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Performance of forage cactus submitted to different levels of irrigation and organic fertilization in the semi-arid region of Paraiba

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Abstract
The forage cactus represents one of the main sources of fodder for livestock in the semi-arid region. However, although it is cultivated on a large scale in several regions, there are still few studies addressing issues of improved management, especially about irrigation and fertilization of recently used varieties, such as those resistant to false carmine cochineal. Thus, this research aimed to evaluate the effect of different levels of irrigation and sources of organic fertilizer on the productive performance of forage cactus variety Mexican Elephant's Ear (*Opuntia stricta*). The experiment was set up at Fazenda Riachão, municipality of Boa Vista, Paraíba. Two types of manure (bovine and caprine) and the control were used, associated with the absence of irrigation and five different depths, which varied from 1.5 to 5.5 L of water per week per plant. A 3x6 factorial design with five repetitions was used in a randomized block design. The depths of water applied promoted a significant increase in the variables analyzed. The goat manure was the most effective in obtaining better values of the number of cladodes per plant and productivity.
Keywords: *Opuntia stricta;* goat manure; water supplementation.

Desempenho de palma forrageira submetida a diferentes lâminas de irrigação e adubação orgânica no semiárido Paraibano

Resumo
A palma forrageira representa uma das principais fontes de forragem para a pecuária do Semiárido. No entanto, embora seja cultivada em larga escala em diversas regiões, ainda são escassos trabalhos que abordem questões de melhoria de manejo, principalmente no que tange a irrigação e adubação de variedades de uso recentes, como as resistentes a cochonilha do carmim. Assim, este trabalho objetivou avaliar o efeito de diferentes lâminas de irrigação e fontes de adubação orgânica sobre o desempenho produtivo da palma forrageira variedade Orelha de Elefante Mexicana (*Opuntia stricta*). O experimento foi instalado na Fazenda Riachão, município de Boa Vista, Paraíba. Utilizou-se dois tipos de esterco (bovino e caprino) e a testemunha, associados com a ausência de irrigação e cinco lâminas diferentes, que variaram de 1,5 a 5,5 L de água por semana por planta. Utilizou-se um fatorial 3x6, com delineamento experimental em blocos casualisados, com cinco repetições. As lâminas de água aplicadas promoveram aumento significativo nas variáveis analisadas. O esterco caprino foi o mais efetivo na obtenção de melhores valores do número de cladódios por planta e de produtividade.
Palavras-chave: *Opuntia stricta;* esterco caprino; complementação hídrica.

Introduction

The Brazilian Semi-arid encompasses part of the states of Alagoas, Bahia, Ceará, Piauí, Rio Grande do Norte, Paraíba, Pernambuco, Sergipe and Minas Gerais. It covers an area of 969,589.4 km^2, which corresponds to almost 60% of the Brazilian Northeast. Under its domains are 137 micro-regions and 1,133 municipalities, most of

which are predominantly rural (BRASIL, 2005). This region presents some obstacles to the sustainability of food production systems. Mainly due to the history of cyclical droughts, responsible for devastating and bringing severe impacts on agriculture and livestock, such as the loss of animals and crops, leading to the worsening of social, environmental, and economic problems (LINDOSO *et al.*, 2013; BATISTA *et al.*, 2018).

Based on the production of small farmers in the semi-arid region, the best use of water, the use of management techniques (LIMA *et al.*, 2016), and the choice of plants and animals adapted to the peculiarities of the region are essential factors for obtaining good economic results. In this sense, agricultural activities should be managed so that the production system is as sustainable as possible (QUEIROZ *et al.*, 2015).

In this context, the production of exotic xerophilous plants such as the forage cactus (*Opuntia* spp. and *Nopalea* spp.) has become an activity of fundamental importance for agriculture and cattle ranching in the Northeast of Brazil. Mainly because of its physiological mechanism, about the absorption, utilization, and loss of water (SILVA *et al.*, 2014a). In the bromatological aspect, it has a high content of water, minerals, organic acids, and carbohydrates (PEREIRA NETO, 2016). These factors make this plant an exceptional reserve of forage, leading it to be consolidated as one of the main alternatives for animal feed, especially during long periods of drought, a time when native pastures and other forage crops are under strong conditions of water stress (BEZERRA *et al.*, 2014).

