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Phenophases and cutting time of forage cactus under irrigation and cropping systems[1]

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ABSTRACT

Management practices can affect the phenology and, consequently, the harvest time and crop production level of forage cactus. This study aimed at evaluating the effect of irrigation depths and cropping systems on the phenophases and cutting time of the forage cactus *Opuntia stricta* (Haw.) Haw. The experimental design was a randomized block with split plots and four replications. Irrigation depths based on reference evapotranspiration (8.75 %, 17.5 %, 26.25 % and 35 % ETo) and a control (0 % ETo) made up the plots, while cropping systems (exclusive cropping, exclusive cropping on mulch and forage cactus-sorghum intercropping) were distributed in the subplots. Cladode emission morphogenesis was used to define the phenological phases, while the extrapolation of the monthly dry matter accumulation rate was applied to obtain the cutting time. The use of irrigation depths significantly increased the phenophase II (higher emission of second-order daughter cladodes), decreasing the phenophase III, associated with third-order daughter cladodes. The phenophase III was lower in the exclusive cropping on mulch and forage cactus-sorghum intercropping systems, when compared to the exclusive cropping system. The ideal cutting time for irrigated forage cactus is 19 months, regardless of the cropping system. The exclusive cropping on mulch and forage cactus-sorghum intercropping systems significantly increased the monthly forage dry matter accumulation rate, with an earlier cutting time for the forage cactus-sorghum intercropping system (17 months).

KEYWORDS: *Opuntia stricta* (Haw.) Haw.; morphogenesis; drip irrigation.

RESUMO

Fenofases e momento de corte de palma forrageira sob irrigação e sistemas de plantio

A adoção de práticas de manejo pode afetar a fenologia e, consequentemente, o momento de colheita e o nível produtivo de palma forrageira. Objetivou-se avaliar o efeito de lâminas de irrigação e sistemas de cultivo sobre as fenofases e o momento de corte da palma forrageira *Opuntia stricta* (Haw.) Haw. O delineamento foi em blocos ao acaso com parcelas subdivididas e quatro repetições. Lâminas de irrigação, com base na evapotranspiração de referência (8,75 %; 17,5 %; 26,25 %; e 35 % ETo), mais uma testemunha (0 % ETo) compuseram as parcelas, e os sistemas de cultivo as subparcelas (cultivo exclusivo, cultivo exclusivo com cobertura morta e consórcio palma-sorgo). Com a morfogênese de emissão de cladódios foram delimitadas as fases fenológicas, e com a extrapolação da taxa de acúmulo mensal de matéria seca de forragem definiu-se o momento de corte. A aplicação de lâminas de irrigação aumentou a fenofase II (maior emissão de cladódios de segunda ordem), em detrimento à fenofase III, associada a cladódios de terceira ordem. A fenofase III foi mais reduzida nos sistemas de cultivo exclusivo com cobertura morta e consórcio palma-sorgo, quando comparada ao sistema cultivo exclusivo. O momento de corte ideal para a palma irrigada é de 19 meses, independentemente do sistema de cultivo. Os sistemas de cultivo exclusivo com cobertura morta e consórcio palma-sorgo incrementaram expressivamente a taxa de acúmulo mensal de matéria seca de forragem, com maior antecipação do momento de corte para o sistema consórcio palma-sorgo (17 meses).

PALAVRAS-CHAVE: *Opuntia stricta* (Haw.) Haw.; morfogênese; irrigação por gotejamento.

INTRODUCTION

The forage cactus is an important foraging resource for herds in the semiarid region, since it offers food stability to the production system (Silva et al. 2015a). In Northeastern Brazil, the species that stand out as crop alternatives belong to the *Opuntia* and *Nopalea* genera (Oliveira et al. 2010). *Opuntia stricta* (Haw.) Haw. cv. 'Orelha de Elefante Mexicana' (IPA 200016 clone) is one of the main cultivation options, due to its high yield, low soil fertility requirements, drought tolerance (Silva et al. 2015a) and resistance to

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Dactylopius opuntiae (Cockerell, 1896) (Hemiptera: Dactylopiidae), one of the most damaging pests to the crop (Lopes et al. 2010). Thus, areas cultivated with this species are expanding, thereby guaranteeing a food source for animals during periods of drought, when the supply of dry matter from native vegetation or other forage species is lower (Queiroz et al. 2015).

