15	29.47
Sheep	1.45	2047.2	2.97	39.57	27.03
Mean	1.39	1936.40	2.88	40.06	27.36
CV%	35.88	36.46	42.23	26.35	26.35

*(1) no differences among variables at 10% probability level, according to the Dunnett's test; *differed from the control treatment (rainfed), by the Dunnett's test at 10% probability.*

Figure 4. Cladode Area Index (IAC) at different irrigation frequencies. Means followed by the same letter do not differ from each other by the Tukey's test at 10% probability level.

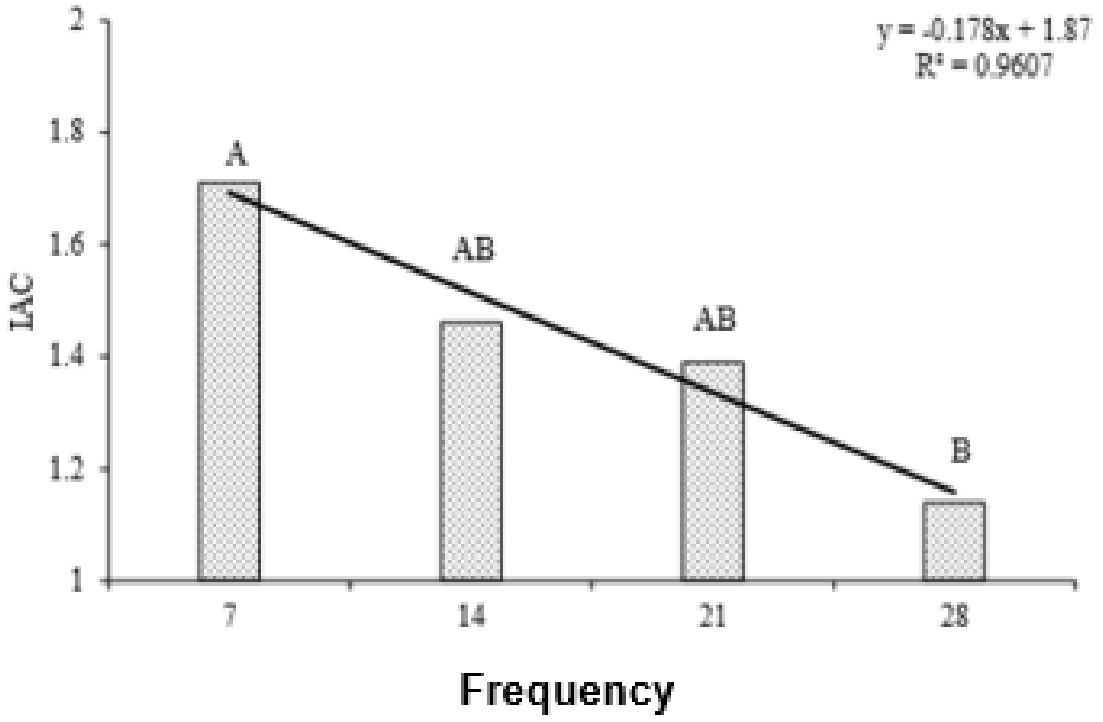
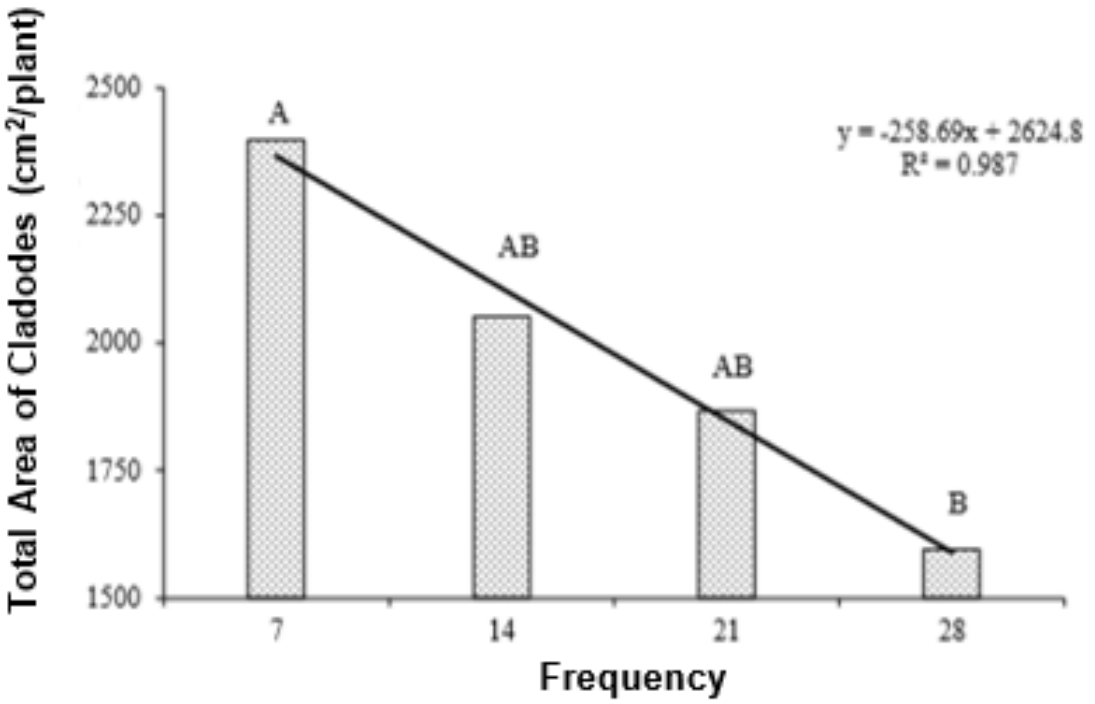