Due to the losses caused by the false carmine cochineal (*Dactylopius opuntiae* Cockerell), which was responsible for decimating about 150,000 hectares of oil cactus culture in several locations in the Northeast (EMPARN, 2015), the introduction of varieties resistant to this pest became necessary, with emphasis on the Mexican Elephant's Ear forage cactus (*Opuntia stricta* [Haw.] Haw.).

Despite all its importance, the culture of the forage cactus is still lacking more in-depths studies, being necessary the development and improvement of research on production systems under different management conditions, providing a better understanding of the factors that influence its adaptation and yield, thus leading to the diagnosis of which strategies and demands are necessary to achieve its full production potential in the semi-arid region (RAMOS *et al.*, 2014).

Due to the climatic characteristics of this region, mainly due to water scarcity, the use of management practices in the water use system leads to increased efficiency of crops, altering or propitiating the increase in plant productivity (DI PAOLO; RINALDI, 2008). The choices of these practices minimize the problems arising from seasonality in the production of forage species, thus allowing food security for livestock throughout the year (REGO *et al.*, 2014). Added to this is the use of fertilization strategies since the cactus is relatively demanding in soil nutrient availability. For every 10 tons of dry matter produced, 90 kg of N, 16 kg of P, 258 kg of K, and 235 kg of Ca are exported per hectare (SANTOS *et al.*, 1990). Therefore, actions to reintroduce these nutrients into the soil are necessary. The addition of manure and other organic sources to the soil reduces the capacity for phosphorus adsorption, making it more available for plant uptake, besides increasing the content of available nitrogen, and providing greater mobility of these nutrients in the soil profile (NOVAIS *et al.*, 2007).

Studies related to the analysis of the performance of the forage cactus submitted to different conditions of water availability and types of organic fertilization are fundamental for the understanding of the response of the crop and the definition of its water requirements, allowing the production of information that supports techniques for the maximization of its productivity (QUEIROZ *et al.*, 2015). In this context, this research aims to evaluate the effect of different irrigation depths and sources of organic fertilizer on the productive performance of Mexican Elephant's Ear forage cactus (*Opuntia stricta*) cultivated in a semi-arid environment, allowing a greater understanding of the joint effects of irrigation and organic fertilization on the biometry and productive characteristics of this variety.

Material and Methods

The experiment was conducted at Fazenda Riachão, located in the municipality of Boa Vista, Paraíba, (7º18'25.7 "S and 36º18'1.03 "O), situated in the Mesoregion of Agreste Paraibano, Microregion of Campina Grande and in the hydrographic basin of the Paraíba do Norte River.

The headquarters of the property has an approximate altitude of 475.0 meters distant 152.65 km from the capital. The type of climate in

the region is Bsh, hot semi-arid, with rainfall from January to April, with average annual temperatures around 24 º C, relative air humidity around 68%, occurring average rainfall of 400 mm per year, with water deficit throughout most of the year (SUDENE, 1996).

The work was implanted under field conditions, in an area of Litholic Neosol, presenting low depths, sequenced by the A - C - R horizons, with the absence of the B horizon. The soil of the experimental area presented the following chemical attributes: pH of 5.7; 36.57 mg dm-3 of P; 119.33 dm-3 of K; 16.05 cmolc dm-3 of Ca; 6.44 cmolc dm-3of Mg; 1.93 cmolc dm-3 of Na; 2.90 cmolc dm-3of H+ + Al+3; 0.05 cmolc dm-3of Al+3; sum of bases of 24,73 cmolc dm-3; 27.63 cmolc dm-3 of CTC and 16.33 g kg-1 of organic matter. The experiment started in October 2017 and remained for three months.

The experimental field was an area cultivated with the variety Mexican Elephant's Ear in its second cycle of production, two years after its implantation. The production field has a spacing of 1.0 m x 0.5 m between plants. When established, it received organic fertilization of 20.0 tons per hectare of bovine manure. The plants used in the experiment were cut, leaving only the matrix cladode/racket.