Given this expansion, there is a need to understand the morphological attributes that contribute to the forage cactus yield. One important trait is phenology, which encompasses the different externally visible stages of plants, denominated phenophases. In C3 and C4 plants, phenological characterization based on leaf growth is common (Pezzopane et al. 2009). In the forage cactus, the leaves are small and fall when plant structures called cladodes emerge and become responsible for photosynthesis, with buds capable of producing new cladodes. Depending on their position on the plant, these structures are classified by the order of their emergence. A planted cladode, responsible for clonal propagation via rooting and plant support, is called "basal cladode". Those that emerge from it are first-order daughter cladodes, which in turn produce daughter cladodes of the second order, and so on successively. The number of orders and cladodes per order depend on the morphology of each species of forage cactus (Pinheiro et al. 2014, Silva et al. 2015a). Thus, the cladode production rate per order of emergence (i.e., number of cladodes produced for a specific order over time, in units month^{-1}) can be used as an indicator of change in the phenological phase. In this respect, understanding each of the different plant stages, i.e., the number and duration of phenophases, contributes to crop management (Pezzopane et al. 2007 and 2009).

Silva et al. (2015a) reported that the dynamics of forage cactus growth is inherent to its species and respective cultivars. However, Pinheiro et al. (2014) and Silva et al. (2014a) showed a positive relationship of several growth variables (i.e., cladode area index) with forage cactus yield. Therefore, the morphogenesis of the cladode area index is associated with the accumulated dry matter rate, which can be used to analyze the ideal cutting time for this crop.

The forage cactus is traditionally harvested every two years, under non-irrigated conditions (Silva et al. 2015a, Lima et al. 2016). However, the climatic conditions and agronomic practices adopted during cropping may accelerate or delay the onset and duration of each development phase, anticipating or postponing harvest and therefore altering yields.

The use of irrigation for producing forage cactus is reported in a number of studies (Flores-Hernández et al. 2004, Queiroz et al. 2015). In Brazil, this method has been used in the States of Rio Grande do Norte, Pernambuco and Ceará (Queiroz et al. 2015, Santos et al. 2013). Lima et al. (2016) harvested *Opuntia ficus-indica* Mill cv. 'Gigante' at one and two years after planting, under irrigated conditions, observing that the highest yields were obtained when harvested at two years. Queiroz et al. (2015) found no significant changes in morphophysiological characteristics or yield with the adoption of different irrigation depths, in exclusive forage cactus cropping systems. Moreover, the use of mulch and intercropping are important for forage cactus cultivation. Mulch reduces soil temperature, improves its physicochemical characteristics and preserves its moisture for longer, providing benefits to crops (Tao et al. 2015). Intercropping results in greater dry matter production per area unit (Sadeghpour et al. 2013) and optimizes abiotic resources such as water, light and nutrients (Yilmaz et al. 2015). According to Souza et al. (2014), intercropping reduces the risk of production losses, especially in dry or semiarid areas.

This study aimed at assessing the effect of irrigation depths and cropping systems on the phenological phases and ideal cutting time of the forage cactus *O. stricta*.

MATERIAL AND METHODS

The experiment was conducted at the Instituto Agronômico de Pernambuco (7º59'S, 38º15'W and altitude of 431 m), in Serra Talhada, Pernambuco State, Brazil, where the climate is BSwh', according to the Köppen classification. This climate is characterized as hot semiarid, with high potential evapotranspiration and alternation between a rainy season in the summer-fall and a dry season with low rainfall (657 mm year^{-1}) (APAC 2016).

The forage cactus *O. stricta* (Haw.) Haw. cv. 'Orelha de Elefante Mexicana', IPA-200016, was planted in March 2011, in a Red-Yellow Argisol (Ultisol) (soil density of 1.5 kg dm^{-3}; particle density of 2.6 kg dm^{-3}; total porosity of 40.8 %; total sand of 662.8 g kg^{-1}; 273,4 g kg^{-1} of silt; and 63.8 g kg^{-1} of clay). The soil was prepared by plowing and harrowing, followed by digging furrows with spacing of 1.60 m x 0.40 m for plantation, resulting in a population density of 15,625 plants ha^{-1}. Basal dressing was not applied at crop planting. The first productive cycle occurred under non-irrigated conditions until the end of May 2012, when the first cutting took place, maintaining only the basal cladode. The second productive cycle extended until June 2013, 396 days after cutting, the period of the present study, which was characterized by a high incidence of global solar radiation, temperature and wind speed, as well as low rainfall and relative humidity (Table 1), in relation to the normal local climate.

The experimental design consisted of randomized blocks with split-plots and four replications. Four irrigation depths were used in the plots, based on reference evapotranspiration fractions (8.75 %, 17.5 %, 26.25 % and 35 % ETo), plus a non-irrigated control treatment, as well as three cropping systems in the subplots (exclusive crop system without mulch, mulch-based exclusive cropping system and forage-sorghum intercropping system). Each subplot consisted of four rows with 15 plants, with a total area of 28.8 m^2 (60 plants) and a useful area of 14.08 m^2 (22 plants).

In June 2012, a drip irrigation system was installed, with spacing of 0.40 m between emitters and 0.25 m from the line of forage cacti, operating with an average flow rate of 1.32 ± 0.12 L h^{-1}, at a pressure of 1 atm. The water used for irrigation exhibited electrical conductivity of 1.1-1.6 dS m^{-1}.

