Evaluation of Application Frequency and Levels of Nitrogen on Cactus Pear

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Abstract

The objective of this study was to evaluate the agronomic characteristics of *Nopalea cochenillifera* (L.) Salm-Dick under different frequencies and levels of nitrogen application (N). Three nitrogen fertilizer application frequencies (1 time year^{-1}, 6 times year^{-1} and 12 times year^{-1}) and four nitrogen levels (0, 100, 200 and 400 kg of N ha^{-1} year^{-1}) were evaluated one year after the planting, in a randomized blocks design with 12 replications. There was no interaction (P>0.05) between application frequencies and nitrogen levels. The number of cladodes, and the green and dry forage mass yields of the cactus pear were higher with the application frequency of 6 times year^{-1}, presenting 18.4 ± 2.0 cladodes per plant, 151.0 ± 17.8 and 9.8 ± 1.0 t ha^{-1}, respectively. The yield doubled with the application of 400 kg N ha^{-1}, when compared to the treatment with no nitrogen application. With the nitrogen application frequency of 1 time year^{-1} the crude protein and neutral detergent fiber contents were higher, presenting 4.0 ± 0.1% and 33.8 ± 0.5%, respectively. When nitrogen is applied 6 times year^{-1} it provides higher growth and yield, but lower protein and fiber contents. The level 400 kg N ha^{-1} provides higher yield and lower nitrogen use efficiency.

Keywords: cactaceae, *Nopalea cochenillifera*, urea, efficiency

1. Introduction

Forage production is one of the most important activities in livestock (Guilhoto et al., 2014), characterized as a low-cost component in ruminant feeding. Forage species that possess Crassulacean Acid Metabolism (CAM), present high efficiency in the use of water, which makes them an alternative to increase the forage mass yield during the dry season of the year (Silva et al., 2014b). The cactus pear, a CAM species, presents high productivity even in dry conditions (Peixoto et al., 2018), and when fertilized with nitrogen, it presents a superior production when compared to many forage species. Moreover, it has good consumption acceptability by the animals, high-energy value and good digestibility (Cândido et al., 2013).

According to Cunha et al. (2012) the cactus pear extracts about 300 kg of N from the soil per year. The nitrogen participates in the composition of several organic molecules inside the plants, and it is the main controller of the photosynthetic processes. Nitrogen may be responsible for changes in the establishment and persistence of cultivated plants (Fragoso et al., 2016). Cândido et al. (2013) reported the importance of nitrogen to the cactus pear because it maintains the crop productive for several cycles, especially in systems of high-density crops with high use intensity.

There is considerable variation in the recommendation of the nitrogen fertilization frequency for cactus pear, for example, the application of nitrogen two (Souza et al., 2017; Silva et al. 2014a; Dubeux Júnior et al., 2010), three (Cunha et al., 2012) and four (Silva et al., 2012) times a year. Understanding the optimal amount and application frequency of nitrogen can improve the development of the perennial crop, allow for fertilization recommendations and increase the efficiency of use, especially if the source of N is urea. The agronomic responses of cactus pear under frequency and levels of nitrogen fertilization still need to be studied to elucidate more information on that subject. The lack of this information induces the farmers to use empirical recommendations, which in most cases leads to unsatisfactory responses, thus discrediting the adoption and use of technology (Cunha et al., 2012).

The objective in the present study was to evaluate the growth, production and chemical composition of cactus pear (*Nopalea cochenillifera*) genotype Doce Miúda under frequencies and levels of nitrogen application.

2. Methods

The experiment was carried out in Bom Jesus, in the southern region of the cerrado of Piauí, Brazil. The town is located at latitude 09°04’28” S, longitude 44°21’31” W, and altitude of 220m and in an area of 5469 Km^2. The region presents the climatic classification BSh, with summer rains and dry winter according to the Köppen classification of 1936, described by Alvares et al. (2013).

The experiment was carried out between January 2015 and January 2016. During the experimental period, a rainfall accumulation of 905.7 mm was recorded, with rains mainly from January to April, October to December 2015 and January 2016, while no rainfall was recorded from May to September 2015. The mean minimum temperature during the experimental period was 21.1°C, the mean maximum was 34.6°C, and the air relative humidity was 42.3%, with records of <15% in the dry period of the year (May to September 2015).