The experimental design used was a randomized block design, constituted by a double factorial 3x6, using six irrigation depths (0; 1.5; 2.5; 3.5; 4.5 and 5.5 L) and three types of fertilization (no manure, bovine manure, and goat manure). Each treatment had five repetitions and each plot was composed of thirty-six plants.

A drip irrigation system was used, in which each dripper supplied water to two plants. Irrigation was carried out weekly for three months. Organic manure from cattle and goat manure was applied at a rate of 20 t/ha based on the usual quantities used by local producers and added in a trench 0.30 m away from the mother plant, 0.20 cm is wide and 0.20 m deep. Weeding was carried out when necessary, when spontaneous plants appeared.

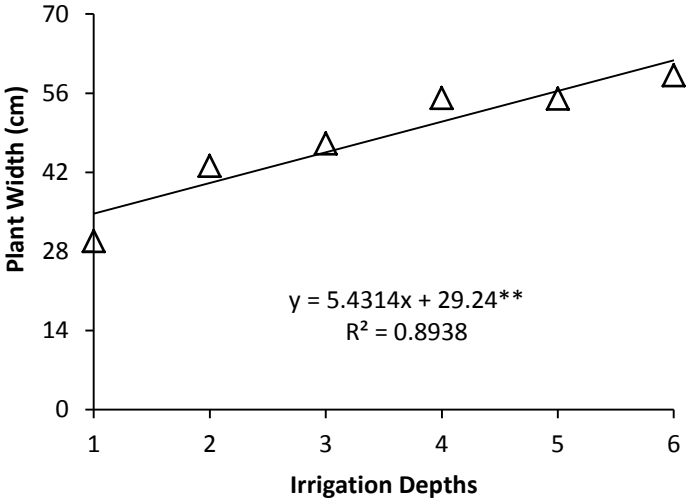
Three months after the initial cut, the width and height of the plants were measured using a graduated tape measure. After this stage, the plants were harvested, preserving the primary cladodes in each plant, to maintain the stand. The plants were weighed and counted for the total number of cladodes, as well as the largest cladode of all plants were separated and weighed. The determination of green mass (GM) production in tons per hectare was extrapolated assuming the average weight of plant per treatment and the density of plants per hectare at harvest time.

The data were submitted to variance analysis, using the statistical program SISVAR (FERREIRA, 2011). Based on the significance, regression analysis was tested up to the 2nd degree, assuming $R^2 \geq 70\%$. The means of the treatments when significant were compared using the Tukey test at a 5% significance level.

Results and Discussion

The width (cm) of the forage cactus plants was directly influenced by irrigation, observing a significant effect in the linear regression model ($p \leq 0.0001$) between this variable and the applied depths (Figure 1). The average plant width tended to increase linearly ($R^2 = 89\%$), presenting average values of 29.86 cm for the treatment with no irrigation to 59.16 cm for the depth of 5.5 L/week. Silva *et al.* (2015) obtained average widths of Mexican Elephant's Ear Cactus (OEM) of 101.78 cm in a study developed in Serra Talhada, Pernambuco, however, it should be considered that these values were obtained two years after the first cut and under dryland conditions. Therefore, the results found here reinforce the efficiency of water supplementation for this crop.

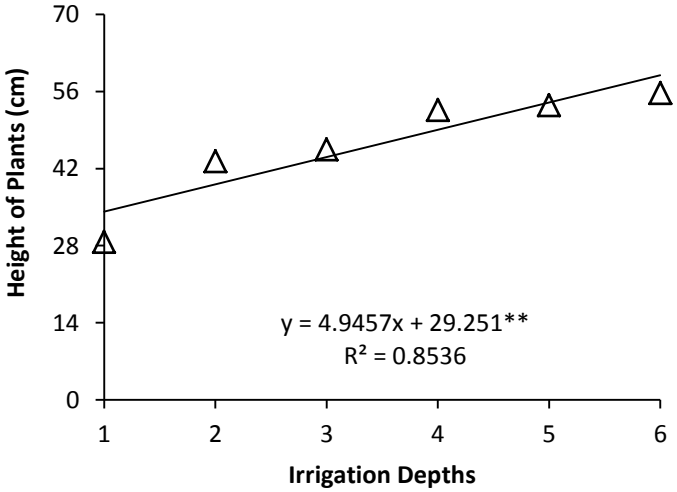
Figure 1. Variation of the width of Mexican Elephant's Ear Cactus (OEM) plants as a function of irrigation levels. Boa Vista - PB. Depths: 1 = 0; 2 = 1.5; 3 = 2.5; 4 = 3.5; 5 = 4.5; 6 = 5.5 L/week. ** significant at 1%.