Standardized irrigation events (total of 583 mm) were conducted from June to November 2012, in order to guarantee plant survival, since the accumulated rainfall was only 22 mm in the period (Table 1). From December 2012, irrigation depths were differentiated based on reference evapotranspiration fractions and estimated using the Penman-Monteith method, according to the FAO Bulletin 56 (Allen et al. 1998) and meteorological data (global solar radiation, temperature, relative humidity, wind speed and atmospheric pressure). The meteorological data, including rainfall, were collected from an automatic weather station belonging to the National Meteorology Institute, located at 1,700 m from the area.

In the period of depth differentiation, irrigation was applied only when the accumulated rainfall between irrigation events was less than the reference evapotranspiration of 8.75 % ETo. The irrigation depths based on reference evapotranspiration fractions, plus that of standardization and rainfall during the 396 days of the cycle, resulted in the following water depths: 976 mm year^{-1} (control); 1,048 mm year^{-1} (8.75 % ETo); 1,096 mm year^{-1} (17.5 % ETo); 1,152 mm year^{-1} (26.25 % ETo); and 1,202 mm year^{-1} (35 % ETo).

The experimental area received broadcast fertilizer with 50 kg ha^{-1} of NPK (14-00-18) formulation, fractionated three times at 60-day intervals after the beginning of the cycle, according

Table 1. Meteorological and irrigation depth variables[1] between June 2012 and June 2013, in a forage cactus cropping area under exclusive systems and intercropping with sorghum, in Serra Talhada, Pernambuco State, Brazil.

Months	Month/	at	mt	nt	ARh	MRh	NRh	u	Rg	Rainfall	D0%	D8.75%	D17.5%	D26.25%	D35%
Cycle	Year	ºC			%			m s^{-1}	MJ m^{-2} day^{-1}	mm					
1	Jun. 2012	25.2	31.2	20.1	55.6	81.2	30.5	2.7	18.1	2	24	24	24	24	24
2	Jul. 2012	23.8	30.0	19.0	59.4	83.0	32.5	3.3	18.2	12	90	90	90	90	90
3	Aug. 2012	23.7	30.4	18.5	56.0	82.3	27.7	3.7	20.3	5	120	120	120	120	120
4	Sep. 2012	25.7	32.7	19.3	46.8	75.0	22.6	3.3	23.8	1	92	92	92	92	92
5	Oct. 2012	26.9	34.0	20.7	46.0	71.9	22.1	3.2	24.4	0	110	110	110	110	110
6	Nov. 2012	28.9	35.7	22.5	40.7	68.7	17.4	2.9	24.7	2	147	147	147	147	147
7	Dec. 2012	28.7	35.2	23.0	43.3	68.8	8.6	2.5	24.3	7	0	23	31	43	52
8	Jan. 2013	27.7	33.9	22.6	51.0	77.5	26.0	2.3	21.8	110	0	17	23	31	38
9	Feb. 2013	28.5	34.9	22.8	45.1	71.4	21.5	2.7	24.6	20	0	10	20	31	41
10	Mar. 2013	28.3	34.6	23.1	50.5	75.0	26.0	2.3	24.6	69	0	9	18	28	38
11	Apr. 2013	26.5	32.6	22.2	60.4	83.4	32.5	2.4	22.3	113	0	5	11	17	22
12	May 2013	25.3	31.0	20.7	63.5	85.4	36.9	2.2	21.4	48	0	5	10	15	21
13	Jun. 2013*	24.9	30.8	20.3	59.6	83.4	33.4	2.4	16.4	5	0	3	7	11	14
Averages/Sum		26.5	32.9	21.2	52.1	77.5	26.0	2.7	21.9	393	583	655	703	759	809

[1] at: average temperature; mt: maximum temperature; nt: minimum temperature; ARh: average relative humidity; MRh: maximum relative humidity; NRh: minimum relative humidity; u: wind speed; Rg: global solar radiation; D: irrigation depth based on reference evapotranspiration fractions (8.75 %, 17.5 %, 26.25 % and 35 % ETo); * only 15 days.

to recommendations by the Instituto Agronômico de Pernambuco. Weeding and pest control were performed when needed.

The mulch-based and forage cactus-sorghum intercropping systems were applied at the end of October 2012. The mulch-based cropping system resulted from the application of 8.2 t ha^{-1} of elephant grass (*Pennisetum purpureum* Schum.) between the rows of forage cactus. The sorghum [*Sorghum bicolor* (L.) Moench] cv. IPA 2502 was planted (0.25 m apart) in rows adjacent to the forage cactus, manually sowed at a density of 18 seeds m^{-1}, in 0.05 m-deep pits. Pruning was performed during the first month after planting (November 2012), when there was no difference in irrigation depths, maintaining a population density of 170,000 plants ha^{-1}. Sorghum was grown over two cycles (planting and regrowth): the first was harvested in February 2013 (at 141 days after planting) and the second in June 2013 (at 105 days after harvest of the first cycle), for a total of 246 days. In both cycles, sorghum was cut at a height of 0.10 m from the ground.