A completely randomized blocks design was adopted in a split-plots scheme over the space, with twelve replications (three blocks and four plants evaluated per block). The plots consisted of three application frequencies of nitrogen fertilizer [1 time $year^{-1}$ (total application of the N level), 6 times $year^{-1}$ (N level divided into six applications, every 60 days) and 12 times $year^{-1}$ (N level divided into twelve applications, every 30 days)] and the subplots the four nitrogen levels (0, 100, 200 and 400 kg of N ha^{-1} $year^{-1}$), all nitrogen applications started 30 days after the planting. The cactus pear (*Nopalea cochenillifera*) used was the genotype Doce Miúda.

Before the implementation of the experiment, a representative soil sample was collected for analysis and chemical characterization from the 0-20 cm layer in the area destined to the experiment. The soil sample was sent to the Soil Laboratory of the *Campus* Professora Cinobelina Elvas (CPCE) - UFPI, in Bom Jesus, Piauí. The soil was classified as Dystrophic Yellow Latosol and the chemical analysis showed the following values: 5.3 pH in water; 9.66 mg dm^{-3} of phosphorus (P); 16.90 mg dm^{-3} of potassium (K); 1.0 $cmol_c$ dm^{-3} of calcium (Ca); 0.5 $cmol_c$ dm^{-3} of magnesium (Mg); <0.01 $cmol_c$ dm^{-3} of aluminum (Al); 1.65 $cmol_c$ dm^{-3} of hydrogen + aluminum (H+Al); 1.54 $cmol_c$ dm^{-3} of sum of bases (SB); 1.22 of effective CEC (t); 3.19 $cmol_c$ dm^{-3} of CEC at pH 7.0 (T); 48.3% of base saturation (V); and 0.0% of saturation by aluminum (M). The soil physical characteristics were: 230 g kg^{-1} of clay, 20 g kg^{-1} of silt and 750 g kg^{-1} of sand.

It was not necessary to do soil correction, considering that the chemical analysis of the soil did not show high levels of acidity and presented SB values adequate for the cactus pear crop. The application of 75 kg of phosphorus ha^{-1} as single superphosphate (18% of P_2O_5) and 40 kg of potassium ha^{-1} as potassium chloride (48% of K_2O) was done for the planting fertilization as recommended by Martha et al. (2007). Thirty days after planting, urea was used as the source of nitrogen (45% CH_4N_2O) at levels 0, 100, 200 and 400 kg of N ha^{-1} $year^{-1}$, being applied according to each treatment regarding the fertilization frequencies (30 and 30/60 days after planting) and the nitrogen levels.

For the cultivation of the cactus pear, it was adopted a spacing of 1.5 m x 0.1 m allowing a density of 66.667 plants ha^{-1}. The plots measured 4.5 m x 5.0 m, with a total of 48 plants with one uncultivated meter between them. The subplots measured 4.5 m x 1.2 m with 12 plants each. Four useful plants were evaluated per subplot.

One year after planting, the analyses of growth, production and chemical composition of the cactus pear were performed. The following non-destructive morphometric observations were done for the growth variables: number of cladodes (simple counting using an analogical counter), plant height (using a measuring tape, from the surface of the soil to the apex of the highest cladode), cladodes thickness (using a digital caliper of 0,05mm precision), width and perimeter (using measuring tape in cm).

The harvest for the determination of green forage mass yield (GFMY) in ton ha^{-1}, dry forage mass yield (DFMY) in t ha^{-1} and chemical composition of the cactus pear was performed using a machete (Tramontina® of 30 cm). The cladodes were removed at their joint in order not to cause damage to those that remained in the plant, leaving only the primary cladodes (21). The material was weighed in the field, using a digital electronic scale, with capacity of 1 g to 5 kg, model Sf-400 UNICASA®, to obtain the total GFMY. Than, a sample of approximately 500 g of green matter was taken for laboratory analyses and determination of the dry forage mass yield in ton ha^{-1} $year^{-1}$.

A simulation of the carrying capacity (CCAP) of the cactus pear genotype Doce Miúda was performed on one hectare to confine sheep for a period of 90 days. Knowing the DMY in ton ha^{-1} and that an ovine with an average weight of 25 kg of live weight (LW) consuming 3% of LV x 60% WG in the diet on a DM basis, with 40% of concentrate, the following formula was used: CCAP = (DMY ton ha^{-1}) / (individual intake x 90 days of confinement), where CCAP = carrying capacity (number of animals). To estimate the water use efficiency (WUE) in kg DM mm^{-1}, the DFMY in ton ha^{-1} was divided by the amount of rain accumulated during the experimental period. The water accumulation (WAC) in t ha^{-1} was estimated through the GFMY in t ha^{-1}, where the GFMY was multiplied by the water percentage of the plant obtained from the DM content, the result was subtracted from 100 and than divided by 1000. The nitrogen use efficiency (NUE) given in (kg of DM kg N^{-1}) was determined by relating the DM yield to the applied N level.