However, results contrasting with those obtained here were observed by Queiroz *et al.* (2015) in the semi-arid region of Pernambuco, where, with the same variety of cactus, there were no differences between this variable and the application of different irrigation sheets. There was also a tendency for the rates of increase in width to decrease with the increase in the amount of water applied, which the authors attributed to the fact that greater water availability may incline to reduce the capacity to use water for plant growth.

The height of the plants also suffered a significant effect of the irrigation depths($p \leq 0.0001$), obtaining linear increases (R^2 = 85%) (Figure 2). The averages were between 29.66 cm and 55.73 cm, corresponding respectively to the absence of irrigation and the depth of 5.5 L/week. Except the depth 0 and 1.5 L/week, all the others were superior for this parameter, when compared with the results obtained by Pereira *et al.* (2015), in which with a depth of 7.5 mm an average of 46.9 cm of height was obtained for the Mexican Elephant's Ear cactus, the measurement being made one year after cutting.

Figure 2. Variation of the height of Mexican Elephant's Ear Cactus (OEM) plants as a function of the irrigation levels. Boa Vista - PB. Depths: 1 = 0; 2 = 1.5; 3 = 2.5; 4 = 3.5; 5 = 4.5; 6 = 5.5 L/week. ** significant at 1%..



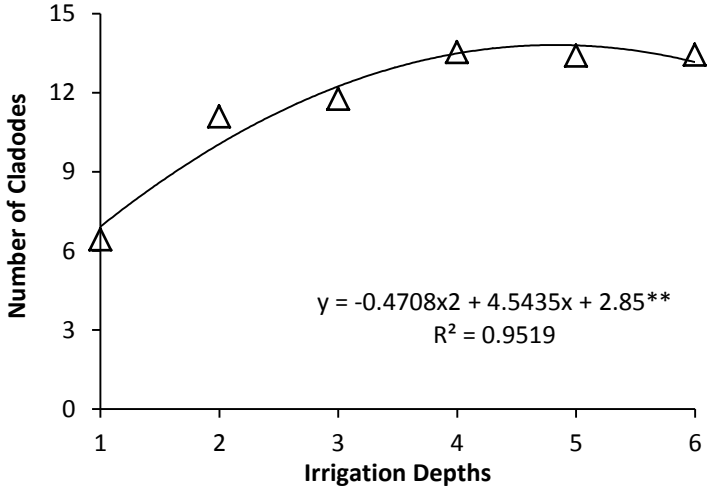
The plant height parameter is very important from the phytotechnical and crop improvement point of view, since its values directly influence the management to be

employed, thus reflecting on the production results (ARANTES *et al.*, 2010). High values of height may also be related to planting density, so that the greater the density used, the greater the final height, due to the reduction of lateral elongation of the stem because of competition between plants (SILVA *et al.*, 2010). This variable together with the width are excellent indicators of productivity, and greater values of these should be prioritized in the selection of clones, especially when considering the production of dry matter (SILVA *et al.*, 2010).

Regarding the number of cladodes per plant (Figure 3), the depth of 3.5 L/week stood out over the others, with an average of 13.53 cladodes per plant at three months after cutting. The values of this variable reflect directly in the greater magnitude of the cladode area index (CAI), an essential measure to estimate the photosynthetic capacity of the plant, serving as a determinant in measuring vegetative growth and also as a guide to the effects of management on the development of the cactus (OLIVEIRA JUNIOR, *et al.*, 2009). Pereira *et al.* (2015) using a depth of 7.5 mm obtained an average of 13.5 cladodes for Mexican Elephant's Ear cactus one year after cutting. Values higher than those found for the IPA Sertânia variety (9.8 cladodes/plant) and lower than for the Miúda cactus (13.9 cladodes/plant).

