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Agronomic performance of cactus with different harvesting practices in the semiarid

Desempenho agronômico de palma forrageira com diferentes manejos de corte no semiárido

Comportamiento agronómico de nopales forrajeros con diferentes manejos de corte en la región semiárida

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ABSTRACT
The harvest management of forage cactus must be carried out respecting cutting intervals, as this influences its structural characteristics. The objective of the work was to evaluate the agronomic performance of four varieties of forage cactus under different cutting management in rainfed conditions in the north of Minas Gerais. The experiment was in a block design, in a 4 × 4 factorial, with four replications. The first factor consisted of the four fodder palm cultivars (Gigante, Miúda, Orelha de Elefante and IPA Sertânia). And the second factor is the four cladode harvest management: Management C9m_21 - Harvest at nine months preserving the mother cladode; Management C9p_21- Harvest at nine months preserving the mother and primary cladode; Management C15p_21- Harvest at 15 months preserving the mother and primary cladode; Management C21 - Harvest at 21 months preserving only the mother cladode. The harvest management system that preserved the primary cladode on the mother plant with collections at nine and 21 months ensured greater regrowth and greater cladode productivity for the forage cactus cultivars (Miúda, Orelha de elefante, IPA and Gigante). The Miúda forage cactus cultivar under the experimental conditions was more productive.

Keywords: *Opuntia fícus-indica* Mill., forage palm harvesting, number of cladodes, *Nopalea cochenillifera* Salm Dyck.

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RESUMO
O manejo de colheita da palma forrageira deve ser realizado respeitando intervalos de corte pois há influência nas suas características estruturais, como o número de cladódios. Objetivou-se avaliar o desempenho agronômico de quatro variedades de palma forrageira sob diferentes manejos de corte em condições de sequeiro no norte de Minas Gerais. O delineamento foi em blocos casualizados, em fatorial 4 × 4, com quatro repetições. O primeiro fator consistiu das quatro cultivares de palma forrageira (Gigante, Miúda, Orelha de elefante e IPA Sertânia). E o segundo fator os quatros manejos de colheitas dos cladódios: Manejo C9m_21 - Colheita aos nove meses preservando o cladódio mãe; Manejo C9p_21- Colheita aos nove meses preservando o cladódio mãe e primário e colheita aos 21 meses; Manejo C15p_21- Colheita aos 15 meses preservando o cladódio mãe e primário e colheita aos 21 meses; Manejo C21 - Colheita aos 21 meses preservando apenas o cladódio mãe. Foram observados aspectos morfométricos dos cladódios e das plantas. O sistema de manejo de colheita que preservou o cladódio primário na planta mãe com coletas aos nove e 21 meses assegurou para as cultivares de palma forrageira (Miúda, Orelha de Elefante, IPA e Gigante) maior rebrota e maior produtividade de cladódios. A cultivar de palma forrageira Miúda nas condições do experimento é mais produtiva.

Palavras-chave: *Opuntia fícus-indica* Mill, colheita de palma forrageira, número de cladódios, *Nopalea cochenillifera* Salm Dyck.

RESUMEN
El manejo de cosecha del nopal forrajero debe realizarse respetando los intervalos de corte, ya que influye en sus características estructurales, como el número de cladodios. El objetivo fue evaluar el desempeño agronómico de cuatro variedades de nopales forrajeros bajo diferentes prácticas de cosecha en condiciones de temporal en el norte de Minas Gerais. El diseño fue en bloques al azar, en factorial 4 × 4, con cuatro repeticiones. El primer factor estuvo constituido por los cuatro cultivares de palma forrajera (Gigante, Miúda, Orelha de Elephant e IPA Sertânia). Y el segundo factor es el manejo de cosecha de los cuatro cladodios: Manejo C9m_21 - Cosecha a los nueve meses preservando el cladodio madre; Manejo C9p_21- Cosecha a los nueve meses conservando el cladodio madre y primario y cosecha a los 21 meses; Manejo C15p_21- Cosecha a los 15 meses conservando el cladodio madre y primario y cosecha a los 21 meses; Manejo C21 - Cosecha a los 21 meses conservando únicamente el cladodio madre. Se observaron aspectos morfométricos de cladodios y plantas. El sistema de manejo de cosecha que conservó el cladodio primario en la planta madre con recolecciones a los nueve y 21 meses aseguró un mayor rebrote y mayor productividad de cladodios para los cultivares de cactus forrajeros (Miúda, Orelha de Elefante, IPA y Gigante). El cultivar de palma forrajera Miúda bajo las condiciones del experimento es más productivo.