Regarding the analysis of chemical composition and determination of the dry matter (DM) (Method INCT-CA G-003/1), crude protein (CP) (Method INCT-CA N-001/1), ether extract (Method INCT-CA G-004/1), and neutral detergent fiber (NDF) (Method INCT-CA F-002/1), the methodologies described by Detmann et al. (2012) were adopted, and they were carried out at the Animal Nutrition Laboratory (LANA) of the UFPI.

The data were submitted to analysis of variance, the means of the nitrogen application frequencies were compared by the Tukey's test and the levels of the nitrogen fertilizer were submitted to linear regression analysis, both with significance of 5%. The software SISVAR version 5.0 (Ferreira, 2011) was used for the analyses.

3. Results and Discussion

There was no effect of interaction (P>0.05) between the nitrogen application frequencies (1 time year^{-1}, 6 times year^{-1} and 12 times year^{-1}) and the nitrogen levels (0, 100, 200 and 400 kg ha^{-1} year) on none of the studied variables (Tables 1, 2 and 3). This shows that, in the present study, the effect caused by the nitrogen application frequency was independent of the nitrogen level.

Table 1. Analysis of variance and effect of the frequencies and levels of nitrogen on growth characteristics of cactus pear (*Nopalea cochenillifera*) genotype Doce Miúda

Variable	*P – value*			General Mean
	Freq.	Level	Freq. x Level	
Number of cladodes	0.04*	0.03*	0.44^{ns}	14.4
Thickness (mm)	<0.01*	0.21^{ns}	0.54^{ns}	11.8
Length (cm)	<0.01*	0.34^{ns}	0.37^{ns}	40.1
Perimeter (cm)	0.03*	0.61^{ns}	0.51^{ns}	10.3
Width (cm)	0.36^{ns}	0.88^{ns}	0.52^{ns}	8.1
Height (cm)	0.03*	0.09^{ns}	0.96^{ns}	67.2
Variable	Nitrogen Application Frequency			
	1 time year^{-1}	6 times year^{-1}	12 times year^{-1}	SEM[a]
Number of cladodes	10.6b	18.4^{a}	14.2ab	2.0
Thickness (mm)	8.8b	13.7^{a}	12.5a	0.4
Length (cm)	15.9b	19.3^{a}	17.9ab	0.6
Perimeter (cm)	37.5b	42.1^{a}	40.8ab	1.1
Height (cm)	57.5b	73.5^{a}	70.2ab	4.1

Variable	Nitrogen Level (kg ha^{-1})				*P – value*	R^2
	0	100	200	400	Linear	
Number of cladodes	10.1	13.4	20.4	13.7	0.24^{ns}	-

[a]SEM: standard error of the mean; Level: level of nitrogen. *significant at P<0.05 for the linear effect; ns not significant at P<0.05 for the linear effect.

The number of cladodes was influenced by the application frequency (P=0.04) and by the levels of N (P=0.03). The highest number of cladodes was observed in the application frequency of 6 times year^{-1}, with 18.4±2.0 cladodes per plant. Similar performance was observed by Cunha et al. (2012), in studies with increasing levels of nitrogen fertilization, where it was verified significant differences regarding the number of cladodes per plant. This fact can be evidenced due to the nitrogen function in the plant, which acts stimulating the expansive capacity, and increases its vigor and cellular division.

There was no linear effect (P=0.24) of the N levels regarding the number of cladodes of the cactus pear, but a quadratic tendency was observed for this effect (Table 1). Although the data did not present linear adjustment, it is possible to observe an increase in the number of cladodes according to the availability of nitrogen, with values ranging from 10.1 to 20.4 cladodes for absence of fertilization and for the level 200 kg ha^{-1} of N, respectively. For the level 400 kg ha^{-1} of N, it was observed a decrease to 13.7 cladodes. Leite et al. (2018) reported that with increase in nitrogen availability, an increase in the cladodes thickness is observed up to 450 kg ha^{-1} of N, and than a subsequent decreased.