Rocha *et al.* (2017) in a study developed in Curaçá, Bahia, used irrigation complementary to rainfall, with an applied depth of 16.4 mm every 15 days, in which an average of 8.20 cladodes per plant was obtained with cuttings every 4 months, and 14.90 cladodes with cuttings every one year, values measured from a production field from planting. Thus, when compared with the results found here, it can be seen that the production of cladodes from pre-planted plants is more effective, besides being more economically profitable for the producer than planting a new production field of forage cactus.

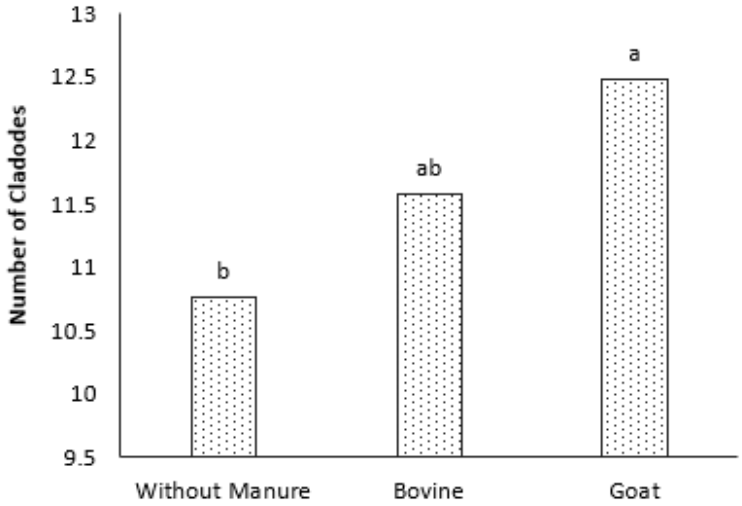
Figure 3. Variation of the number of cladodes of Mexican Elephant's Ear Cactus (OEM) cactus plants as a function of the irrigation levels. Boa Vista - PB. Depths: 1 = 0; 2 = 1.5; 3 = 2.5; 4 = 3.5; 5 = 4.5; 6 = 5.5 L/week. ** significant at 1%.



Compared with production under dryland conditions, the values found here were higher than those observed by Silva *et al.* (2014b) in Sergipe, for the Giant cactus when an average of 12.29 cladodes per plant was obtained after one year of planting. Under the same conditions, Silva *et al.* (2015) found 14.11 cladodes for the Mexican Elephant's Ear cactus two years after planting.

Organic manure performed better than the control, with better average numbers of cladodes per plant (Figure 4). Among the types of manure, goat manure stood out, accounting for an average of 12.48 cladodes. It is estimated that 250 kg of goat manure is responsible for producing the same effect as 500 kg of bovine manure (ALVES; PINHEIRO, 2007).

Figure 4. Average values of the number of cladodes per plant of Mexican Elephant's Ear Cactus (OEM) as a function of the organic inputs used. Boa Vista - PB. The bars followed by the same letter do not differ by the test of Tukey at 5%.