Palabras clave: *Opuntia fícus-indica* Mill, cosecha de palma forrajera, número de cladódios, *Nopalea cochenillifera* Salm Dyck.

1 INTRODUCTION

In the Brazilian semiarid region, characteristics such as high temperatures, scarce and poorly distributed rainfall, and long periods of drought. Due to these factors, there is a lower yield of forage grasses, which has been a limiting factor for livestock farming, which uses forage as a food base for cattle. Therefore, the search for forage species adapted to local climatic conditions is of great importance to guarantee the food and nutritional quality of animals (Oliveira et al., 2010; Pereira et al., 2021).

The forage palm (*Opuntia ficus-indica* Mill) is an option widely used by producers in these regions because it is a plant that has good bromatological quality, allows the animal to hydrate in addition to being undemanding in water (Lédo et al., 2019). Forage palm production in Brazil is approximately 3.6 million tons in 126,925 establishments (IBGE, 2017). From national production, 99.8% (3.573.401 tons) of the Brazilian Northeast and northern portions of the territories of Minas Gerais and Espírito Santo. The states with the largest plantations are Sergipe, Alagoas, Rio Grande do Norte, and Ceará – with the three largest producing states being Bahia (1.5 million tons), Paraíba (742 thousand tons) and Pernambuco with 481 thousand tons (IBGE, 2017).

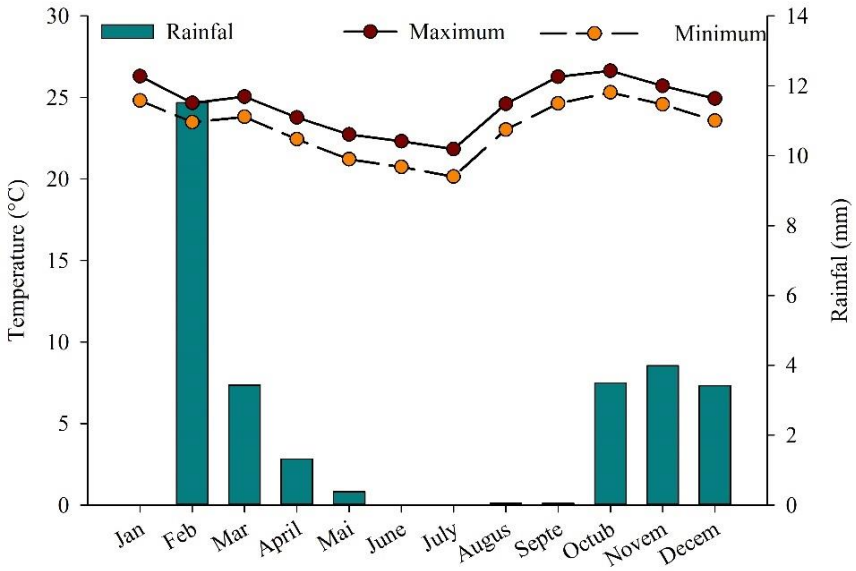
The cultivation and biomass yield of forage cactus are influenced by some factors, such as weeds, soil fertility management, planting density/spacing, harvest frequency, as well as the intensity of cutting, which can influence the morphological development of the forage palm and, consequently, its productivity (Donato et al., 2014; Matos et al., 2021). The study of appropriate times for harvesting cladodes is of great importance so that rural producers can establish crop management and plan the feeding of their animals during a given period. The cutting intervals can influence structural characteristics, such as height and productivity of cactus pear genotypes (Rocha et al., 2017).