Biometric measures of three plants from each subplot were taken over time, where the number of cladodes was monitored per order of emergence (basal, 1^{st} order, 2^{nd} order… n^{th} order). The length and width of the cladodes were also recorded. All the measurements were taken, on average, every 40 days (at 40, 78, 107, 171, 200, 242, 263, 291, 326, 354 and 396 days after the onset of the cycle), totaling 10 periods of measurement and following the procedures adopted by Silva et al. (2015a). The area occupied by the cladodes was estimated based on their length and width, using the mathematical equation suggested by Silva et al. (2014a). The cladode area index (CAI, in m^2 m^{-2}) was calculated according to Pinheiro et al. (2014), using the length and width data of cladodes. All the plants in the useful area were weighed at harvest time, and then ten representative cladodes were sampled for drying in a forced air oven at 65 ºC, until reaching constant mass. The harvest yield (Wh, t ha^{-1}) was obtained using the final plant density, fresh weight of the useful plot and dry matter content resulting from the ratio between the dry and fresh forage mass of 10 cladodes.

The CAI*i* values were used to estimate the absolute dry matter (We) across the cycle by the equation previously obtained from independent experimental data [$We_i = 7.1942.\sum CAI_i^{1.6214} + \varepsilon$, in which We*i* (t ha^{-1}) and CAI*i* are the cladode area index on date *i*, in the 10 biometric measurements, and ε the relative error in relation to the yield measured and yield estimated on the last date (harvest time) ($\varepsilon = Wh - We_{10}$, being 10 the 10^{th} date) and inserted into the data estimated for We on each date, aiming to reduce the error of yield estimation over time].

For intercropping, the absolute dry matter of sorghum (Whs) at harvest was obtained by weighing 10 plants from the useful area, drying three plants and extrapolating, with the same procedure used for forage cactus. The monthly sorghum dry matter accumulation rate, obtained by the Whs/13 months ratio, was summed with that of the forage cactus in the intercropping system for estimation of the total dry matter growth rate.

To establish the plant phenology of the forage cactus, the onset of a new phase was considered when the cladode production rate of a certain order was surpassed by the cladode production rate of the subsequent order.

Regression analysis was used to test the association between the number of cladodes per order with the number of days after cutting. Regressions were conducted with sigmoid models. Models with coefficients of determination greater than 0.90 and significant equations and parameters ($p < 0.05$), using the F and t tests, in that order, were derived from the calculation of daily cladode production rates. The daily values were integrated to obtain the monthly rate and the increase in the cladode production rate per order was used to identify and determine the duration of phenophases.

The same procedure was conducted with the dry matter values, in order to define the cutting time. The ideal cutting times were identified by extrapolating the rate of forage cactus dry matter accumulation and observing which was the month with a dry matter rate lower than half the average of the 13-month cycle.

The duration of phenophases, monthly dry matter accumulation rate and cutting time under different irrigation depths and cropping systems were compared by analysis of variance, followed by a comparison of averages by the Tukey test (5 %).

RESULTS AND DISCUSSION

During the forage cactus cycle, three phenophases were observed based on the cladode production rate. However, irrigation depths and cropping systems showed no interaction effect on phenophases ($p > 0.05$). Besides, both factors showed isolated effects on phenophases II and/or III ($p < 0.05$) (Figures 1 and 2).

Phenophase I was found in all the treatments (Figure 3), with average duration of seven months, and its length was not affected by the different irrigation depths and cropping systems. In other words, the cladode production rate of the first order did not change, although the highest number of cladodes was observed in the exclusive cropping system without mulch and at intermediate water depths (1,048-1,096 mm), with cladode size in this system related to higher water depths (data not shown). This increase occurred primarily when phenophase I had already been surpassed, indicating that the production of lower order cladodes may occur, even when the plant is in a more advanced phenophase.

Phenophase II was also observed in all the treatments (Figure 3), however, it was characterized by higher cladode production and occurred predominantly in months with greater solar radiation intensity, temperature and water availability (Table 1). The duration of phenophase II increased with a rise in irrigation depth (Figure 1A). Phenophase III, in turn, was observed in the three cropping systems (Figure 3), and its duration declined with an increase in water depth ($p < 0.05$) (Figure 1B). The mulch-based and intercropping systems caused a reduction only in phenophase III (Figure 2).