Figure 5. Total Cladode Area per plant, in cm2/plant at different irrigation frequencies. Means followed by the same letter do not differ from each other by the Tukey's test at 10% probability level.



de elefante mexicana' and 'Miúda' cactus pear cultivars equal to each other and higher when compared to 'IPA sertânia' cultivar. Even with lower cladode biometrics when compared to the 'Orelha de elefante mexicana', Miúda' cactus pear is compensated with higher cladode emission per plant and thus, increased IAC value.

Total cladode volume per plant (liters/plant), water use efficiency (EUA - kg DM/mm of water) and cactus pear yield (t DM/ha) values also showed no differences in relation to irrigation frequencies and fertilization strategies (Table 3).

Control treatment (rainfed) presented yield of 23.84 t DM/ha, being the lowest yield obtained when irrigation frequencies were compared, and the highest productivity was obtained at irrigation frequency of 14 days, which was 30. 11 t MS/ha. Although there were no significant differences, the discrepancy between yields was 6.27 t DM/ha, an economically significant value when considering the daily animal feed of 300 kg of live weight and consuming 2% of live weight daily.

Borges (2018) emphasizes that external sources of mineral nutrients, especially nitrogen, are essential to increase the production of forage cactus pear biomass in order to enable positive effects on productive development. Barros et al. (2016), reported that changes in management such as nitrogen fertilization associated with greater water availability change the physiological behavior of forage cactus and, therefore, increase crop productivity in semiarid regions.

EUA is a parameter related to plant density and influence production per area, and in this case, the spacing between rows. This characteristic directly affects productivity, given that these values are used to estimate efficiency, associated with the amount of water made available by the sum of rainfall and the applied water depth (Morais, 2017).

The water use efficiency (EUA) did not result in significant differences and showed average value of 40.06 kg DM/mm of water, a value lower than that found by Rocha et al. (2017), which was 62.38 kg DM/mm of water.

According to Morais et al. (2017), cactus pear is able to maintain dry matter accumulation in situations of water availability. EUA on forage cactus cultivars is lower when submitted to irrigation compared to rainfed cultivars, in a rainfall period of 471 mm.

The efficiency of cacti is due to CAM metabolism. CAM plants are superior to C3 and C4 metabolism plants. In relation to C3 plants, this superiority reaches up to 11 times (Sampaio, 2005). However, the adaptive advantages of CAM plants require mild temperatures at night (Taiz & Zeiger, 1998), where stomata open and close during the day, preventing water loss. When they reach a critical water status, physiological activities enter a latency state (Nobel & Bobich, 2002; Cushman et al. 2015).

Silva et al. (2014) evaluated forage cactus cultivars and found that 'Orelha de elefante' and 'IPA Sertânia' are cultivars that stood out in terms of water use efficiency in relation to the 'Miúda' cultivar. In terms of dry mass, clones have the same water use efficiency, both in terms of precipitated water and evapotranspiration.

Based on results presented, it could be inferred that the irrigation frequency of 7 days, with reuse water, promotes better morphological results in forage cactus pear. If the water factor is not limiting, 'Miúda' cactus pear reaches its maximum growth point at 18 months of age, regardless of fertilization strategy, and that the point of maximum growth is reached with the appearance of 5th order cladodes.

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