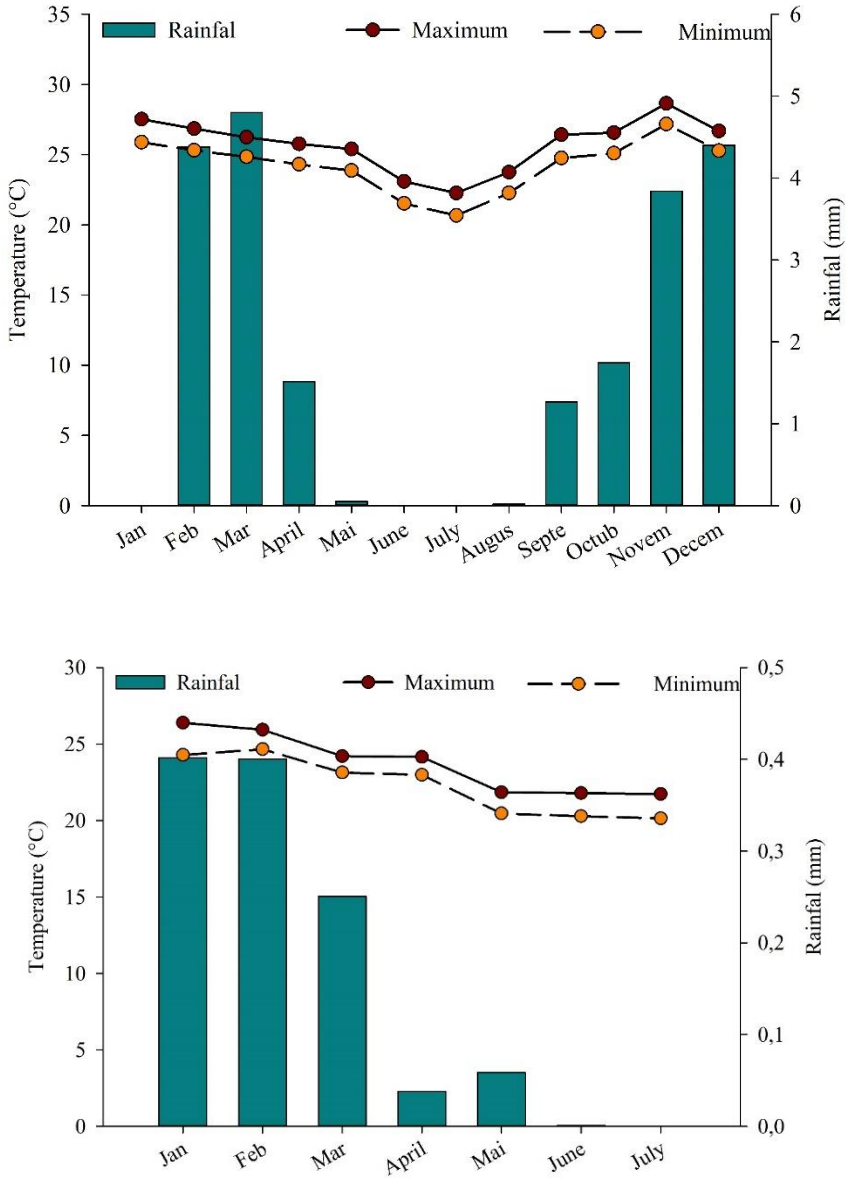
The study of the frequency and intensity of harvesting and the structural characteristics of cactus in the semi-arid region of Minas Gerais are essential for producers to obtain correct management of cactus. Thus, the objective was to evaluate the agronomic performance of four varieties of forage cactus under different harvesting practices in rainfed conditions in the north of Minas Gerais.

2 METHODOLOGY

The experiment was conducted from October/2018 to July/2020 in the experimental area of the Institute of Agricultural Sciences (ICA), of the Federal University of Minas Gerais (UFMG), Campus Montes Claros, Brazil. The geographic location of the area is between the parallels 16º 51' 00'' south latitude and between the meridians 44º 55' 00'' west and altitude of 630 m. The soil was classified as Haplic Cambisol (EMBRAPA, 2018; IUSS, 2015). The climate in the region is Aw type, with dry winters and rainy summers (Alvares et al., 2013). The precipitation and temperature data for the experimental period are in Figure 1.

Figure 1. Maximum and minimum temperature and precipitation during the experimental period in Montes Claros-MG in the years 2018 (A), 2019 (B) and 2020 (C), according to information from the National Institute of Meteorology – INMET.





Source: (INMET, 2020)

The experiment was carried out in a randomized block design, in a factorial scheme 4 × 4, with 4 repetitions. The first factor consisted of the four forage palm cultivars planted (Gigante, Miúda, Orelha de Elefante and IPA Sertânia). And the second factor four cladode harvest management: Management C9m_21- Split harvest at nine and 21 months preserving the mother cladode; Management C9p_21- Split harvest at nine and 21 months preserving the mother and primary cladode; Management C15p_21 - Harvest at 15 and 21 months preserving the mother

and primary cladode; Management C21- Harvest at 21 months preserving the mother cladode. Therefore, the experiment consisted of 64 plots. Each plot consisted of 14 plants (seven in each row).

To set up the experiment, the following species were used: *Nopalea cochenillifera* Salm Dyck, which corresponds to the cultivars Miúda and IPA Sertânia, and the species *Opuntia fícus-indica* and *Opuntia Stricta*, which correspond to the cultivars Gigante and Orelha de Elefante Mexicana. The seedlings were donated by the State University of Montes Claros, Janaúba-MG, and Model Site (Janaúba-MG).