In general, both low and high water availability in the soil may alter the occurrence of phenophases, in this order, as a defense mechanism against water stress or only due to the presence of favorable conditions for development (Cunha et al. 2012). In the present study, the reduction in phenophase III was most associated with the effects of water depth on phenophase II, intensifying the second-order daughter cladode production to the detriment of their size, which was smaller in mulch-based and intercropping systems (data not shown). The presence of mulch favors water storage and lower temperature, and increase cycling and soil nutrient content, contributing to the plant development (Borges et al. 2014). Consequently, mulch stimulates the second-

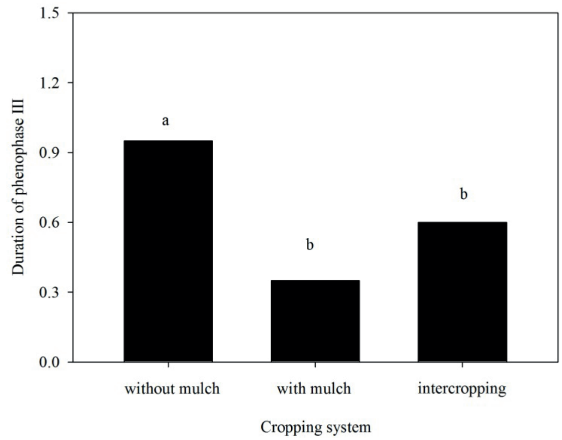

Figure 2. Effect of cropping systems (forage cactus without mulch, forage cactus with mulch and forage cactus-sorghum intercropping) on phenophase III of the irrigated forage cactus *Opuntia stricta*. Means followed by the same letter do not differ statistically.

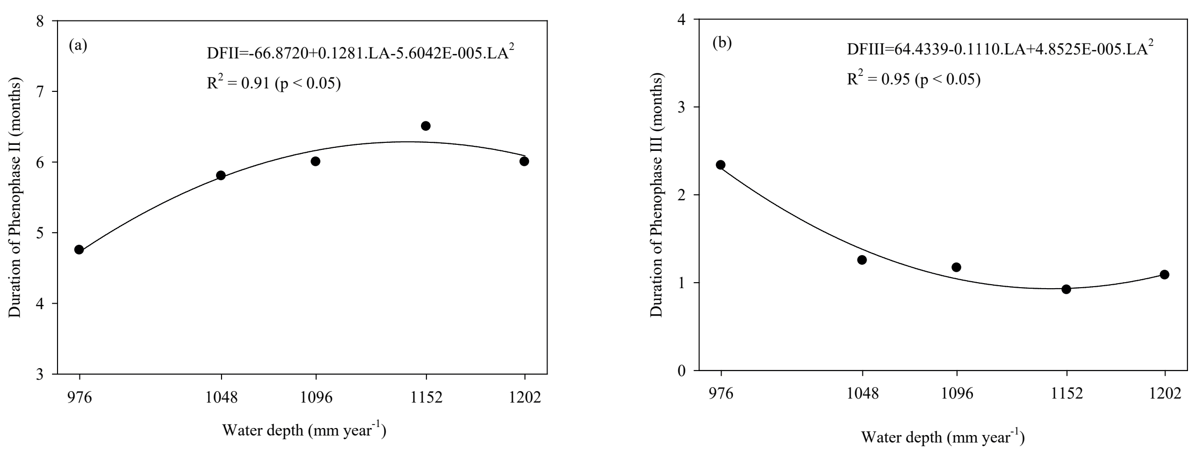

Figure 1. Effects of irrigation depths based on reference evapotranspiration fractions (8.75 % , 17.5 % , 26.25 % and 35 % ETo) plus a control (0 % ETo) on phenophase II (a) and phenophase III (b) of the forage cactus *Opuntia stricta* under three cropping systems (forage cactus without mulch, forage cactus with mulch and forage cactus-sorghum intercropping), with water depths resulting from standardized irrigation events, and irrigation events based on fractions of ETo plus rainfall events.