The thickness, length and perimeter of the cactus pear cladode were affected (P<0.05) only by the nitrogen application frequency. The cactus pear presented higher values of thickness, length and cladode perimeter in the application frequency of 6 times $year^{-1}$, with 13.7±0.4 mm, 19.3±0.6 cm and 42.1±1.1 cm, respectively. The same was observed for height of the plant (P=0.03) where the nitrogen application frequency of 6 times $year^{-1}$ showed the highest value (73.5 ± 4.1 cm). Cunha et al. (2012), did not observe effect of levels of nitrogen fertilization on the morphogenic characteristics, evidencing that the increase of the application frequency has greater effect than the increase in the dosage of N for these characteristics.

Significant effects on these variables can be expected because nitrogen acts as a cell division and elongation stimulator, which promotes direct effects on these variables when N is applied in a fractional way throughout the cactus pear's cycle. Thus, it is evident that the application frequency of 6 times $year^{-1}$ allows a higher incidence of nutrient availability in the soil and the effective use of this nutrient by the plants, converting the absorption into greater plant vigor (Cunha et al., 2012).

The cladode width was not influenced (P>0.05) neither by the frequency nor by the application levels of N. This fact can be explained by the increase of the number of cladodes due to the greater nitrogen availability. Thus, the higher need of nutrients translocation to new cladodes (drains), influences the characteristics related to the development of the cladodes (Lemaire e Chapman, 1996).

Green (GFMY) and dry forage mass yield (DFMY), water accumulation (WAC), water use efficiency (WUE), and nitrogen use efficiency (NUE) were influenced (P<0.01) by the nitrogen application frequency (Table 2). The application frequency of nitrogen has a direct effect on the variables related to production, as it stimulates the increase in cellular content and in the expansive capacity of the plant, thus maximizing crop productivity.

Table 2. Analysis of variance and effect of the frequencies and levels of nitrogen on agronomic characteristics of cactus pear (*Nopalea cochenillifera*) genotype Doce Miúda

Variable	*P – value*			General Mean
	Freq.[g]	Level	Freq. x Level	
GFMY[a]	<0.01*	0.04*	0.54[ns]	106.3
DFMY[b]	<0.01*	0.02*	0.34[ns]	7.0
CCAP[c]	0.09[ns]	0.02*	0.42[ns]	193.7
WAC[d]	<0.01*	0.04*	0.55[ns]	107.6
WUE[e]	<0.01*	0.03*	0.35[ns]	7.6
NUE[f]	<0.01*	<0.01*	0.06[ns]	40.4
Variable	Nitrogen Application Frequency			SEM
	1 time year^{-1}	6 times year^{-1}	12 times year^{-1}	
GFMY[a]	62.5b	151.0a	105.0ab	17.8
DFMY[b]	4.5b	9.8a	6.7ab	1.0
WAC[d]	58.0b	155.8a	109.0ab	18.5
WUE[e]	4.5b	10.9a	7.5ab	1.1
NUE[f]	24.6b	53.2a	43.5a	4.7

Variable	Nitrogen Level (kg N ha^{-1})				*P - value*	R^2
	0	100	200	400	Linear	
GFMY[a]	59.6	112.1	114.2	139.3	0.01*	80.07
DFMY[b]	3.8	6.8	8.3	9.2	0.01*	82.7
CCAP[c]	115.0	181.9	227.6	250.1	<0.01*	85.1
WAC[d]	59.9	114.6	114.9	141.0	0.02*	78.7
WUE[e]	4.2	7.3	9.0	10.0	<0.01*	83.2
NUE[f]	-	64.5	31.5	25.3	<0.01*	71.2

GFMY[a]: Green forage mass yield (t ha^{-1}); DFMY[b]: Dry forage mass yield (t ha^{-1}); CCAP[c]: Carrying capacity (animals ha^{-1}), WAC[d]: Water accumulation (t ha^{-1}), WUE[e]: Water use efficiency (kg DM mm^{-1}); NUE[f]: Nitrogen use efficiency (kg of DM kg N^{-1}). [g]Freq.: nitrogen application frequency; Level: level of nitrogen. *significant at P<0.05 for the linear effect; ns not significant at P<0.05 for the linear effect.