The cladodes were removed from plants that had been unharvested for one to two years, selecting those that had uniform and mature sizes, that is, those that had already emitted shoots or were close to emitting and free from diseases and injuries. The cuts were made with a machete as close as possible to the junction between the cladodes in order to reduce the exposure of large wounds and, consequently, reduce the healing time ("healing"). The use of tender cladodes was avoided, as they are susceptible to rot, or old ones, which are difficult to root.

The 10 central plants were evaluated. The four plants at the end (highlighted in light green) were used as a border and vertically at each end of the crop line. Each plot had a size of 4.2 m² (3.0 × 1.4 m), with a total area of 269 m² (22.4 × 12 m).

The planting was carried out after the "healing" period (15 days) of the cladodes. The cladodes were planted in double rows considering a spacing of 2 meters between rows. The distance between plants (cladodes) was 0.80 m. The planting depth of the cladodes was approximately 50% of their total length. The cladodes were planted vertically.

After soil analysis and interpretation of the results, it was verified the need for fertilization with 150 kg ha^{-1} of P_2O_5 (Donato et al., 2014). Covering fertilizers were carried out as recommended for the crop, with 150 kg ha^{-1} of N and 75 kg ha^{-1} of K (Donato et al., 2014), divided into three applications on 02/15/2019, 07/24/2020 (after harvest) and 01/23/2020 (after harvest). It required three applications of Actara 750 SG (100 g ha^{-1}) for control of scale insect (*Diaspis echinocacti*) (BRASIL, 2021). After planting, manual weeding was carried out when necessary.

In evaluating the vegetative growth of cactus pear, morphometric aspects of the cladodes and plants were observed. The characteristics analyzed in the cladodes were: width (cm), length (cm) with the aid of a tape measure and thickness (mm) the cladode with a caliper. These

evaluations were carried out on all plants in the fourth and eighth month after planting; and twelfth month after the first cut in management Management C9m_21 and C9p_21.

The number of cladodes was evaluated by direct counting on the plant, with this variable being analyzed in all plants in the fourth, eighth, and ninth month after planting, the twelfth month after the first cut in management C9m_21 and C9p_21 and in the fifteenth month in management C15p_21. After harvest, regrowth was evaluated by counting the number of shoots in the harvested plants. Evaluations were carried out 30, 60 and 90 days after harvest in the management C9m_21 and C9p_21 (Figure 2).

At the time of harvest, the height of each plant was measured, with the aid of a measuring tape, determining the greatest vertical distance between the soil surface and the upper end of the highest cladode (Figure 2). In the eighteenth month it was evaluated in addition to NB, NC and AP, the third and final cut took place in the twenty-first month, before harvesting the managements C9m_21, C9p_21, C15p_21 and C21 was evaluated AP, LP, NC, MF and %MS.

The forage palm productivity was determined from the harvest nine and 15 months after planting and the last harvest in the twentieth month (Figure 2). For the procedure, 10 plants were collected in each treatment and arranged in the useful areas of the plots. The plants were cut at the first insertion, leaving only the mother cladode (C9m_21, 9 months), with the mother cladode and son (C9p_21, 9 months with the mother cladode and son (C15p_21, 15 months) and in the last cut, harvesting all the management C9m_21, C9p_21, C15p_21 and C21 (21 months). Then, all harvested cladodes were weighed on a precision scale, separating them by plot and treatment.

Cladodes of different orders were collected in each plot to compose a sample weighing approximately 300 g. Subsequently, the material was taken to a forced air circulation oven with a temperature of 65 °C for 72 hours to dry. Then, the material was weighed, and based on the weighing data of the dry sample, it was possible to calculate the dry mass content per plot (Dry mass/Green mass × 100).

For the data obtained in the fourth, eighth and fifteenth months, a single factor was considered, with the four varieties studied as levels. For the data obtained in the ninth, eleventh and twelfth months, the 2 x 4 factorial scheme was considered, considering the two forms of harvest for the four varieties.

The statistical analyzes were performed based on data obtained at different stages of the experiment. In all analyses, the Bartlett test was used to verify the homogeneity of residual

variance and the Shapiro-Wilk test to test the normality of residuals. Verifying compliance with these assumptions of the analysis of variance, the Tukey test was performed for multiple comparisons whenever significances were identified by the F test. All analyzes were carried out considering the of significance $p \leq 0.05$, in the R software.

3 RESULTS AND DISCUSSIONS

For the four cladode harvest management systems analyzed, there was different behavior for each cultivar. When evaluating the number of cladodes four months after planting, it was possible to observe that the Gigante cultivar expressed a lower number of cladodes than the others (Table 1). As for the length, width and thickness of cladodes, the cultivar Miúda presented the lowest values (Table 1). The Orelha de elefante cultivar presented greater cladode width and the greatest thickness was observed in the cultivar 'Giant' (Table 1).