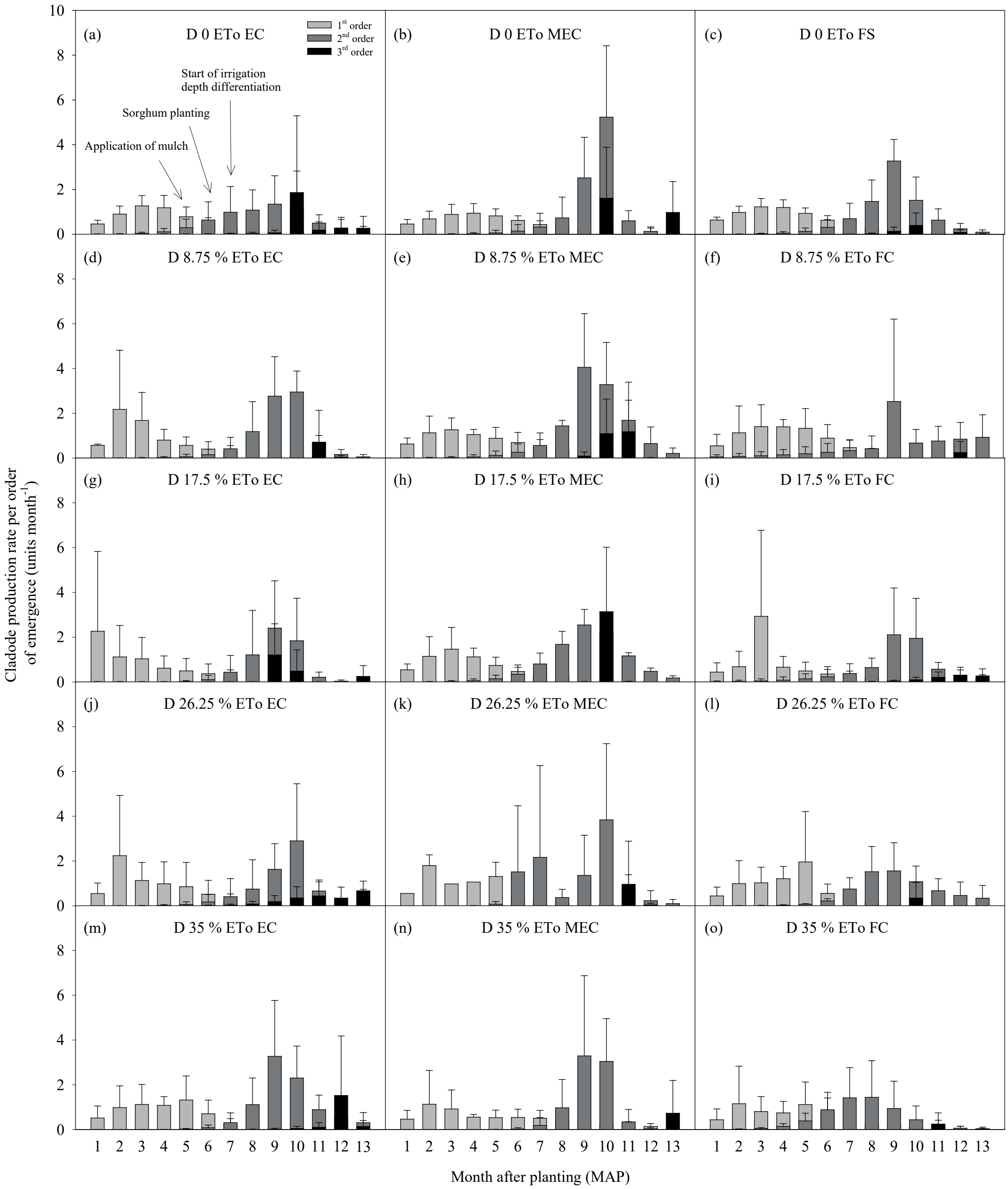

Figure 3. Phenological phases of plants (phenophases) based on the monthly production rate of 1st, 2nd and 3rd order forage cactus (*Opuntia stricta*) daughter cladodes under irrigation depths (D), based on reference evapotranspiration fractions (8.75 %, 17.5 %, 26.25 % and 35 % ETo), plus a control (non-irrigated land, D0) and three cropping systems (EC: forage cactus without mulch; MEC: mulch-based forage cactus; and FS: forest cactus-sorghum intercropping).

order daughter cladode production, as observed in this study. Silva et al. (2015a) and Queiroz et al. (2015) reported that this morphological characteristic of second-order daughter cladode production is intrinsic to the species *O. stricta* (Haw.) Haw., whether under non-irrigated or irrigated conditions. Silva et al. (2015b) found that better knowledge of growth and environmental factors can improve management with a view to enhancing crop yields.

In the forage cactus-sorghum intercropping, the decrease in the third-order daughter cladode production rate culminated in fewer and smaller cladodes (data not shown). The competition for light, water and nutrients delays the crop development, as reported by Souza et al. (2014) and Silva et al. (2014b).

In some cases (Figures 3A, 3B, 3E, 3H and 3I), the second-order daughter cladode production rate exceeds that of the third order. This result indicates that, during the 13-month cycle, maximizing the number of higher-order forage cactus daughter cladodes may not be advantageous, given that younger cladodes are smaller and exhibit low growth potential, in addition to act as a photoassimilate drain for a longer time period. Thus, plants invest more in lower-order cladodes, both in number and size, as observed in first-order daughter cladodes, in order to compensate vascular restrictions and decrease intercladode competition. These changes in the source-drain relation and in plant morphogenesis are strongly emphasized for other species (Alves et al. 2000, Alexandrino et al. 2005).