The nitrogen application frequency of 6 times year^{-1} presented higher GFMY and DFMY (P<0.01) with values of 151.0±17.8 and 9.8±1.0 t ha^{-1}, respectively, surpassing the application frequency of 1 time year^{-1} in 88.5 and 5.3 t ha^{-1} of dry and green forage mass, respectively, than. In studies carried out by Silva et al., (2014b), with different genotypes of cactus pear, similar effects were observed, where the genotype Doce Miúda presented higher values of GFMY and DFMY in comparison to the other evaluated genotypes.

The DFMY found in this study is lower the one found by Dubeux Junior et al. (2006) in studies developed with different levels of nitrogen and phosphate fertilization, where they observed dry matter values ranging from 6 to 17 ton ha^{-1} at a density of 5,000 plants ha^{-1} and 17,8 to 33,7 t ha^{-1} at a density of 40,000 plants ha^{-1}. The lower production in this experiment is justified by the fact that the evaluation was carried out one year after planting and due to the low air relative humidity in the region, which in October 2015 was less than 15%.

Regarding the variable GFMY, the results obtained in the present study were inferior to the results obtained by Junior et al. (2016) who studied the effects of chemical, organic and organic-mineral fertilization on morphometric and yield characteristics of the cactus pear 'Gigante', and observed values higher than 115 ton ha^{-1}. It is worth mentioning that the cited authors considered the productivity at 650 days after planting, presenting a greater accumulation of forage mass.

WAC and WUE presented higher values at the application frequency of 6 times year^{-1}, 155.8±18.5 ton ha^{-1} and 10.9±1.1 kg DM mm^{-1}, respectively. The NUE was higher in both application frequencies of 6 times year^{-1} and 12 times year^{-1}. The use of urea as a source of nitrogen should consider the relative susceptibility to losses by volatilization and leaching, which may make it impossible to absorb and assimilate the entire nitrogen content (Cunha et al., 2012). Nitrogen partitioning makes it possible to make the fertilizer available in smaller and more frequent volumes, what avoids losses, and allows the plant to assimilate the necessary amounts of the fertilizer. This explains the better performance of the crop in productive and morphological characteristics when N is supplied divided throughout the life cycle of the plant.

There was an increasing linear effect ($P<0.01$) on GFMY and DFMY in relation to the increase of the nitrogen levels. GFMY and DFMY increased more than twice with the application of 400 kg N ha^{-1}, when compared to the treatment without nitrogen. Gonzalez (1989) observed the positive effect of nitrogen and phosphorus application on the green mass production of *Opuntia lindheimeri*. In cactus pear, the N acts in the expansion of cladodes, and consequently, in the increase of the number of cladodes, a characteristic that presents direct relation with the production. Differently from the study of Cunha et al. (2012), where no effects of nitrogen fertilization were observed on fresh mass yield in tons per hectare.

For the variables carrying capacity (CCAP), WAC and WUE, it was observed that the increase of the nitrogen levels (0, 100, 200 and 400 kg N ha^{-1}) provided increasing linear increments, being observed that the higher the level of nitrogen the higher the cactus pear production (Table 2). However, the same pattern was not observed on NUE, which presented decreasing linear effect, and this behavior was similar to those found by Araújo Filho et al. (2013), who obtained maximum N efficiency at the lowest nitrogen level (50 kg ha^{-1}), associating this effect to the higher assimilation and lower nutrient loss by leaching or volatilization to the environment. In the present study, the lowest level tested (100 kg N ha^{-1}) presented the best efficiency, which means it took a lower amount of N applied to produce one kg of accumulated DFMY, and this efficiency reduced as the N level applied increased.

The increasing linear effects (Table 2) can be explained by the fact that nitrogen provides an increase in the forage mass, which is directly linked to the other variables. WAC presented increasing values ranging from 59.9 to 141.0 ton ha^{-1}, and this increasing behavior was also found by Cavalcante et al. (2014) for water accumulation in different cactus pear genotypes as a function of density increase, and Ramos et al. (2017) for *Nopalea cochenillifera* as a function of different planting densities in cultivation with and without weeding, with the difference between genotypes and environmental conditions equivalent to the different nitrogen levels.

Rocha et al. (2017) evaluating WUE and WAC in different genotypes of cactus pear in Petrolina-PE, observed that the genotype that presented the highest efficiency in the use and accumulation of water, was the most productive. Similar values of the cactus pear genotype

Doce Miúda of 7.4 and 7.7 kg DM mm^{-1} were found by Silva et al. (2014b) for the variable WUE, evaluating indicators of water and nutrients use efficiency of cactus pear clones under rainfed conditions.