Table 1. Assessment of cladode characteristics number of cladodes (NC), length of cladodes (CC), width of cladodes (LC) and thickness of cladodes (EC), four months after planting cactus cultivars
Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$

Cultivar	NC	CC	LC	EC
	(un.)	(cm)	(cm)	(mm)
Gigante	2,53 b	19,60 b	10,02 b	12,03 a
Miúda	3,83 a	15,89 c	6,24 d	7,71 c
Orelha de elefante	3,44 a	18,72 b	13,56 a	9,61 b
IPA	3,91 a	23,83 a	9,02 c	10,33 b
Coeficient of variation (%)	25,16	7,11	8,09	8,67

Source: Originator, 2019

In the evaluation carried out at eight months, the highest number of cladodes was found in the cultivars Miúda and Orelha de elefante, which were statistically similar to each other (Table 2). When evaluating the length of the cladodes, no statistical difference was found between the cultivars 'Gigante' and IPA. The Gigante and IPA cultivars expressed greater length, the Orelha de elefante cultivar had greater width and the Gigante had greater cladode thickness. In this sense, an inverse relationship can be observed between the number of cladodes and length, width, and thickness (Table 2).

Table 2. Number of cladodes (NC), length of cladodes (CC), width of cladodes (LC) and thickness of cladodes (EC) eight months after planting cactus cultivars.

Cultivar	NC	CC	LC	EC
	(un.)	(cm)	(cm)	(mm)
'Gigante'	4,26 c	25,51 a	11,82 b	12,68 a
Miúda	9,15 a	17,64 c	6,99 d	7,16 c
Orelha de Elefante	8,71 a	20,17 b	14,02 a	7,32 c
IPA	6,15 b	26,25 a	10,48 c	10,73 b
Coefficient of variation (%)	24,14	6,63	6,77	12,15

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

In the ninth month after planting there was no significant interaction between cultivars and harvest management for any variable analyzed ($p > 0.05$). The number of harvested cladodes was greater for the Miúda cultivar, not statistically different from the elephant ear. The Gigante and IPA cultivars had fewer harvested cladodes (Table 3). Regarding the dry matter content, the Miúda cultivar presented a higher value than Gigante.

Table 3. Number of harvested cladodes (NHC) and percentage of dry matter (%DM) in the first cut at nine months of forage cactus cultivars.

Cultivars	NHC	%DM
	un.	%
Gigante	3,41 b	10,48 b
Miúda	8,35 a	17,05 a
Orelha de Elefante	7,24 a	13,52 ab
IPA	4,23 b	13,92 ab
Coefficient of variation (%)	29,87	20,16

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

When comparing the harvesting systems, for the variables number of harvested cladodes and fresh matter there was a significant difference ($p < 0.05$). A greater number of harvested cladodes and fresh matter was observed in the first management system (Table 4).

Table 4. Number of harvested cladodes (NCC) and fresh matter (MF) in the first cut of different cactus harvesting practices.

Harvesting systems	NCC	MF
	un.	kg
Management C9m_21	7,61 a	1,72 a
Management C9p_21	4,00 b	0,75 b
Coefficient of variation (CV%)	29,87	41,44

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

The harvesting at 9 months and preserving the mother cladode and also preserving the primary cladodes (Management C9p_21) provided greater increases to cultivars in relation to structural characteristics, when compared to the harvest management system (C9m_21), which preserves only the mother cladode. Santos (2010) indicated that cactus harvesting should be carried out every two years, to maintain the preservation of a significant area of residual cladode. However, the recommendation is that harvesting should be done annually, in the dry season, to meet animal demand and facilitate mealybug management (Silva et al., 2020). This ensures greater reserve content and a greater number of sprouting buds, thereby reinforcing regrowth and ensuring greater longevity for the plant.

For the number of sprouts evaluated eleven months after planting, no significant effect ($p > 0.05$) of the interaction between harvesting systems and cultivars was identified. An isolated effect was verified for each of the factors. The Miúda and IPA cultivars were statistically superior to the Gigante and Orelha de Elefante cultivars for the number of shoots (Table 5).

Table 5. Number of shoots (NB) 60 days after the first cut of cactus cultivars.

Cultivars	NB
Gigante	1,35 b
Miúda	5,28 a
Orelha de Elefante	2,12 b
IPA	6,45 a
Coefficient of variation (CV%)	38,93

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

In the evaluation of harvesting systems for the number of shoots, the harvesting system at 9 and 21 months of cladodes was superior to the harvesting system preserving the mother and primary cladodes in the same harvesting periods (Table 6). This result indicates the importance of maintaining the greatest number of cladodes in the mother plant to ensure that regrowth is efficient and that new cladodes are formed (Pereira et al., 2021). This difference was probably due to the greater accumulation of photoassimilates and water in primary cladodes. These results corroborate Fonseca et al. (2019) who observed an increase in the emission of cladodes with greater water input. A smaller leaf area also results in less use of solar radiation and nutrients and consequently reduces net photosynthesis (Aumonde et al., 2013; Nunes et al., 2021).