Changes in phenophases, as a function of irrigation depths and/or cropping systems, affected the dry matter accumulation rate and, therefore, the cutting time of forage cactus (Figure 4). In most

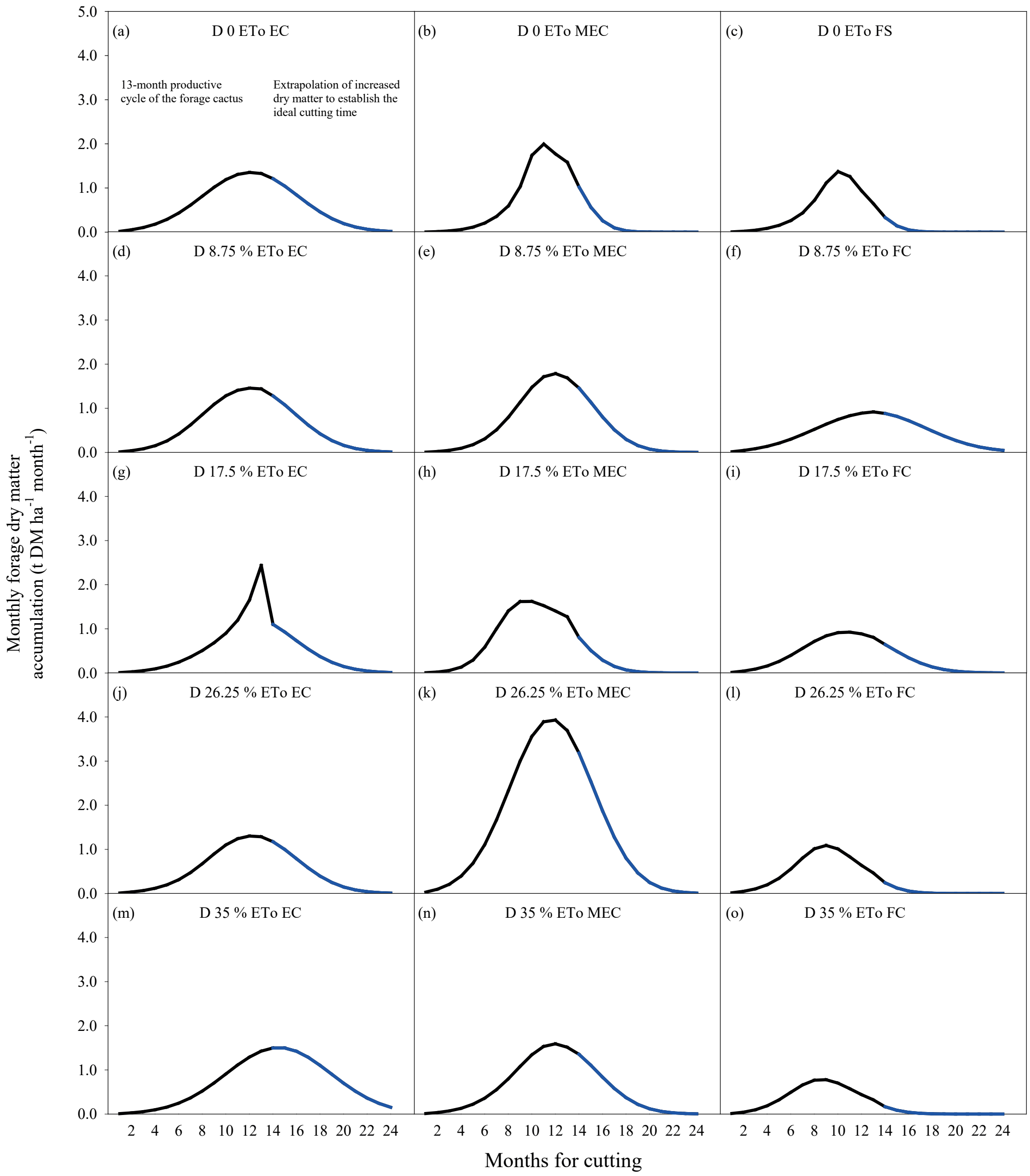

Figure 4. Monthly accumulation rate for the 13 month-cycle of the forage cactus *Opuntia stricta* (black line) and its extrapolation (blue line) to indicate the crop harvest time at different irrigation depths (D), based on reference evapotranspiration fractions (8.75 %, 17.5 %, 26.25 % and 35 % ETo), plus a control (non-irrigated, D0) and cropping systems (EC: forage cactus without mulch; MEC: mulch-based forage cactus; and FS: forest cactus-sorghum intercropping).

treatments, the maximum dry matter accumulation occurred around 13 months after planting, and there was a wide range in its magnitude. Irrigation depths showed no effect on the monthly accumulation of dry matter, but cropping system did ($p < 0.05$) (Figure 5).

The use of mulch increased the monthly dry matter of forage cactus by 62 % ($p < 0.05$), when compared to the exclusive cropping system without mulch. The intercropping system did not differ from the exclusive system (Figure 5A), indicating that the competition with sorghum did not reduce the monthly dry matter growth rate of the forage cactus. Thus, even with a shorter phenophase III in the mulch-based system (Figure 2), the increases in phenophase II ensured a rise in the rate of forage dry matter accumulation. A number of studies confirm that the larger number of cladodes from the 'Orelha de Elefante Mexicana' clone are of the second order, and therefore contribute more to the final yield (Pinheiro et al. 2014, Silva et al. 2015a).