Regarding the chemical composition of the cactus pear (Table 3), it was observed effect of the nitrogen application frequency (P<0.01) on the dry matter (DM), crude protein (CP), neutral detergent fiber (NDF) and ether extract (EE) contents. The DM content was lower in the application frequency of one time year^{-1} with 6.2±0.2%, whereas the CP and NDF contents were higher in this frequency, with 4.0±0.1% and 33.8±0.5%, respectively. These results can be explained by the higher production of cladodes, which is potentiated, thus diluting the proportion of nutrients in the plant.

Table 3. Analysis of variance and effect of the frequencies and levels of nitrogen on chemical composition of cactus pear (*Nopalea cochenillifera*) genotype Doce Miúda

Variable	Freq.[e]	*P – value* Level	Freq. x Level	General Mean	
DM[a]	<0.01*	0.05*	0.25^{ns}	8.0	
CP[b]	<0.01*	0.01*	0.07^{ns}	3.3	
NDF[c]	<0.01*	0.04*	0.15^{ns}	30.1	
EE[d]	<0.01*	0.14^{ns}	0.08^{ns}	1.1	
Variable	Nitrogen application frequency: 1 time year^{-1}	6 times year^{-1}	12 times year^{-1}		EPM
DM[a]	6.2b	8.7a	9.1a		0.2
CP[b]	4.0a	3.0b	2.8b		0.1
NDF[c]	33.8a	28.2b	28.4b		0.5
EE[d]	1.1ab	1.6a	0.7b		0.1

Variable	Nitrogen Level (kg N ha^{-1}): 0	100	200	400	*P - value* Linear	R^2
DM[a]	7.7	7.7	8.8	7.8	0.58^{ns}	-
CP[b]	3.1	3.6	3.2	3.1	0.18^{ns}	-
NDF[c]	28.8	29.6	30.2	31.6	<0.01*	97.2
EE[d]	0.97	1.42	0.94	1.35	0.34^{ns}	-

[a]DM: Dry Matter (%); [b]CP: Crude protein (% DM); [c]NDF: Neutral detergent fiber (% DMS); [d]EE: Ether Extract (% DM). *significant at 5%; ^{ns} not significant at 5. [e]Freq.: nitrogen application frequency; Level: level of nitrogen. Means followed by different letters in the rows are different (P<0.05) by the Tukey's mean test.

Regarding the nitrogen levels, there was a positive linear effect (P<0.01) on the NDF content, presenting 31.6±0.5% in the highest N level. There was no linear effect on the contents of DM, CP and EE of cactus pear with the increase of the nitrogen fertilization. The increase in the nitrogen application frequency presented a higher effect than the increase in the nitrogen level on the chemical composition of the cactus pear, showing that the nitrogen fertilizer application strategy is important to both growth and production, as well as to the chemical composition of the cactus pear.

In an analysis of the economic viability performed on a corn crop regarding the level and application frequency of N, Duete et al. (2009) reported that the non-application of N provided a lower economic return and was not feasible, and pointed the application of the nitrogen fertilizer in three times for that crop with 140 DAS as the alternative that presented higher benefit/cost and gross revenue. Knowing that the cactus pear crop has 365 DAP, the application frequency of 6 times year^{-1} may be a viable option, since it presented higher productivity indexes.

When the nitrogen is applied 6 times year^{-1}, it provides greater values of number of cladodes, thickness, and length, perimeter and yield characteristics. When the nitrogen is applied 1 time year^{-1} it provides higher crude protein and fiber content in the cactus pear (*Nopalea cochenillifera*) genotype Doce Miúda.

The level 400 kg of N ha^{-1} provides higher yield of cactus pear and less efficiency in the use of nitrogen.

References

Alvares, C. A., Stape, J. L., Sentelhas, P. C., Moraes, G., Leonardo, J., & Sparovek, G. (2013). Köppen's climate classification map for Brazil. *Revista Meteorológica*, *22*(6), 711-728. https://doi.org/10.1127 / 0941-2948 / 2013/0507.