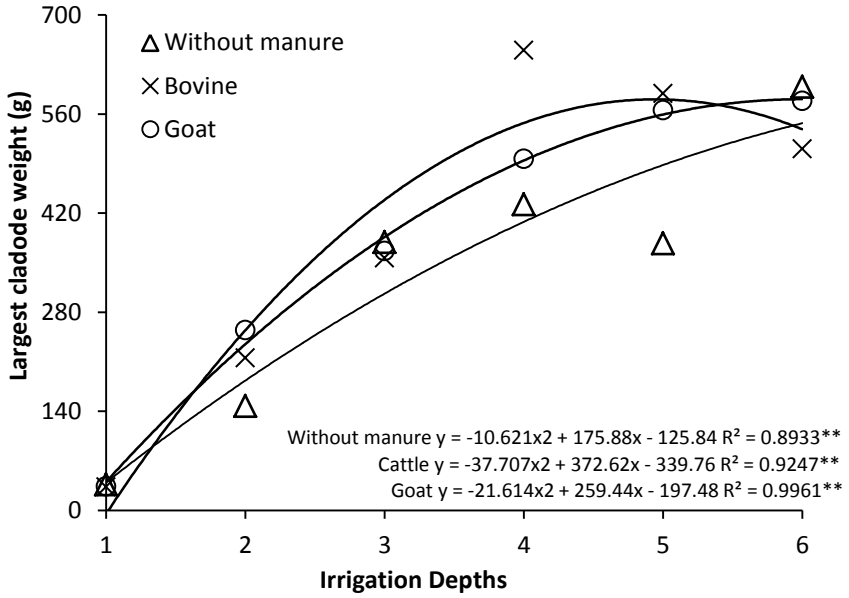


Goat manure is an excellent source of nutrients and can replace both bovine manure and worm humus in crops (DUTRA *et al.*, 2016). From the physical point of view, it is less watery and more solid than bovine manure, and due to its fluffier structure, it has a greater capacity for aeration, which is responsible for a faster fermentation, thus enhancing its use after a shorter "tanning" time than other animal manures (HENRIQUES, 1997).

Ramos et al. (2015) applying doses of 10, 15, and 20 Mg ha-1 of goat manure, obtained averages of 19.64 cladodes at 720 days after planting. In contrast to the results found here, Rego *et al.* (2014) obtained an average of 13 cladodes in Miúda cactus, in which the mother cladode was preserved, and fertilization with bovine manure and an irrigation depth of 2.5 L/week were used, and the count was performed one year after cutting.

For the average weight of the largest cladode, a significant interaction ($p \leq 0.0001$) was observed between the various sources. The best results for the average weight of the largest cladode were obtained with bovine manure at a rate of 3.5 L/week, with an average weight of 680 grams (Figure 5). This result directly implies cladodes of greater thickness, width, and length. As most of the time, the size of the racemes of the same class on the plant is similar, then it is assumed that this variable reflects a good general indicator.

Figure 5. Variation of the weight of the largest cladode of Mexican Elephant's Ear Cactus (OEM) as a function of the irrigation levels and the type of organic fertilizer used. Boa Vista - PB. Depths: 1 = 0; 2 = 1.5; 3 = 2.5; 4 = 3.5; 5 = 4.5; 6 = 5.5 L/week. ** significant at 1%.

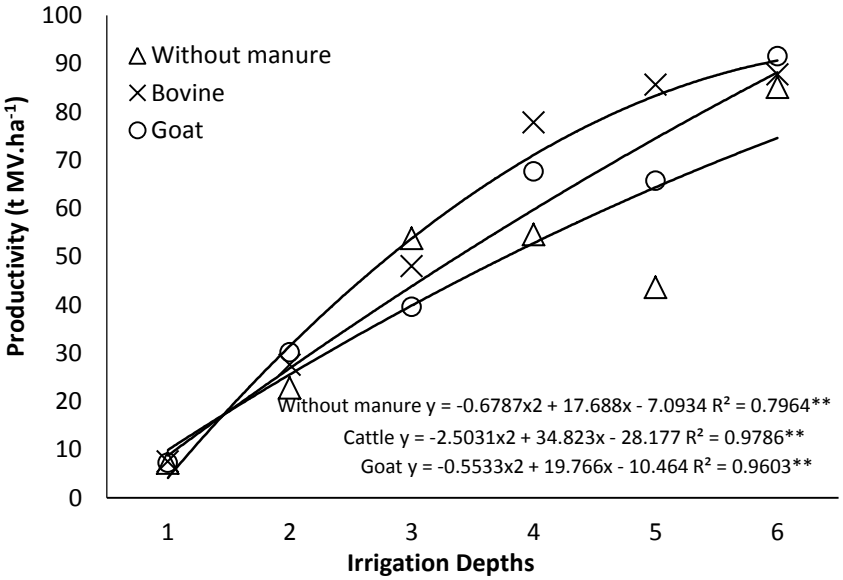


In general, heavier cladodes have a higher water content in the spongy parenchyma, which can attest that the type of manure and the depth used were more effective in providing a greater accumulation of intracellular water. This storage allows the chlorenchyma, where the photosynthetic apparatus is located, to function well, allowing photosynthesis to take place even under conditions of prolonged water stress (NOBEL, 2001).