Table 6. Number of shoots (NB) 60 days after the first cladode cut with different cactus harvesting management.

Harvesting systems	NB
	un.
Management C9m_21	4,91 a
Management C9p_21	2,68 b
Coefficient of variation (%)	38,93

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

In the evaluation of the twelfth month after planting, no significant effect was observed for the interaction ($p > 0.05$) between management systems and cultivars for any of the characteristics evaluated.

For the isolated factor harvesting system, the number of shoots and the number of cladodes was greater, the number of shoots and cladodes in the harvesting system at 9 and 21 months, preserving the mother and primary cladode, in relation to the harvesting system preserving the cladode mother at 9 and 21 months (Table 7).

Table 7. Number of shoots (NB) and number of cladodes (NC) ninety days after the first cut in cactus harvest management systems.

Harvesting systems	NB	NC
	un.	un.
Management C9m_21	5,89 b	5,76 b
Management C9p_21	7,18 a	10,38 a
Coeficiente de variação (%)	26,61	24,53

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

After the first harvest, there was an evaluation in the 12th month after planting, it was observed that the number of cladodes did not differ ($p < 0.05$) between the cultivars Miúda, IPA and Orelha de eelefante. The IPA cultivar had a greater cladode length and number of shoots 90 days after the first cut. While for cladode width, greater width was observed for the Orelha de elefante cultivar. And greater thickness for the Gigante cultivar, differing from the other cultivars (Table 8).

Table 8. Characteristics of cladodes (NC), length (CC), width (LC), thickness (EC) and shoot number (NB) at ninety days after the first cut of forage cactus cultivars.

Cultivar	NC	CC	LC	EC	NB
	un.	cm	cm	mm	un.
Gigante	4,61 b	22,36 a	9,72 b	7,47 a	3,55 b
Miúda	9,13 a	16,93 c	6,28 c	5,16 b	7,67 a
Orelha de Elefante	9,19 a	19,56 b	11,61 a	5,27 b	7,21 a
IPA	9,35 a	23,88 a	9,15 b	5,67 b	7,71 a
Coefficient of variation (%)	22,55	12,13	10,97	17,85	26,61

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

In the harvesting system C15p_21, the cultivars Miúda and Orelha de elefante had a higher number of cladodes when compared to the cultivars Giant and IPA (Table 9). For the cultivars Giant and IPA, lower numbers of harvested cladodes were observed (Table 9). When analyzing the number of cladodes in the different harvest management systems, it was possible to verify that the Gigante and IPA cultivars developed fewer cladodes, regardless of the harvest management system. Indicating that for these cultivars, harvest management can be carried out according to the producer's needs from 9 months of planting, with the possibility of leaving or not the primary cladodes, without this causing damage to the growth of new cladodes.

The Orelha de elefante and Gigante cultivars had greater plant height, plant width and fresh leaf matter (Table 9). The cultivar Orelha de elefante obtained the highest fresh matter, but did not differ from the cultivar Gigante and Miúda.

The Gigante and Orelha de elefante cultivars achieved greater fresh mass gain (t MV ha^{-1}) compared to the Miúda and IPA cultivars. This is because these cultivars have a larger cladode area, which is essential for plant growth and increased photosynthetic rates. Therefore, gains in fresh mass obtained with the advancement of the cutting interval were expected and justified by the continuous supply of water and nutrients to the plants throughout the entire cultivation cycle (Rocha et al., 2017).

Table 9. Number of harvested cladodes (NCC), plant height (AP) and width of plant (LP) and fresh matter (MF) in the first cut of forage cactus cultivars.

Cultivar	NCC	AP	LP	MF
	un.	cm	cm	kg
Gigante	8,95 bc	97,17 a	72,72 ab	5,51 ab
Miúda	25,77 a	74,75 b	63,62 b	4,09 ab
Orelha de elefante	17,00 ab	83,10 ab	85,07 a	6,30 a
IPA	7,16 c	79,97 ab	60,94 b	3,43 b
Coef. of variation (%)	28,08	11,41	12,67	25,66

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

The Gigante cultivar had a higher plant height than the IPA and Miúda cultivars at 30 days after the second cut (DASC). At 60 DASC, it obtained greater height than the other cultivars (Table 10).