Araújo Filho, J. T. D., Paes, R. D. A., Amorim, P. L. D., Comassetto, F. F., & Silva, S. C. D. (2013). Características morfológicas e produtivas da maniçoba cultivada sob lâminas hídricas e doses de nitrogênio. *Revista Brasileira de Saúde e Produção Animal*, *14*. https://doi.org/10.1590/S1519-99402013000400001.

Cândido, M. J. D., Gomes, G. M. F., Lopes, M. N., & Ximenes, L. J. F. (2013). Cultivo de palma forrageira para mitigar a escassez de forragem em regiões semiáridas. *Informe Rural Etene*, *7*(3), 1-7. https://www.researchgate.net/profile/M_Candido/publication/274637254_Cultivo_de_palma_forrageira_para_mitigar_a_escassez_de_forragem_em_regioes_semiaridas/links/552424350cf22e181e7389e8/Cultivo-de-palma-forrageira-para-mitigar-a-escassez-de-forragem-em-regioes-semiaridas.pdf

Cavalcante, L. A. D., Santos, G. R. A., Silva, L. M., Fagundes, J. L., & Silva, M. A. (2014). Respostas de genótipos de palma forrageira a diferentes densidades de cultivo. *Pesquisa Agropecuária Tropical*, *44*. https://doi.org/10.1590/S1983-40632014000400010

Cunha, D. D. N. F. V., Gomes, E. D. S., Martuscello, J. A., Amorim, P. L. D., Silva, R. C., & Ferreira, P. S. (2012). Morphometric and biomass accumulation in small forage cactus grow under nitrogen fertilization. *Revista Brasileira de Saúde e Produção Animal*, *13*(4), 1156-1165. https://doi.org/10.1590/S1519-99402012000400005.

Detmann, E., Souza, M. A., Valadares Filho, S. .C., Queiroz, A. C., Berchielli, T. T., Saliba, E. O. S., ... Azevedo, J. A. G. (2012). Métodos para Análise de Alimentos - INCT - Ciência Animal. 1. ed. Visconde do Rio Branco. 214p.

Dubeux Júnior, J. C. .B., Araújo Filho, J. T., Santos, M. V. F., Lira, M. A., Santos, D. C., & Pessoa, R. A. S. (2010). Adubação mineral no crescimento e composição mineral da palma forrageira-Clone IPA-20. *Revista Brasileira de Ciências Agrárias*, *5*(1), 129-135. https://doi.org/10.5039/agraria.v5i1a591.

Dubeux Júnior, J. C. B., Santos, M. F., Lira, M. A., Santos, D. C., Farias, I., Lima, L. E., & Ferreira, R. L. C. (2006). Productivity of Opuntia ficus-indica (L.) Miller under different N and P fertilization and plant population in north-east Brazil. *Journal of Arid Environments*, *67*(3), 357-372. https://doi.org/10.1016/j.jaridenv.2006.02.015.

Duete, R. .R. C., Muraoka, T., Silva, E. C., Trivelin, P. C. O., & Ambrosano, E. J. (2009). Viabilidade econômica de doses e parcelamentos da adubação nitrogenada na cultura do milho em Latossolo Vermelho Eutrófico. *Acta Scientiarum. Agronomy*, *31*(1), 175-181. https://doi.org/10.4025/actasciagron.v31i1.6646.

Ferreira, D. F. (2011). Sisvar: a computer statistical analysis system. *Ciência e agrotecnologia*, *35*(6), 1039-1042.

Fragoso, R. D. .O., Temponi, L. G., Pereira, D. C., & Guimarães, A. T. B. (2016). Rehabilitation of a degraded area in the field of semideciduous seasonal forest under different treatments. *Ciência Florestal*, *26*(3), 699-711. https://doi.org/10.5902/1980509824194.

Gonzalez, C. L. (1989). Potential of fertilization to improve nutritive value of pricklypear cactus (Opuntia lindheimeri Engelm.). *Jounal de ambientes áridos*, *16*(1), 87-94. https://doi.org/ 10.1016/S0140-1963(18)31050-4.