When the accumulation of sorghum dry matter is considered (Figure 5a), the intercropping performance was greater than that of the mulch-based system and 133 % higher than that of the system without mulch, explaining the decrease in phenophase III observed in this system (Figure 2). This productive advantage of forage cactus-sorghum intercropping was reported by Farias et al. (2000), even with a decline in the individual yield of crops due to competition for light, water and nutrients, as described by Soares et al. (2009).

Based on the extrapolation of the monthly increase in forage dry matter, it was found that the ideal cutting time was not affected by water depths, with 19 months being the most adequate harvest age, regardless of cropping system. This result is five months earlier than the 24 months commonly reported in the literature for the traditional non-irrigated system (Silva et al. 2014c and 2015a). Although this information is of great importance for the management of forage cactus, it is understood that these estimates may present errors because of extrapolation. Therefore, monitoring crop growth in the field is important to refine these estimates.

The ideal cutting time did not differ between systems with or without mulch ($p > 0.05$), with an average of 20 months (Figure 5B). In the intercropping system, on average, harvest is recommended at 17 months, but did not differ from the mulch-based system ($p > 0.05$). Thus, adopting the forage cactus-sorghum intercropping system caused a significant increase in the forage dry matter accumulation rate, with a reduction in the harvest time. However, it is important to underscore that, despite recommendations regarding the ideal cutting time for forage cactus, it is up to producers to choose the most convenient frequency, based on the herds needs and availability of other food sources, during the period of demand (Farias et al. 2000).

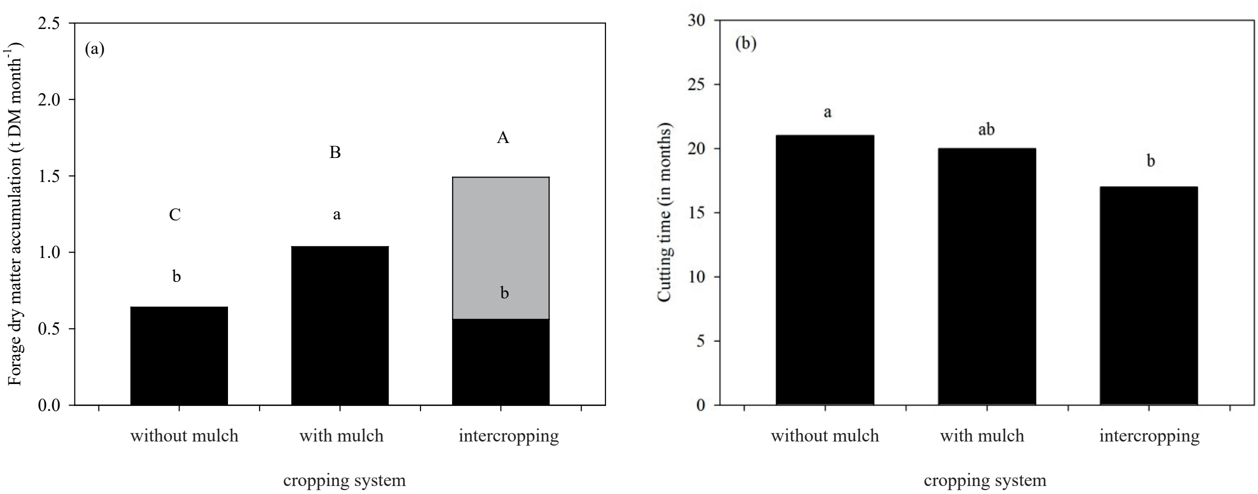

Figure 5. Effect of cropping systems (forage cactus without mulch, mulch-based forage cactus and forage cactus-sorghum intercropping) on the average monthly dry matter accumulation rate (a) and cutting time (b) of irrigated forage cactus (*Opuntia stricta*). Means followed by the same lower case letters indicate that the individual dry matter accumulation of forage cactus and cutting time (black columns) do not differ statistically. Means followed by the same upper case letters indicate that the dry matter accumulation, including sorghum yield in intercropping (grey column), do not differ statistically.

CONCLUSIONS

1. The duration of the forage cactus phenophase I was of seven months, independently of the irrigation depth and cropping system adopted;
2. Applying irrigation depths to the forage cactus cropping system significantly increased the phenophase II, to the detriment of the phenophase III;
3. The use of mulch favored an increase in the forage dry matter accumulation rate, reducing the cycle of the cropping system, if compared to that without mulch;
4. Forage cactus-sorghum intercropping increased the forage dry matter accumulation and anticipated the cutting time of the forage cactus.

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