Table 10. Plant height (cm) 30 and 60 days after the second cut (DASC).

Cultivar	30 DASC	60 DASC
Gigante	64,21 a	71,43 a
IPA	47,64 b	55,87 b
Miúda	47,17 b	54,65 b
Orelha de Elefante	53,08 ab	60,44 b
Coeficient of variation (%)	19,84	15,79

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

In the evaluation of the Number of Cladodes at 30 DASC, a greater number of cladodes was observed for the cultivars IPA, Miúda and Orelha de Elefante. In the 60s and 90s DASC, the cultivar Miúda had a higher number of cladodes, differing from the other cultivars (Table 11).

The Miúda forage cactus cultivar produced more cladodes per plant but smaller cladode length and width, regardless of harvest time. Similar results were observed by Cavalcante et al. (2014), who justified this result due to intrinsic characteristics of the Miuda cultivar, as plants belonging to the genus *Nopalea* sp. have a greater number and smaller size of cladodes when compared to those of the genus *Opuntia* sp. Snyman (2006) highlighted that there are differences in the cactus clones cultivated. This is because, in most cases, cultivars have adaptations peculiar to their morphologies (Falcão et al., 2013).

Another possible explanation is the inverse relationship between the number and length of cladodes. This contradiction may be associated with the densification caused by the anatomy of the cultivars, in which in the case of Miúda the cladodes did not develop due to overlapping,

and the densification of planting favored the greater emission of new shoots and consequently a greater number of cladodes with shorter lengths (Cavalcante et al., 2014).

Table 11. Number of Cladodes (NC) at 30, 60 and 90 days after the second cut of cactus cultivars.

Cultivars	30 DASC	60 DASC	90 DASC
Gigante	5,64 b	6,18 c	9,25 c
IPA	9,24 ab	10,42 b	14,33 b
Miúda	12,50 a	14,40 a	19,48 a
Orelha de Elefante	10,55 a	10,22 b	14,56 b
Coef. of variation (%)	38,24	30,52	24,53

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

When we compared the three harvest management systems after the second cut, it was possible to observe that the number of cladodes was higher in the management C9m_21 and management C9p_21 to the 30 DASC. Already at 60 and 90 DASC the management C9p_21 was superior to other management systems (Table 12).

Table 12. Number of cladodes (un.) in different managements 30, 60 and 90 days after the second cut (DASC) of forage palm.

Harvest System	30 DASC	60 DASC	90 DASC
Management C9m_21	11,51 a	9,70 b	13,33 b
Management C9p_21	13,18 a	12,53 a	17,03 a
Management C15p_21	3,73 b	8,39 b	12,46 b
Coeficient of variation (%)	38,24	30,52	24,53

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

The harvest management systems and cultivars showed a significant interaction ($p < 0.05$) for plant height. The Gigante cultivar had the lowest height in management system 3 (Table 13). For the other genotypes, there was no difference in relation to cladode harvest management systems. Regarding management systems, the cultivars did not statistically differ from each other for management C9m_21 and management C15p_21 (Table 13).

Table 13. Cladode harvesting management for plant height (cm) 90 days after the second cut of cactus cultivars.

Cultivar	Management C9m_21	Management C9p_21	Management C15p_21
Gigante	78,28 Aa	91,45 Aa	55,27 Ba
IPA	64,02 Aa	69,87 Ab	65,96 Aa
Miúda	59,73 Aa	68,92 Ab	52,74 Aa
Orelha de Elefante	68,72 Aa	61,24 Ab	58,47 Aa
Coeficient. of Variation (%)	14,57	14,57	14,57

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

It was found that the Gigante cultivar had a higher plant height than the other cultivars for harvesting in the 21st month (Table 14). For fresh matter, there was no statistical difference between the cultivars IPA, Orelha de elefante and Gigante. Regarding the percentage of dry matter, the Orelha de elefante cultivar was superior to the Miúda cultivar, not differing from the others (Table 14).

The Miúda forage palm cultivar is the worst adapted to locations with low rainfall and high night temperatures (Silva et al., 2015). However, during the cultivation of Miúda genotype plants, the productive responses observed were similar to the other cultivars evaluated. Pereira et al. (2021) studied the behavior of three forage cactus cultivars, Miúda, Orelha de elefante and IPA in salinity levels, and concluded that the greatest gain in fresh mass was from the Miúda cultivar (13,36 kg per plant), in a salinity of 4,04 dS m^{-1}. This indicates the good capacity of this cultivar to obtain good fresh mass, even in conditions of water deficit or in soils with higher salinity.