Guilhoto, J. J. M., Azzoni, C R., & Ichihara, S. .M. (2014). Contribuição da agricultura e do agronegócio familiar para o PIB do Nordeste. *Revista Econômica do Nordeste*, *5*(5), 157-174. https://doi.org/10.2139/ssrn.2516931

Junior, M. .P., Donato, S. L. R., Silva, J. A., Donato, P. E. R., & Souza, E. S. (2016). Características morfométricas e rendimento da palma forrageira 'Gigante'sob diferentes adubações e configurações de plantio. *Revista Verde de Agroecologia e Desenvolvimento Sustentável*, *11*(1), 67-72, 2016. https://doi.org/0.18378/rvads.v11i1.3710

Leite, J. R. A., Sales, E. C. J. D., Monção, F. P., Guimarães, A. D. S., Rigueira, J. P. S., & Gomes, V. M. (2018). Nopalea cactus pear fertilized with nitrogen: morphometric, productive and nutritional characteristics. Acta Scientiarum. *Animal Sciences*, *40*. https://doi.org/10.4025/actascianimsci.v40i1.38325

Lemaire, G., & Chapman, D. Tissue flows in grazed plant communities. In: Hodgson, J., Illius, AW. (1996). (Eds.). The ecology and management of grazing systems. London: CAB International. p.3-36.

Martha Jr, G. B., Vilela, D., & Sousa, D. M. G. (2007). Cerrado: uso eficiente de corretivos e fertilizantes em pastagens. Planaltina, DF: Embrapa Cerrados, 224p.

Peixoto, M. J. A., Carneiro, M. D. S., Amorim, D. S., Edvan, R. L., Pereira, E. S., & Costa, M. R. G. F. (2018). Características agronômicas e composição química da palma forrageira em função de diferentes sistemas de plantio. *Archivos de Zootecnia*, *67*(257), 35-39. https://doi.org/ 10.21071/az.v67i257.3489

Ramos, J. P. F., Souza, J. T. .A., Santos, E. M., Pimenta Filho, E. C., & Ribeiro, O. L. (2017). Crescimento e Produtividade de Nopalea Cochenillifera em função de diferentes densidades de plantio em cultivo com e sem capina. *REDVET. Revista Eletrónica de Veterinária, 18*. http://www.veterinaria.org/revistas/redvet/n080817/081704.pdf

Rocha, R. S., Voltolini, T. V., & Gava, C. A. T. (2017). Características produtivas e estruturais de genótipos de palma forrageira irrigada em diferentes intervalos de corte. *Archivos de zootecnia, 66*(255), 363-371. http://ainfo.cnptia.embrapa.br/digital/bitstream/item/171540/1/Tadeu-2017.pdf

Santos, M. V. .F., Lira, M. A., & Dubeux Júnior, J. C. B. (2010). Plantas forrageiras. 1 ed., Viçosa: Editora UFV, v.unico, p.459-493.

Silva, J. A., Bonomo, P., Donato, L. R. S., Pires, A. J. V., Rosa, R. C. C., & Donato, P. E. R. (2012). Composição mineral em cladódios de palma forrageira sob diferentes espaçamentos e adubações química. *Revista Brasileira de Ciências Agrárias, 7*, 866-875. https://doi.org/10.5039/agraria.v7isa2134

Silva, L. M., Fagundes, J. L., Viegas, P. A. A., Muniz, E. N., Rangel, J. H. .A., Moreira, A. L., & Backes, A. C. (2014b). Produtividade da palma forrageira cultivada em diferentes densidades de plantio. *Ciência Rural, 44*(11), 2064-2071. https://doi.org/10.1590/0103-8478cr20131305

Silva, M. V. T., Santos, A. P. F., Oliveira, F. L., Sousa, M. S., & Medeiros, J. F. (2014a). Eficiência agronômica e fisiológica na melancia fertirrigada com diferentes doses de nitrogênio e fósforo. *Revista Verde de Agroecologia e Desenvolvimento Sustentável, 9*. http://oaji.net/articles/2015/2238-1445529059.pdf

Silva, T. G. F., Primo, J. T. .A., Morais, J. E. F., Diniz, W. J. S., Souza, C. A. A., & Silva, M. C. (2015). Crescimento e produtividade de clones de palma forrageira no semiárido e relações com variáveis meteorológicas. *Revista Caatinga, 28*(2), 10-18. https://periodicos.ufersa.edu.br/index.php/caatinga/article/view/3630/pdf_241

Souza, T. C., Santos, M. V. F., Dubeux, Júnior, J. C. B., Lira, M. A., Santos, D. C., Cunha, M. V., ... Silva, R. R. (2017). Productivity and nutrient concentration in spineless cactos under different fertilizations and plant densities. *Revista Brasileira de Ciências Agrárias, 12*(4), 555-560. https://doi.org/10.5039/agraria.v12i4a5473