Since the genus *Opuntia* has fewer cladodes per plant, its varieties have heavier cladodes compared to the genus *Nopalea* (NASCIMENTO *et al.,* 2011). When considering the average weight of the cladodes, together with their number and thickness, one can have a basis for the selection of accessions with good production characteristics (NEDER *et al.* 2013).

The irrigation depths were determinant for the increase of productivity, being registered significant interaction ($p \leq 0.0001$) with the organic fertilization. For depth 0, the minimum value of 7.22 tons of green mass/ha was recorded (treatment without manure), contrasting with the 91.54 t/ha obtained with the depth of 5.5 L (treatment with goat manure)(Figure 6).

Figure 6. Variation of productivity (green mass) of Mexican Elephant's Ear Cactus as a function of the irrigation levels and the type of organic fertilizer used. Depths: 1 = 0; 2 = 1.5; 3 = 2.5; 4 = 3.5; 5 = 4.5; 6 = 5.5 L/week. ** significant at 1%.



The results found were very satisfactory, especially when taking into consideration that the measurement of this variable occurred three months after cutting. This early production is important because it allows the producer an option of forage in a short period after the previous cut, providing food for the flocks in critical periods, or even the rapid obtaining of seedlings both for the implementation of new areas, as for marketing, especially because the cladodes of OEM are very sought after as it is a variety resistant to false carmine cochineal. It should also be noted that in areas that depend exclusively on rainfall for cactus production, the first cut is usually made between two to four years after planting (ALMEIDA, 2011).

Queiroz *et al.* (2015) observed for Mexican Elephant's Ear Cactus, average yields of 135.43 tons of MV/ha when applying complementary rainfall, totaling 976 mm in a cycle of 380 days after cutting. For the other depths up to a total of 1202 mm, the authors observed no statistical difference in the results of green mass, which corroborates the thesis that the planting of cactus in regions with a rainfall regime above 1000 mm per year can compromise the productivity indices, which is mainly due to the local hydric excess to which the plants will be subjected.

Rocha *et al.* (2017) using a depth of 16.4 mm every 15 days, reached an average production of 208.88 tons of MV/ha for OEM, with cuts performed every 4 months, during one year after planting. However, it should be considered that the authors used a density of 50,000 plants per hectare, contributing to obtaining higher values.

Silva *et al.* (2015) in Serra Talhada, Pernambuco, under dryland conditions obtained a production with the OEM of 163 tons of green mass per hectare, being cut two years after planting. Under these conditions the variety was superior to IPA Sertânia (124.3 t DM/ha) and the Miúda cactus (117.5 t DM/ha). Silva et al. (2014a) also under dryland conditions, obtained green mass productivity of 118 t ha-1 for the Miúda cactus, 113 ha-1 for the Redonda cactus, and 100 t ha-1 for the Gigante cactus, with cutting done one year after planting.

Souza *et al.* (2013) in Taperoá, a municipality in Cariri Paraibano, the same region as the municipality in this study, observed that only 6% of the farmers use goat manure alone as a source of organic fertilizer on oil cactus. The great majority of the farmers (54%) stated that they use bovine manure, which was linked to the greater availability of this material, and 40% use bovine and goat manure together. However, it was observed that the farmers recognize the superiority of goat manure, associating the use of this source with more satisfactory results and in a more rapid manner in the production of oil cactus.

Conclusions

The applied water rates promoted a significant increase in the analyzed variables and the final results of the productivity of the Mexican Elephant's Ear Cactus.

Goat manure was more effective in obtaining better values of the number of cladodes per plant and productivity.

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