Table 14. Plant height (AP), fresh matter (MF), percentage of dry matter (%DM) in the third cut of forage cactus cultivars.

Cultivar	AP	MF	%DM
	cm	kg	%
Gigante	85,56 a	9,31 ab	11,13 a
Miúda	66,13 b	7,52 b	10,93 b
Orelha de elefante	71,44 b	9,81 a	11,77 ab
IPA	70,64 b	10,17 a	11,78 ab
Coeficient of variation (%)	15,34	21,3	13,58

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

Thus, the four cactus cultivars studied presented different results for the length, width and thickness of the cladode and, consequently, obtained different areas. The cultivars Gigante and IPA had the longest and thickest cladodes, while the greatest width of cladodes was obtained by the cultivar Orelha de elefante. While the Miúda cultivar had shorter and less wide cladodes compared to the others (Table 1 and 2). These results indicate that the Miúda forage palm cultivar has as a growth strategy the increase in the number of cladodes in order to compensate for the size and area of each cladode (Silva et al., 2015). These results indicate that the Miúda forage palm cultivar has as a growth strategy the increase in the number of cladodes in order to compensate for the size and area of each cladode.

There was a significant interaction between the factors of harvest management and cactus cultivars for the number of cladodes harvested in the third cut. It was observed that for the giant

cultivar the Management C9m_21, Management C9p_21 and Management C21 obtained a lower number of cladodes collected (Table 15). To cultivate Miúda the Management C9p_21 provided a lower number of harvested cladodes (Table 15). There was no difference for the other cultivars regarding the cladode harvest management system. In the Management system C9m_21 the Giant cultivar was inferior to the other cultivars studied. The management C9p_21 and C21 in the Miúda cultivar it was superior to the others and in the management system C15p_21 there was no difference between cultivars regarding the number of cladodes harvested (Table 15).

Table 15. Number of harvested cladodes (units) and different cladode harvest management systems of forage cactus cultivars.

Cultivars	C9m_21	C9p_21	C15p_21	C21
Gigamte	7,20 Ab	9,52 Ac	12,65 Aa	12,29 Ab
IPA	12,52 Aa	19,72 Ab	17,70 Aa	15,44 Ab
Miúda	29,40 Ba	29,08 Ba	21,29 Ba	41,25 Aa
Orelha de elefante	11,70 Aa	15,97 Abc	17,17 Aa	18,85 Ab
Coef. of variation (%)	26,15	26,15	26,15	26,15

Means followed by the same uppercase letter in the row and lowercase letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

The C9m_21, C9p_21 and C21 harvest management systems did not differ in relation to the height and width characteristics of plants in the third cut (Table 16). For the fresh matter characteristic, the C21 management system was superior to the other management systems. Regarding %dry mass, management C9m_21, C9p_21 and management C15p_21 obtained similar dry mass (Table 16).

Table 16. Cladode harvesting systems in plant height (AP), plant width (LP), fresh matter (MF) and percentage of dry matter (%DM) in the third cut of forage palm.

Harvest System	AP	LP	MF	%DM
	cm	cm	kg	%
Management C9m_21	73,05 ab	71,44 ab	7,16 c	11,25 a
Management C9p_21	78,22 a	77,57 a	10,09 b	10,49 ab
Management C15p_21	61,36 b	58,67 b	7,18 c	12,18 a
Management C21	81,58 a	84,05 a	12,36 a	11,70 b
Coef. of variation (%)	15,34	23,33	21,3	31,48

Means followed by the same letter in the column do not differ from each other using the Tukey test at $p \leq 0.05$
Source: Originator, 2019

When evaluating the sum of the number of cladodes, fresh matter and dry matter in the three cuts, no significant effect ($p \leq 0.05$) was found between cultivars and cladode harvesting management.

In general, it can be inferred that the different cactus harvest management systems influenced the productive responses of the four cultivars evaluated, with greater interference for the Miúda cultivar in the C9p_21 and C15p_21 management systems that maintained the primary cladodes on the mother plant and, consequently, guaranteed a greater source of energy for the budding of new cladodes. In other harvesting practices, there was no difference between the development and morphology of the cladodes, reinforcing that these characteristics are specific to each cactus cultivar. Another important function of the harvest at 21 months after planting the forage cactus is the possibility of providing animals with food at a time of year with a greater period of scarcity of rain and biomass of forage grasses.

4 CONCLUSION

The C9p_21 harvest management system (preserving the primary cladode on the mother plant) with collections at nine and 21 months ensured that forage cactus cultivars (Miúda, Orelha de elefante, IPA and Gigante) greater regrowth and greater cladode productivity.

The Miúda forage palm cultivar was more productive than the other cultivars evaluated.

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